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SOFTWARE FOR REDUCING WAITING TIME AT MEAL SERVICE IN STUDENT CANTEENS

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ABSTRACT: Canteens often present challenges regarding queue management, causing a reduction in efficiency which results in inconveniences and lost revenue. This article examines strategies for addressing these challenges by utilizing technologies such as image recognition and machine learning. While self-checkout systems have become commonplace in fast-food establishments and supermarkets, there has been limited progress towards adapting these solutions for canteens and buffets, resulting in their diminishing relevance in today's fast-paced society. This article serves as a study on implementing image recognition models for use in self-checkout systems tailored for canteens and the various possible approaches that were considered during our research.

KEYWORDS: canteen, image recognition, self-checkout

1. Introduction

The university canteen serves as a vital hub within the academic environment, providing a space for relaxation and social interaction between students and faculty staff alike.

Despite their significance, canteens in universities are often understaffed, resulting in lengthy queues that cause inconveniences and lost revenue.

To address this issue, it was proposed to introduce a self-checkout system similar to those found in fast-food chains and supermarkets, bringing the canteen in line with modern practices present within dining establishments. To provide adequate performance of the proposed self-checkout system it is necessary to incorporate image recognition technologies. This will enable the self-checkout terminals to identify the food items placed on a tray before any payment is made.

This paper aims to examine multiple methodologies for implementing an image recognition algorithm to accurately detect food items. Throughout the development process multiple approaches for implementing the system were considered, which significantly influenced the trajectory of the project, leading to its current state.

The initial approach that was considered is a system that relies on QR codes. By making use of this method, it is possible to keep a reference of the individual plates in the canteen. The rejection of this method was based on the financial implications and extra tasks that would have to be done by the canteen staff. Additionally, the durability of the QR codes needed to withstand the high pressure of the dishwashers used for cleaning the plates was also a concern. An alternative approach that aligns closely with our proposed implementation was the utilization of preexisting image recognition frameworks, specifically single-shot detectors such as YOLOv8 or Detectron2 [1, 2]. While these frameworks offer very high detection accuracy, they present high hardware requirements that are beyond the hardware proposed for low cost of operation. All the operations of this system must be executed locally on cost-effective hardware. Another important concern regarding this method is the requirement for a large-scale training dataset.

The current model architecture is written in the Python language and utilizes a comparator-based method paired with the Hough Circle Transform and serves as a proof-of-concept implementation for the system. Due to the shortcomings of this method, future developments include the implementation of a more robust image recognition architecture such as recursive convolutional neural networks (R-CNN) in the C++ programming language by leveraging libraries such as ncnn or mlpack [3, 4].

The source code of the current image recognition system is publicly available at https://github.com/eCantinaUPB/eCantinaUPB under the AGPLv3 license in order to promote collaboration and open development while also maintaining intellectual property rights for licensing within commercial applications. The code also includes a web-based interface for ease of use. Future developments will be published under the eCantinaUPB GitHub organization.

2. Methodology

To ensure a smooth implementation and integration process of the image recognition algorithms into the self-checkout terminals, the model training process will be divided into multiple stages.

The first step of the development process is the collection of high-quality training images. The current estimates indicate that approximately 100 images are required for each food article, including images that contain combinations of multiple food items. The aim is to collect data by utilizing two distinct strategies. The initial deployment of the system will require the collection of a dataset to bootstrap the model. This endeavor will be carried out through the joint efforts of student organizations via a crowdsourcing platform. After the system will become operational, the next step is to utilize the images collected by the self-checkout terminals in combination with human validation. This method offers benefits such as the partial elimination of the need for manual image tagging and ensuring a continuous production of training data.

After the collection of training data, the images can be processed. Unsuitable images will be removed to minimize detection inaccuracies. If the images are not tagged, tagging will be done manually during this stage. Data augmentation techniques will be implemented, such as rotating and flipping images in order to increase the size of the dataset and improve detection performance. The training images will be resized to a common resolution, denoising filters and brightness compensation methods will be applied afterwards.

Once the training dataset size is sufficient, the model will be trained. One objective is to enhance the efficiency of this stage to enable its execution on the self-checkout terminals while the canteen is not open to customers. Another feature that will be implemented is on-demand model training, where models are exclusively trained on the food items that will be served on a specific day to reduce memory requirements and increase detection accuracy by removing unnecessary data.

To assess the performance and stability of the model, a portion of randomly selected training images will be moved from the training dataset to a validation dataset. Once the model has been trained, these images will be utilized to assess detection accuracy rates and performance, and to check for issues such as model overfitting and drifting.

The current image recognition system is written in the Python programming language with some libraries included such as OpenCV and NumPy. The algorithm architecture consists of two modules, the first dealing with image segmentation to turn a picture containing multiple plates into individual images of plates and the second implementing food article detection.

The separator module utilizes the Hough Circle Transform [5] to detect the individual plates. As the Hough Circle Transform has O(n^3) time complexity in this application, the input image is downscaled to a more approachable size. Brightness and contrast are adjusted, and a Gaussian filter is applied to remove noise and irrelevant data from the image. This algorithm returns information about the recognized plates such as the position and radius of each plate.

The food item identifier utilizes a comparator-based system, where each plate is compared with a set of weights that correspond to food items. The input images and model weights can be downscaled to a more approachable size to increase performance, with brightness and contrast compensation being applied afterwards. We calculate the model weights by computing the arithmetic mean of a set of training images. This step returns a list of values corresponding to the sum of all the elements resulting from the comparison step for each type of food item. This algorithm has O($n^2 * m$) time complexity, where n is the width/height of the input image and m is the number of food item types.

3. Results

When using the web interface for the image recognition system an image must first be selected from disk or from a webcam such as in Figure 1. Then the user will select if the image contains a tray with plates or a single plate and the detection algorithm will be run. If the single plate option is selected the segmentation module will be bypassed. Example results are displayed in Figures 2 and 3.

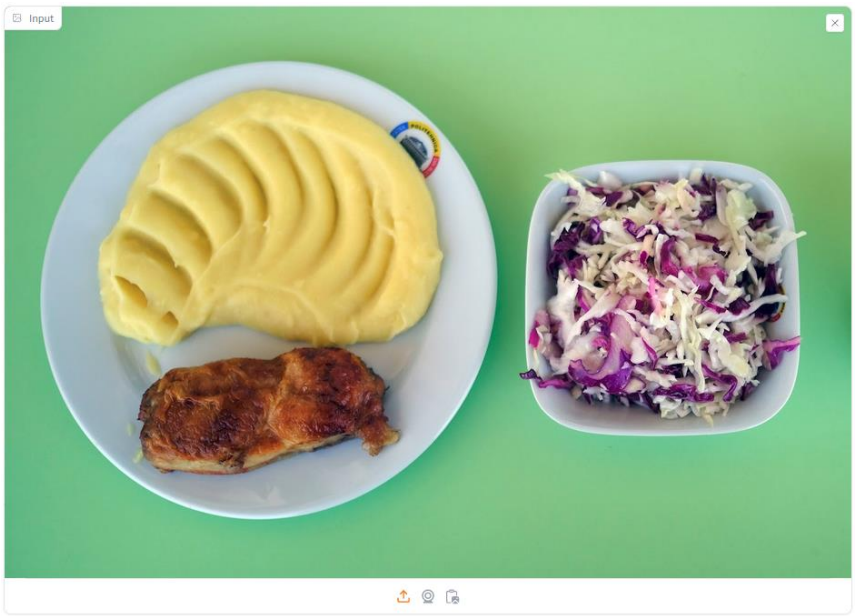

Fig. 1 Example input image

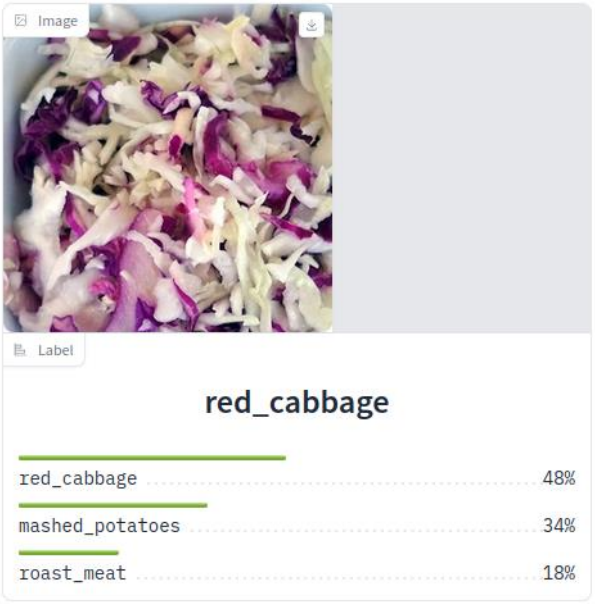

Fig. 2 First detection result

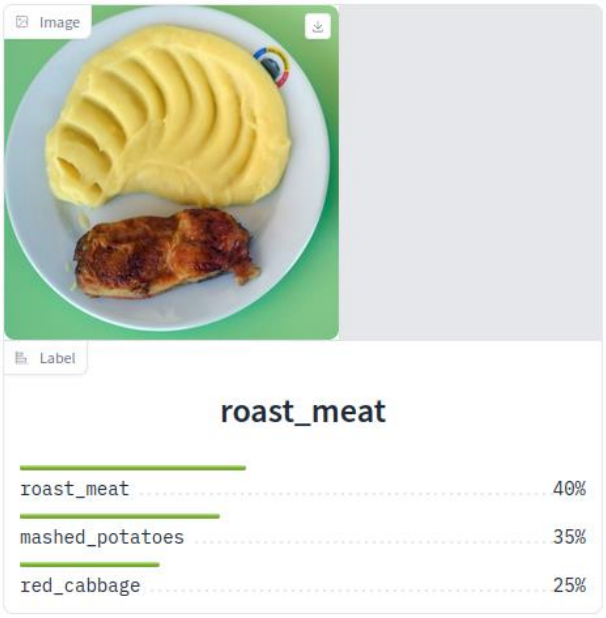

Fig. 3 Second detection result.

Table 1. Model benchmark

Number of food items on a single plate	Total number of plates	Accuracy rate
1	1	83,4%
2	1	72,5%
1	2	80,6%
2	2	64.2%

This table depicts the detection accuracy rates of the comparator-based algorithm when run on a dataset containing 5 food item types depending on the number of plates and food items present on the plates using a validation dataset of 25 images.

While the current implementation of the image recognition algorithm shows promising detection rates despite its simplicity, it falls short in multiple areas. One major issue with this system is the low detection accuracy of multiple food items on a single plate. While the system performs well with liquid food items, not enough tuning was performed for solid foods, as the current system does not take into consideration the orientation and size of food items, this will be addressed in the R-CNN implementation of the algorithm.

4. Conclusions

In conclusion, this paper has addressed the key challenges in the design and implementation of an image recognition system tailored to food item detection for canteens by exploring and reviewing multiple possible solutions. The successful deployment of this system depends on the collaborative efforts of researchers, developers and canteen staff, working together towards the goal of advancing technology in areas where it is underdeveloped. With continued dedication and cooperation, this project will provide much needed enhancements for canteens through novel technological solutions.

4. Bibliography

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[3] H. Ni, Tencent Inc., ncnn, https:/ /github.com/Tencent/ncnn, 2017

[4] R. R. Curtin, M. Edel, O. Shrit et al., “Mlpack 4: A fast, header-only c++ machine learning library” in “Journal of Open Source Software”, vol. 8, no. 82, p. 5026, 2023

[5] R. O. Duda and P. E. Hart, ‘‘Use of the hough transformation to detect lines and curves in pictures,’’ in “Communications of the ACM”, vol. 15, no. 1, pp. 11–15, 1972.

5. Notations

The following notations were utilized throughout the paper:

O(n) - Specifies the time complexity of an algorithm where n specifies the number of individual operations.

ROBOTIC ARM MANIPULATOR

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ABSTRACT:Technological advancements in recent decades have led to extensive development of robotic arms, used in various fields ranging from manufacturing to medical assistance and exploration. The aim of the research is to create a robotic arm controlled through a joystick, replicating human movements. Methods include computer-aided design, 3D printing, and experimental testing.

KEYWORDS: robotic arm, 3D printing, 3D design.

1. Introduction

In recent decades, technological advancements have led to the widespread development and implementation of robotic arms in various aspects of daily life and the technological sphere. These complex and versatile devices have become indispensable in numerous fields, contributing to process efficiency, quality and safety improvement, and the exploration of dangerous or inaccessible environments for humans. In the modern technology era, the development of robotic arms is driven by innovations such as additive manufacturing, which allows the creation of complex components at reduced costs and time.

The articulated robotic arm is one of the most popular industrial machines in the world. This robotic arm can have between 3 to 7 rotary joints and is typically used in applications such as welding or painting in the automotive industry, where the end effector needs to be in very specific positions and orientations.

The primary aim of this research is to create a joystick-controlled robotic arm that ingeniously replicates the movements of a human arm in a similar miniature, thus allowing intuitive and precise interaction between the user and the robotic device. Additionally, this research explores the process of creating a robotic arm using 3D printing. The creation of the robotic arm's casing through 3D printing focused on designing and optimizing it for the intended purpose.

The research also focuses on optimizing the performance of the robotic arm through experimental tests and computer simulations. Real-time testing facilitates the identification and resolution of potential issues and the overall performance improvement of the system. Through personal experience in the process of creating the robotic arm, I have analyzed and optimized the arm's efficiency.

2. The current stage

The evolution of robotic arms in recent decades has brought significant transformations across various fields, from manufacturing to services and research. In the manufacturing industry, robotic arms have become faster, more precise, and flexible, optimizing production processes and increasing efficiency. Additionally, the development of collaborative robots has facilitated cooperation between robots and humans, opening new opportunities in work environments. In the services sector, robotic arms are increasingly used in healthcare assistance, elderly and childcare, contributing to the improvement of quality of life. In research and exploration, robotic arms are essential for space exploration, underwater exploration, and other hazardous environments, providing innovative solutions for research and investigation of new frontiers. The integration of artificial intelligence in robotic arms gives them learning and adaptation capabilities, reinforcing their role in modern society. As technology advances, robotic arms are becoming increasingly integrated and ubiquitous, contributing to the transformation of how we work, live, and explore the surrounding world.

1. Equations

$$pulse_{wide} = map(Val_{pot}, 800{,}240, \text{Minpulse}_{\text{width}}, \text{Maxpulse}_{\text{width}}) \quad (1)$$

$$pulse_{width} = \frac{pulse_{wide}}{1000000} * Frequency * 4096 \quad (2)$$

Where:

- Val_{pot} represents the value read from the potentiometer,
- $\text{Minpulse}_{\text{width}}$ represents the minimum pulse width,
- $\text{Maxpulse}_{\text{width}}$ represents the maximum pulse width,
- $pulse_{wide}$ represents the pulse width calculated after mapping the value read from the potentiometer to the range specified by $\text{Maxpulse}_{\text{width}}$ and $\text{Minpulse}_{\text{width}}$,
- $pulse_{width}$ represents the pulse width adjusted according to the frequency and specific constant.

2. Methods used

The design and development of the robotic arm involved a series of specific steps and techniques.

Step 1: A preliminary research was conducted to identify various robotic arm models that could be reliable for the intended purpose. Once a project initiated by an engineer named Kelton, a YouTuber [1] who creates various projects using Arduino boards, was identified, I decided to implement this project using the resources and equipment available at home, adapting it and making some improvements to ensure the optimal functionality of the robotic arm.

Step 2: Identifying and purchasing the necessary hardware components:

• 4x Servomotors (20 kg)
• 1 micro-servomotor (90)
• 1 Arduino board
• 1 module IIC Driver Servo Motor
• 4x potentiometers 10kΩ
• mini swich
• different types of cables
• Adjustable Universal Power Converter with Voltage - Transformer 100-240V AC

Step 3: Using Fusion 360 software, detailed virtual models of the robotic arm and its control joystick were created or modified from the original designs, taking into account the dimensions of the hardware components to be integrated as seamlessly as possible into the final model. The design process included multiple iterations to achieve the final form.

Step 4: Utilizing the circuit from (fig. 1) as well as modifying the initial code using open educational resources and artificial intelligence. Using the formula from equation (1) and (2), we assigned the values read from the potentiometers and transformed them into a value from 0 to 180 that changes the position of the servo motors.

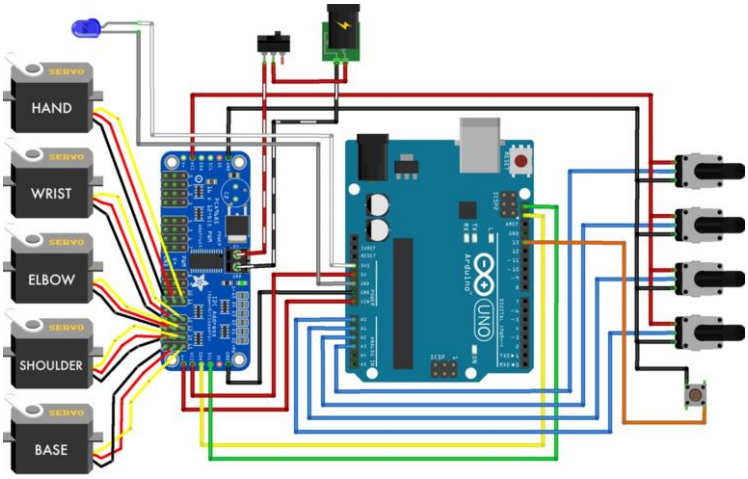

Fig. 1. Circuit of the connections in the arm

Step 5: Using the formula from equation (1), we assigned the values read from the potentiometers and transformed them into a value from 0 to 180 that changes the position of the servo motors[2].

```
36  void moveMotor(int controlIn, int motorOut)
37  {
38    int pulse_wide, pulse_width, potVal;
39
40    potVal = analogRead(controlIn);                                    //citire potentiometru
41
42    pulse_wide = map(potVal, 800, 240, MIN_PULSE_WIDTH, MAX_PULSE_WIDTH);
43    pulse_width = int(float(pulse_wide) / 1000000 * FREQUENCY * 4096);          //formula pentru servomotoare conectate la potentiometru`
44
45    pwm.setPWM(motorOut, 0, pulse_width);
46
47  }
```

Fig. 2. Transforming the values from the potentiometers into values for the servo motors

Step 6: After completing the design, we proceeded to produce a physical prototype using modern manufacturing techniques such as 3D printing (using white PLA). Various design flaws were identified during assembly. These were resolved, and the identified issues were addressed in creating another prototype using a different type of material (black PLA).

Step 7: The resulting prototype underwent testing to evaluate the functionality of the arm. This integrated approach, combining computer-aided design with additive manufacturing techniques, allowed for the rapid creation of a robotic arm.

Step 8: Testing the arm

5) Rezultate:

The following virtual models -components of the robotic arm- were either created or modified.

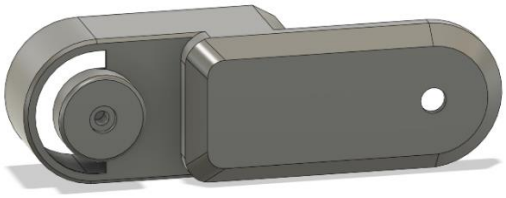

Fig. 3. Forearm-P1

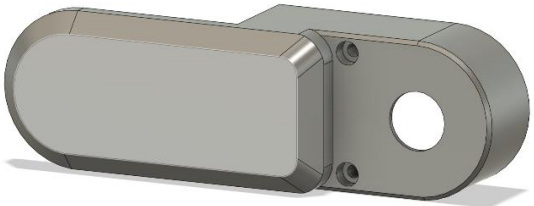

Fig. 4. Forearm-P2

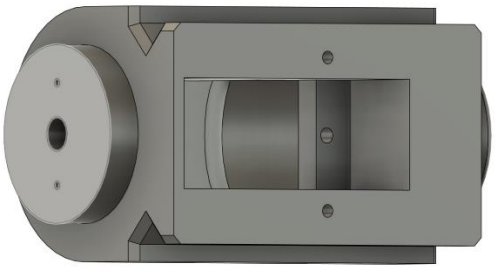

Fig. 5. Forearm-Wrist

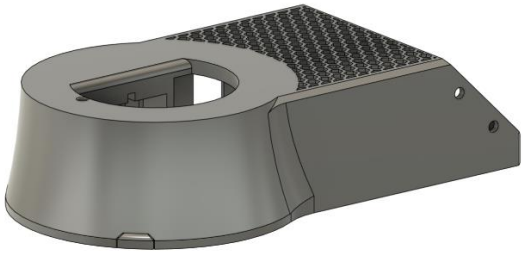

Fig. 6. Base

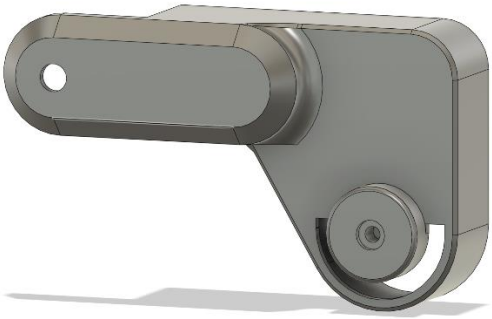

Fig. 7. Arm-P1

Fig. 8. Base-P2

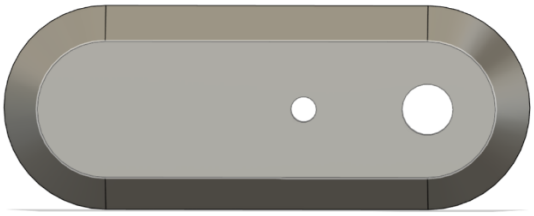

Fig. 9. Cover-Arm

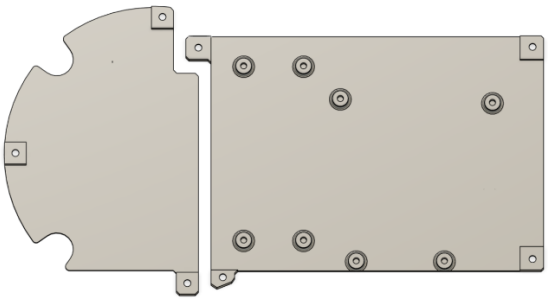

Fig. 10. Cover-Base

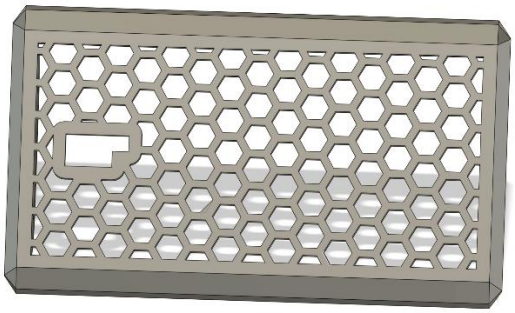

Fig. 11. Cover-Back

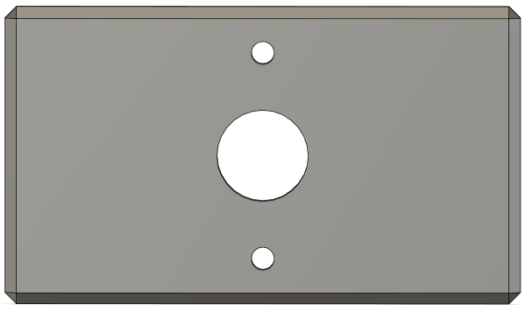

Fig. 12. Cover-Wrist

Fig. 13. Gripper

Fig. 14. Support-Arm

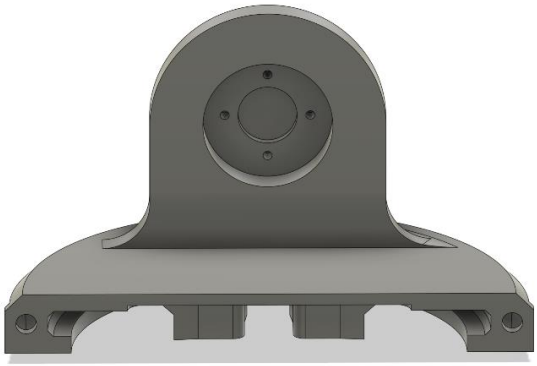

Fig. 15. Shoulder-P1

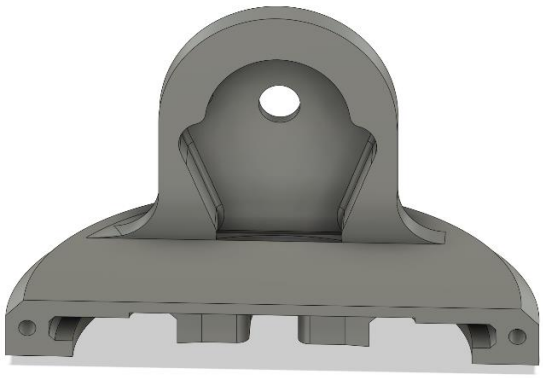

Fig. 16. Shoulder-P2

Fig. 17. Controller-Base

Fig. 18. Controller-Shoulder

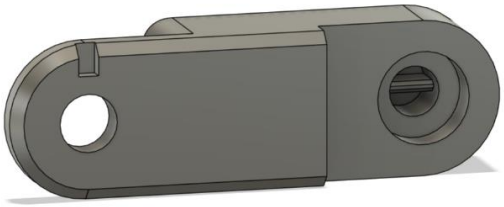

Fig. 19. Controller-Forearm

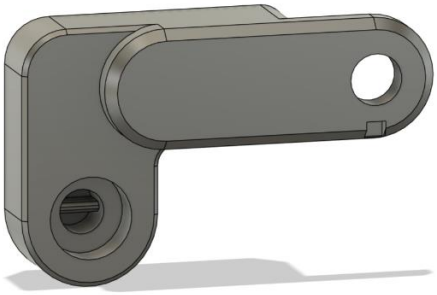

Fig. 20.Controller-Arm

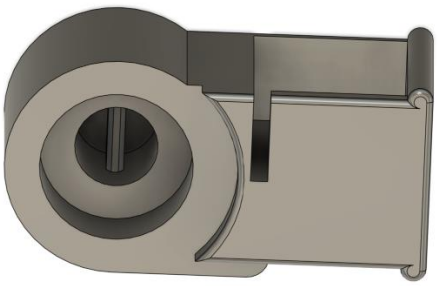

Fig. 21. Controller-Button

After 3D printing and assembling the arm the final result was this

Fig. 22. Robotic Arm

Fig. 23. Arm Controller

The utility of the arm proved itself during the conducted tests and can be used in the future in various contexts, such as educational purposes, technological activities, etc.

6. Conclusions

This analysis highlights the feasibility of using 3D printing technology in the production of manipulator arms intended for industrial use.

Such an arm can be manufactured at extended dimensional sizes and can be equipped with various types of grippers tailored to specific requirements.

Moreover, it is susceptible to integrating motion motors with improved performance, allowing for nanometric motion control and/or very high-speed movements.

7. Webography

[1] https://www.youtube.com/watch?v=5toNqaGsGYs&t=185s&ab_channel=BuildSomeStuff

[2] https://chatgpt.com/c/64f0862b-1e13-45b5-85bc-ef0e64fe9603

[3]https://blog.robofun.ro/2020/06/01/cum-functioneaza-un-brat-robotic-programabil-tipuri-de-brate-robotice-folosite-in-diverse-industrii/

3D PRINTED ROBOTIC HAND CONTROLLED WITH ARDUINO

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ABSTRACT: The abstract of the paper presents in detail the process of constructing a robotic hand, including the materials used for 3D printing of the components, and the methods applied, such as computer-aided modeling and manual assembly. The hand control is achieved using an Arduino board, and the code implemented for it is extensively discussed, with each function explained along with its usage. The conclusions emphasize the importance of adaptability and innovation in the field of manipulator robots, highlighting the educational and research potential of the project.

KEYWORDS: robotic hand, 3D printing, Arduino.

1. Introduction

Robotic hands have become increasingly popular in recent years due to their potential for use in various fields. These hands can be made from different materials and controlled through various methods, including Arduino boards. In recent years, 3D printing technology has rapidly developed, becoming more accessible and easier to use. 3D printing allows the creation of complex objects from various materials, including plastic, metal, or composites. This technology has opened new possibilities for the development of robotic hands, enabling the creation of customized models tailored to the specific needs of users. Arduino is an open-source platform used for building electronic projects, consisting of both a physically programmable circuit board and software that runs on a computer. This project presents the development of a functional robotic hand, created through 3D printing and controlled by an Arduino board. The main goal of the project is to demonstrate the potential of this technology for various applications and to provide a guide for those who wish to build their own robotic hands.

2. Current State

These hands are used for a wide range of applications, including the precise operation of dangerous tools and the handling of objects. They are also found in various industries, such as manufacturing, logistics, and construction, to automate repetitive or hazardous tasks. Additionally, robotic hands are frequently used in research and development of new technologies, such as artificial intelligence and advanced robotics.

3D printing is a manufacturing method where materials like plastic or metal are deposited layer by layer to produce a three-dimensional object, as shown in Figure 1. To date, 3D printing has been primarily used in engineering to create prototypes. However, recent advances in printing materials have enabled 3D printers to produce objects comparable to traditionally manufactured items. NASA, for example, demonstrated the viability of this method by producing a fuel injector for one of their rockets. The finished product was manufactured at one-third of the cost and two-thirds of the time compared to traditional methods. The 3D printing method also has applicability in the medical industry by producing custom prosthetics that are structurally optimized.

3D printing has become an increasingly popular technology in recent years due to its increased accessibility and potential to revolutionize various industries. Currently, there is a wide range of 3D printing technologies available, each with its own advantages and disadvantages.

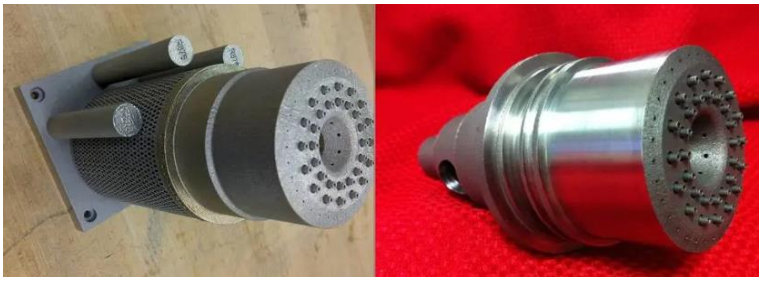

Figure 1 "Injector made with the help of a 3D printer"

3. Materials and Methods

For designing the hand and 3D printing, we started with STL (Stereo Lithography) files available on the website https://inmoov.fr/inmoov-hand/. We made significant improvements and modifications to the original model, adapting it to the specific needs of the project. These modifications included changes to the original model of the bushings, control software, and ligaments. SolidWorks software was used to implement these improvements.

To construct and control the 3D-printed robotic hand with Arduino, we used the following materials and methods. We began by using a 3D printer to print the necessary components of the robotic hand. We used Polylactic Acid (PLA) filament due to its durability and ease of processing. For controlling the hand, we used an Arduino board as the control unit. Another essential component we used was a breadboard. This device allows for prototyping the Arduino project without the need for permanent circuit soldering. To provide movement in the fingers, we used DGServo 9G servomotors. These are DC motors with a limited rotation angle, enabling us to achieve controlled movements. To connect the servomotors to the Arduino board, we used wires and electrical cables, ensuring the transmission of signals and the necessary electrical power for the robotic hand's operation. The breadboard was powered by the Arduino board using jumper wires, which were also used to form the circuit by connecting resistors, switches, and other components.

After printing the components, we realized that the surfaces needed to be smoothed. We used sandpaper of various grits and files to remove roughness and imperfections, making assembly easier. After sanding, we proceeded with assembly. Screws, nuts, and other fastening materials were used to join the components and ensure stability. To lift the fingers, we used fishing line, attaching one end of the line to each finger's bushing. To allow the fingers to return to their initial position, we used elastic bands. We cut pieces of elastic and fixed them between the base of each finger and the corresponding hand component using screws. This way, the elastic created tension that caused the fingers to return to their starting position.

Figure 2 "3D Printed Robotic Hand Controlled with Arduino"

For controlling the hand, we wrote the code used in the Arduino IDE development environment. This code enabled the hand to perform finger movements.

```
#include <Servo.h>


Servo deget_mic;
Servo inelar;
Servo mijlociu;
Servo aratator;
Servo deget_mare;



void setup() {
  // put your setup code here, to run once:
  deget_mic.attach(4);
  deget_mic.write(0);

  inelar.attach(5);
  inelar.write(0);

  mijlociu.attach(6);
  mijlociu.write(0);

  aratator.attach(7);
  aratator.write(0);

  deget_mare.attach(8);
  deget_mare.write(0);

  delay (3000);

  Serial.begin(9600);

}

void pumn() {
 for (int pos = 0; pos <= 180; pos += 1) {  // rotate slowly from 0 degrees to 180 degrees, one by one degree
    // in steps of 1 degree

    // control servo to go to position in variable 'pos'
    deget_mic.write(pos);
    inelar.write(pos);
    mijlociu.write(pos);
    aratator.write(pos);
    deget_mare.write(pos);
      delay(10);         // waits 10ms for the servo to reach the position
  }

}



void deschide_mana(){

 for (int pos = 180; pos >= 0; pos -= 1) {  // rotate from 180 degrees to 0 degrees, one by one degree
    // control servo to go to position in variable 'pos'
    deget_mic.write(pos);
    inelar.write(pos);
    mijlociu.write(pos);
    aratator.write(pos);
    deget_mare.write(pos);
    delay(15);                              // waits 10ms for the servo to reach the position
  }
}

void inchide_degete(){
 for (int pos = 0; pos <= 180; pos += 1) {  // rotate from 180 degrees to 0 degrees, one by one degree
    // control servo to go to position in variable 'pos'
    deget_mic.write(pos);
    delay(10);                              // waits 10ms for the servo to reach the position
  }
  //delay(1000);
  for (int pos = 0; pos <= 180; pos += 1) {  // rotate from 180 degrees to 0 degrees, one by one degree
    // control servo to go to position in variable 'pos'
    inelar.write(pos);
    delay(10);                              // waits 10ms for the servo to reach the position
  }
  //delay(1000);
  for (int pos = 0; pos <= 180; pos += 1) {  // rotate from 180 degrees to 0 degrees, one by one degree
    // control servo to go to position in variable 'pos'
    mijlociu.write(pos);
    delay(10);                              // waits 10ms for the servo to reach the position
  }
  //delay(1000);
  for (int pos = 0; pos <= 180; pos += 1) {  // rotate from 180 degrees to 0 degrees, one by one degree
    // control servo to go to position in variable 'pos'
    aratator.write(pos);
    delay(10);                              // waits 10ms for the servo to reach the position
  }
  //delay(1000);
  for (int pos = 0; pos <= 180; pos += 1) {  // rotate from 180 degrees to 0 degrees, one by one degree
    // control servo to go to position in variable 'pos'
    deget_mare.write(pos);
    delay(10);                              // waits 10ms for the servo to reach the position
  }
 // delay(1000);
}

void loop() {
  // put your main code here, to run repeatedly:
//pumn();
inchide_degete();
 delay(3000);
 deschide_mana();

}
```

Figure 3 "The code used for the operation of the robotic hand"

In the code provided, we use the *Servo.h* library to control the servo motors and perform the movements of the robotic hand. We include the "*Servo.h*" library to utilize the servo motor control functionality. Next, we define five Servo objects for the five servo motors we will use for the pinky, ring, middle, index, and thumb fingers. Through these objects, we will control the movement of each servo motor.

In the *setup()* function, we perform the initial configurations of the program. First, we attach each servo motor to a specific pin on the Arduino board using the *attach()* method. This allows us to establish a connection between the Arduino board and each servo motor individually. Then, we set the initial position of each servo motor to 0 degrees using the *write()* method. After attaching the servo motors and initializing their initial positions, we introduce a delay of 3 seconds using the *delay(3000)* function. This delay allows us to stabilize the components and prepare for the next action. Next, we initialize serial communication at a baud rate of 9600 bits per second using the *Serial.begin(9600)* function. This allows us to send and receive data through the serial port.

The *void fist()* function is defined to close the hand. In this function, we use a "for" loop to rotate each servo motor from the 0-degree position to the 180-degree position, with increments of 1 degree. Thus, the hand gradually closes as the servo motors rotate.

At the end of the code, in the *loop()* function, we call the previously created *fist()* function to close the hand. After this, we introduce a delay of 3 seconds using delay(3000). Then, we call the *open_hand()* function to fully open the hand. This sequence repeats continuously, allowing the robotic hand to perform repeated closing and opening movements.

To use the code presented above, we created a connection diagram in the Fritzing program. This software is an electronic design automation software aimed at providing easy-to-use tools for documenting and sharing physical computing projects, producing PCB prototypes, and teaching electronics.

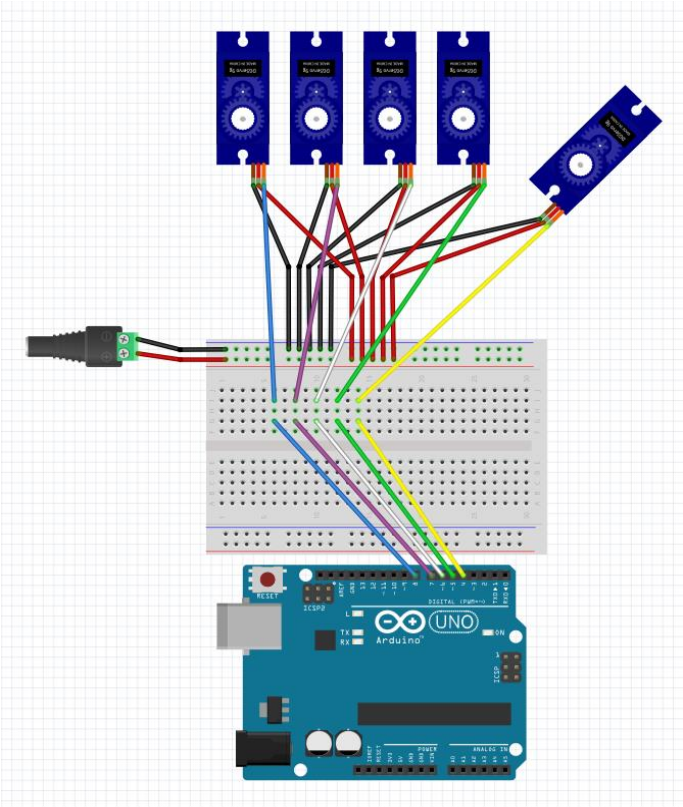

Figure 4 "The connection diagram for the robotic hand control"

The connection diagram from Fritzing provides a visual representation of how electronic components are interconnected in a circuit. This schema serves as a basis for designing a printed circuit

board (PCB). The Fritzing software allows the conversion of connection diagrams into PCB designs, as shown in figure 4.

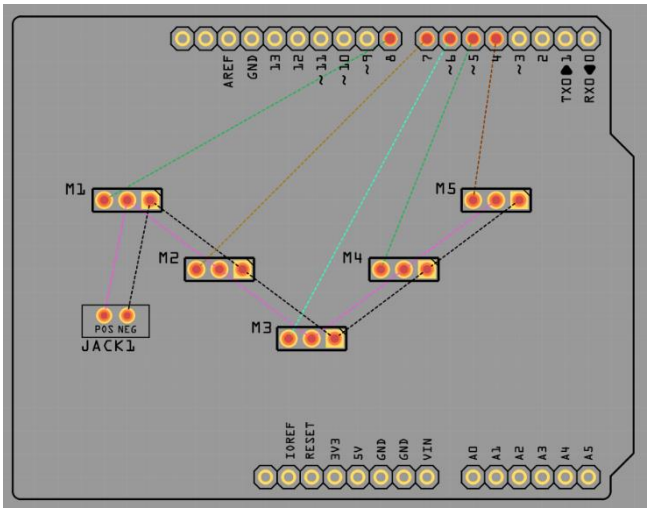

Figure 5 ”PCB Layout”

The PCB layout is useful for transforming connection diagrams into a physical layout of the circuit on a printed circuit board (PCB). The PCB layout allows for the optimal placement of components on the circuit board, minimizing size and maximizing space efficiency.

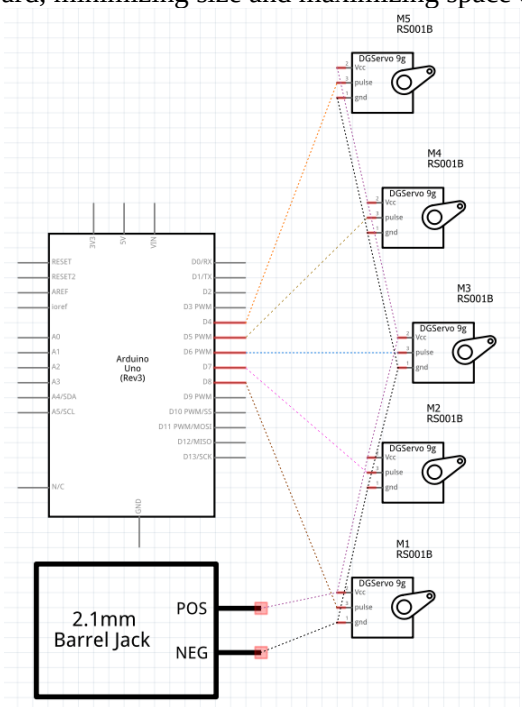

Figure 6 ”Diagram for Robotic Hand Control”

4. Results and Discussion

3D printing has proven to be an efficient and accessible method for constructing the components of the robotic hand. This technology allowed for the customization of the design and creation of components tailored to the project's needs. The Arduino board provided a versatile and easy-to-use platform for controlling the servomotors. The implemented code allowed for individual control of each finger, offering high flexibility in the movements of the robotic hand. During development, we went through several changes to optimize the functioning of the fingers. Initially, we tried to use springs, as was intended in the original model. However, we found that the springs were not effective in our

case, as they did not ensure the desired movement of the fingers. As a result, we abandoned the use of springs and used elastics, which proved to be more effective in controlling the tension and movement of the fingers.

One of the current limitations of the robotic hand is the limited force of the fingers. In the future, more powerful servomotors can be used, or force amplification mechanisms, such as lever systems, can be implemented. Additionally, the precision of movements can be improved by using position sensors. The modular design of the robotic hand, with easily assembled and disassembled components, allowed for quick modifications and different configurations of fingers and joints. This characteristic makes the project an ideal tool for STEM education, offering students the opportunity to explore and learn through practical experimentation.

5. Conclusions

The conclusions drawn from this project underscore the importance of adaptability and innovation in the development of robotic hands. The utilization of elastics instead of springs has shown a significant improvement in finger control, highlighting the ongoing need for exploring ingenious solutions to optimize performance. Moreover, the relevance of STEM education and the potential for rapid prototyping emphasize the significance of this project in technological education and research. Further improvements and research are essential to maximize the potential of robotic hands in future industrial and medical applications.

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PRACTICES REGARDING CUSTOMER ORIENTATION IN THE WRITING INSTRUMENTS INDUSTRY

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ABSTRACT: In a constantly changing world, customer orientation is becoming increasingly important for the success of a business. In the writing instruments industry, where innovation and quality are as essential as functionality and design, a company's ability to understand and respond to its customers' needs can make the difference between being just a product supplier and becoming a trusted partner in the daily lives of consumers. By analyzing case studies of companies in this industry, we will explore how customer orientation strategies can influence innovation, marketing, and long-term business success.This study highlights the strategic importance of customer orientation in the writing instruments industry by examining how companies in this field adapt their products, services, and marketing strategies to meet their customers' needs and preferences. By exploring this aspect, we will reveal the impact that customer orientation can have on competitiveness and success.

KEYWORDS: writing instruments, customer, innovation, competitors.

1. Introduction

The writing instruments industry is a vast and dynamic field, facing a series of challenges and opportunities in today's context. On one hand, consumers are becoming increasingly demanding, expecting innovative, high-quality products that meet their specific needs. In this context, customer orientation becomes an essential factor for the success of companies in the industry. The objective of this project is to analyze practices regarding customer orientation in the writing instruments industry. Through case studies, we will explore how companies in this domain adapt their products, services, and marketing strategies to meet the needs and preferences of their customers. This study aims to achieve the following objectives: 1. Identifying the main needs and preferences of consumers in this industry, which will be achieved through the analysis of data from case studies, as well as through surveys addressed to consumers, and 2. Comparing the customer orientation strategies implemented by the analyzed company with those used by competitors, which will be achieved by studying the marketing strategies and customer orientation practices of key competitors.

2. Current Situation

The company analyzed in this study is LAMY, a German writing instrument company with a history of over 50 years. It is known for its innovative, high-quality products and ergonomic, elegant design. Lamy focuses on customer orientation and strives to provide an exceptional experience to its customers. According to the website https://www.lamyshop.ro/, all LAMY products undergo strict quality control before production is finalized. All components are manufactured in the Heidelberg factory, dating back to 1930. Maintaining production exclusively in the German location is the most important factor for high standards, as all manufacturing stages, from design and development to final assembly, take place there. Quality assurance begins during the production of materials and

components. The company even produces ink cartridges using the injection molding process. The German standard DIN ISO 12757-2 defines the permanence standards for ink color visible on paper when held against the light, chemical solutions, and the quality of the nib [1]. The manufactured nibs are marked with the DIN symbol, ensuring protection against counterfeiting. In all specialty stores, LAMY offers the opportunity to test the pen before purchasing it. This helps the customer identify the nib that suits them best [2].

3. Competitor Analysis - Benchmarking

Parker and Faber Castell are two of the most important competitors. These brands are often compared to each other in terms of the quality, design, and innovation of their products, as well as their marketing strategies and customer orientation. Parker is renowned for its elegant and refined design, superior quality of its products, and constant innovation in technology and design. Faber Castell is known for the diversity and versatility of its product range, including both premium writing instruments and affordable options, catering to a wide range of consumers.

The writing instruments industry is a competitive one, with numerous brands vying for consumer attention. To succeed, companies must focus on customer orientation, offering quality products, excellent services, and a positive customer experience. This benchmarking analysis compares Parker and Faber Castell with LAMY, with a focus on LAMY as the primary company analyzed. This analysis is based on company reports, online sources, and aspects such as product quality, innovation, diversity, and pricing, availability, as well as warranties, certifications, and showroom testing opportunities, along with the accessibility of product information. The goal is to identify the strengths and weaknesses of the analyzed company, compared to its competitors, in order to formulate improvement strategies. The benchmarking analysis will be based on the following criteria: product portfolio, prices, quality, certifications, awards, innovation, marketing, and communication.

All three companies offer a wide range of products, including fountain pens, ballpoint pens, pencils, and accessories. Parker's product range focuses more on the premium segment, offering high-quality fountain pens and ballpoint pens with fine materials and refined designs. These products are more suitable for adults as they are created to be more elegant and sophisticated. The available colors and finishes focus on classic and modern tones, suitable for a mature and professional audience. Parker's fountain pen range includes models such as Sonnet, IM, and 51. [3]

Faber-Castell's product range is known for its diversity and quality. It includes writing instruments suitable for all age categories and preferences. The colors and designs range from bright and playful to elegant and classic to satisfy the tastes and needs of each customer. The fountain pen range includes popular models such as Amition, Loom, and Ondoro. [4]

LAMY focuses on high-quality fountain pens, renowned for their durable and reliable nibs, as well as for their elegant and ergonomic design. LAMY's fountain pens for children are designed to be easy to use and comfortable for small hands. This range includes models such as ABC, Joy, and Safari. Fountain pens for teenagers are sleek and modern, with a variety of colors and designs available, such as AL-Star, Nexx, and Scala. Fountain pens for business people are durable and reliable, with an elegant and professional design. The designed models are LAMY 2000, Dialog 3, and Studio. Each fountain pen comes in a variety of colors, including standard colors and limited edition colors. Limited edition colors are available only for a limited period of time and are often inspired by current trends or special events. The company also offers multifunctional ballpoint pens, which combine the functionality of a mechanical pencil with that of a ballpoint pen. It is designed to provide versatility and convenience in one instrument. Additionally, LAMY produces digital pens. The AL-Star EMR is an innovative digital pen, compatible with tablets, phones, and laptops with touchscreens that support EMR (Electro-Magnetic Resonance) technology. This pen offers a natural and precise writing experience, with a pressure sensitivity of 4096 levels. LAMY ncode is another digital pen, which can transcribe what is written on the LAMY digital notebook. This pen is used together with the notebook and a mobile app.

The pen recognizes handwriting and transcribes it into digital text, which can be edited, shared, and saved in the Cloud. [5]

In terms of prices, we observe a similarity between brands for products in the same range. The compared fountain pens have similar characteristics, such as construction materials, ergonomic design, nib, ink feed system, and availability in various colors. However, premium products, such as those manufactured by Parker, tend to be more expensive than those from LAMY, reflecting the brand's reputation and prestige.

Table 1 "Price comparison for mid range products"

Range of products	**AL Star LAMY** 	**Jotter Parker** 	**Loom Faber Castell** 
Prices	141 RON	150 RON	125 RON

Table 1 "Price comparison for the premium range"

Range of products	**Studio LAMY** 	**Sonnet Parker** 	**Graf Faber Castell** 
Prices	1200 RON	1350 RON	1290 RON

The companies Parker, Faber-Castell, and LAMY are internationally known for their high-quality products and commitment to sustainability and social responsibility. In this context, the recognized certifications held by these companies are a reflection of high standards in quality, environmental protection, and efficient resource management. Next, we will explore the important certifications held by Parker, Faber-Castell, and LAMY, and what they mean for consumers.

Table 2 "Certifications of the analyzed companies"

Company / Certifications	**ISO 9001**	**ISO 14001**	**FSC**	**EMAS**
Parker	X	X	X	
Faber-Castell	X	X	X	X
LAMY	X	X		X

In Table 3, the certifications held by each analyzed company are presented. The ISO 9001 certification, for the quality management system, demonstrates the companies' commitment to quality and customer satisfaction. The ISO 14001 certification for the environmental management system highlights the company's commitment to environmental protection. The FSC (Forest Stewardship Council) certification guarantees the origin of wood from responsible sources, and the EMAS (Eco-Management And Audit Scheme) certification is a voluntary instrument of the European Union for improving the environmental performance of organizations.

In terms of awards, Parker receives the Good Design Award for its products, which have been praised for their aesthetics and superior functionality. The company has also won "Red Dot Design" awards for some products, recognized for their exceptional and innovative design. Additionally, Parker has received "IF Design" awards, highlighting the quality and design excellence. The same awards have been obtained by Faber Castell.

Lamy has been honored with the prestigious German Brand Award twice in a row for its successful combination of design, quality, and marketing. In 2016, it won the gold award in the "Office

and Stationery" category. This success was continued in 2017, when it received the "Excellence in Branding" award in the premium class. On this occasion, LAMY was honored with another German Brand Award as the "product brand of the year", highlighting its excellence in branding in the industry - Office and Stationery category. Every year, the German Design Council awards the German Brand Award to innovative brands. Lamy has won over the independent jury several times. Thus, the consistent recognition of its quality and value is reaffirmed by these prestigious awards. Over the years, Lamy has won 16 different types of awards, some of them being awarded annually. This repeated recognition consistently underscores its quality and excellence in the writing instruments industry and confirms its position as a leader in the field.

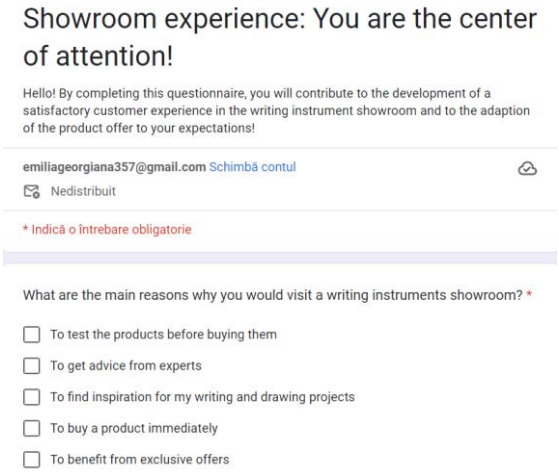
Innovation is a central element for all three brands. Parker invented the ballpoint pen in 1954, which revolutionized the writing instruments industry. Faber-Castell is known for its technological innovations in pencil production. For example, their pencils have been constantly improved through the introduction of new formulas and manufacturing technologies. LAMY has always been at the forefront of innovation in the design and technology of writing instruments. They are recognized for introducing innovative materials into the design of fountain pens and ballpoint pens, as well as developing new ink filling technologies and writing systems. Lamy has developed the blade nib, which offers a finer and more precise writing experience. The company has recently launched digital pens, compatible with tablets, phones, and laptops with touchscreens.

In terms of marketing and customer communications, the three brands communicate through a variety of channels, including advertising, public relations, digital marketing, and social media. LAMY is the only one of the three mentioned brands that has a dedicated test showroom, where customers can experience products before purchasing and receive advice from experts. Customers can test different models, nibs, and ink colors to find the perfect writing instrument for their needs.

The conclusion of the benchmarking analysis reveals that LAMY, Parker, and Faber Castell are renowned companies in the writing instruments industry, each having their own strengths and weaknesses. This analysis highlights the importance of customer orientation in the writing instruments industry and the competitive advantage of LAMY through its dedicated test showroom. By providing customers with the opportunity to test products before purchase and receive personalized advice, this company demonstrates its commitment to a positive customer experience. Within this analysis, the need to evaluate customer orientation and actively address their needs and preferences has been emphasized.

4. Customer Orientation Practices Questionnaire

The previous analysis highlighted the need to assess customer orientation and actively address their needs and preferances. So, in the following we created a questionnaire addressed to customers, focusing on their needs and preferances regarding the visit to the showroom. Feedback and suggestions will be the guiding features of our LAMY showroom visit. The second section of the questionnaire focuses on customer preferences for writing instruments. The questionnaire was completed by people between 18-40 years old, from rural and urban areas.


Showroom experience: You are the center of attention!

Hello! By completing this questionnaire, you will contribute to the development of a satisfactory customer experience in the writing instrument showroom and to the adaption of the product offer to your expectations!

emiliageorgiana357@gmail.com Schimbă contul

Nedistribuit

* Indică o întrebare obligatorie

What are the main reasons why you would visit a writing instruments showroom? *

- [ ] To test the products before buying them
- [ ] To get advice from experts
- [ ] To find inspiration for my writing and drawing projects
- [ ] To buy a product immediately
- [ ] To benefit from exclusive offers

What expectations do you have for visiting a showroom for writing instruments? *

- [ ] The possibility to test different models and pens
- [ ] A practical and enjoyable experience
- [ ] Personalized advice and assistance
- [ ] Acces to detalied information about products and features
- [ ] A relaxing and welcoming atmosphere
- [ ] Ohers

What are your expectations regarding the availability and accessibility of the products in the showroom? *

- [ ] All products on the website should be available in the showroom
- [ ] The possibility of ordering customized products
- [ ] The possibility of customization in the showroom
- [ ] Others

What should a showroom for writing instruments contain in order to feel completely satisfied? *

- [ ] Additional services, such as product repair or maintanence
- [ ] The possibility to customize the purchased products
- [ ] Pleasant and relaxing atmosphere
- [ ] The diversity of the product range
- [ ] Others

What payment methods would you prefer to be available? *

- [ ] Cash
- [ ] Credit/Debit card
- [ ] Bank transfer
- [ ] Online payment
- [ ] Others

Characteristics of writing instruments

What are your favorite types of writing instruments? *

- [ ] Quill pens
- [ ] Pens
- [ ] Roller
- [ ] Crayons
- [ ] Marker
- [ ] Others

What are the most important features of writing instruments, for you? *

- [ ] Quality
- [ ] Design
- [ ] Innovation
- [ ] Sustainability
- [ ] Price
- [ ] Ergonomics
- [ ] Variety of colors and writing thicknesses
- [ ] Others

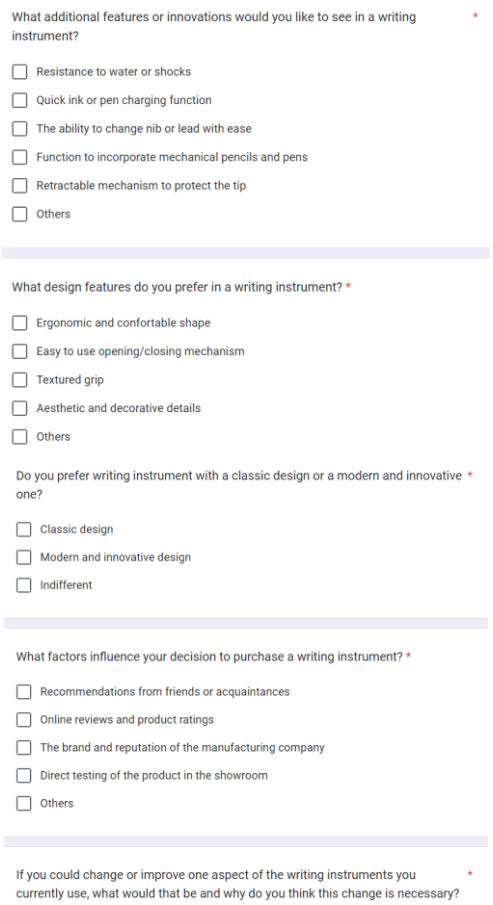


Figure 7 „Questionnaire”

5. Analysis of the questionnaire results

The analysis of the questionnaire results has revealed a series of needs and preferences of customers regarding their visit to the showroom. The main reasons why customers want to visit the showroom are to test products before making a purchase and to receive advice and consultancy from experts to choose the ideal writing instrument. As expectations, they wish to have the opportunity to experience different writing instruments, models, nibs, and to receive personalized assistance in a welcoming atmosphere. Regarding the availability and accessibility of products, customers want to find all items that are available on the website also in the showroom and to have the option of customization in the showroom. To feel completely satisfied, customers want to be able to customize their purchased products and to benefit from additional services such as repair or maintenance of writing instruments. As payment methods, they prefer card and cash payment. The results indicate a set of expectations and needs that customers have during a showroom visit, and we, as customers conducting this research, have taken these aspects into consideration to improve and personalize our experience and that of others in the showroom.

Taking into account the second section of the questionnaire regarding the "Features of Writing Instruments," clear preferences were identified among consumers. Fountain pens and ballpoint pens were the main favorites, and the features considered most important for these instruments included the variety of colors and nib sizes or lead thicknesses, ergonomics, and quality. Among the additional or innovative features desired by customers were the ability to easily change the nib or lead and the integration of a mechanical pencil and a pen into a single writing instrument. Regarding design, they expressed a preference for comfortable and ergonomic shapes, with aesthetic and decorative details. Most wanted a modern and innovative writing instrument. Factors influencing the purchase decision included the opportunity to test the product directly in the showroom and recommendations from friends

or acquaintances. Consumers expressed certain desires and suggestions regarding the writing instruments they use from various competing companies. They want increased flexibility to use the writing instrument for different types of writing and drawing, a wide variety of colors, the elimination of plastic materials from the components of the pen, the use of alternative materials for an elegant design, and the ability to replace worn components.

6. Showroom experience and product compliance with customer expectation

In the course of this research, we visited the LAMY showroom to directly experience the interaction with the products and the environment provided to customers. Located in Bucharest, on Locotenent Alexandru Paulescu Street, no. 6, the LAMY showroom is a well-appointed and attractive space designed to offer a pleasant and informative experience to customers. Upon our arrival at the LAMY showroom, we were greeted by a friendly and professional atmosphere. While waiting to be served, we observed another customer receiving personalized advice to choose a suitable gift. To make our waiting more enjoyable, we were offered a coffee, and we had several catalogs with detailed information about the various pen models at hand. After the departure of the customer in front of us, we sat down at the desk and accessed the website using the computer provided to view the full range of products. On the desk, there was a pen holder with the most common writing instruments available for testing. We chose to have a specific pen model brought to us, and we requested different pen nib options to test. During our consultation, we were provided with a wealth of information about the materials used in pen manufacturing, the possibility of nib replacement, the availability of spare parts, and the international warranty offered by the LAMY brand, which allows for the on-the-spot replacement of a factory-defective pen, regardless of the country of purchase. An interesting aspect we discovered is that each pen is designed by a different designer, giving each model a unique personality. During our showroom experience, we noticed that the available payment method was exclusively by card and bank transfer. It is important to mention that, currently, cash payments are only accepted for legal entities, a policy that may be reconsidered in the future. The LAMY showroom intends to introduce a pen personalization service. We were informed that the special machines necessary for personalization have already been purchased, and the implementation of this service is underway. As stated in SR EN ISO 9004:2018,sustained success is achieved by organizations that consistently meet the needs and expectations of their customers and other interested parties over the long term. This involves the implementation of a quality management approach that is aligned with the organization's overall strategy and goals. The LAMY showroom exemplifies this principle through its commitment to customer satisfaction and continuous improvement.[6]

7. Conclusions

Based on the analysis of our experience at the LAMY showroom and the results obtained from the questionnaire, we can conclude that the majority of customers expectations and needs have been satisfactorily met. The LAMY showroom manages to provide a comprehensive and personalized experience, adapting to the diverse requirements and preferences of customers. A significant aspect is that LAMY is dedicated to addressing customers issues related to writing instruments, offering products and services that meet their specific needs. The variety of colors, models, and customization options demonstrates the company's commitment to innovation and adaptability, which strengthens the relationship with customers and builds trust in the brand.

We believe they have conducted numerous market studies and analyzed customer feedback to better understand their needs and preferences regarding writing instruments. The production of the 2-in-1 pencil with mechanical pencil is a clear example of their response to the requirements and desires expressed by customers. The rich variety of colors and customization options reflect their efforts to

provide a diverse and tailored experience. The ability to change the nib and combine different components is a clever way to allow customers to create their own style and express their creativity.As stated in ISO 9001:2015, organizations should strive to understand and meet customer needs, enhance customer satisfaction, and improve their quality management systems continuously [7]. LAMY's dedication to these principles is evident in their customer-centric approach and continuous innovation.

In conclusion, LAMY remains a trusted choice for writing instrument enthusiasts, offering quality products and personalized services designed to enhance the writing experience for each individual customer. All these initiatives underscore the commitment to innovation and customer satisfaction.

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AUTOMATION OF INTERNAL PROCESSES IN A PUBLIC INSTITUTION USING THE 6Σ METHOD

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ABSTRACT: This research focuses on the automation of internal processes in a public institution using the 6Σ method. Considering the European Union's strategy to create a connected, efficient and safe community through the implementation of innovative solutions, the objectives of the National Recovery and Resilience Plan, the digital transformation component in conjunction with the low degree of digitization of public institutions in Romania the need to implement digital solutions within public institutions has been identified. In the first stage, an E.F.Q.M analysis will be carried out. of the institution, analysis that will provide an overview of areas for improvement. In the second stage, a technical, digital solution will be implemented, with the help of which an internal process will be automated within the institution using the 6Σ method.

KEYWORDS: automation, internal process, 6Σ method, public institution

1. INTRODUCTION

Starting from the objectives of the National Recovery and Resilience Plan, the digital transformation component in conjunction with the low degree of digitization of public institutions in Romania and the difficult management of physical documents, we identified the need to implement a document management application. The implementation of such a solution would bring with it a series of advantages, such as: reducing the consumption of paper to print documents, reducing the time of assigning the document, reducing the space needed to store and archive documents, facilitating quick access to them.

The reason for this research "the automation of internal processes in a public institution with the help of the 6Σ method", is the need to align with European policies aimed at sustainable development objectives. Also, compared to the current statistics, it is clear that this is a current and relevant concern in the current context of public administration in Romania and around the world. Public institutions are under increasing pressure from citizens and other stakeholders to be more efficient and effective in fulfilling their mission of providing quality public services and managing public resources responsibly.

2.PRESENTATION OF THE ORGANIZATION

The institution is organized and functions as a specialized body of the central public administration, a public institution with legal personality. It is a government institution in Romania, whose main responsibilities are the administration of the fiscal system and the collection of the revenues needed to finance public expenditures. Among the main tasks of the institution are the collection of fees and taxes, as well as the verification and control of compliance with tax legislation. Also, its main objective is to improve the level of taxpayers' voluntary compliance with fiscal obligations, by simplifying procedures and increasing the transparency of the administrative act. The institution is divided into several directions, each with specific duties in the fiscal field.

Thus, an evaluation of the internal managerial control system of the institution was carried out in order to have an overview of the procedures, means, actions and dispositions regarding the activities of the entity as a whole. The assessment was made possible with the help of the excellent E.F.Q.M. model. (European Foundation for Quality Management). During the evaluation, 9 main criteria were taken into account according to fig. No. 1, and in order to reach a precise result, all the sub-criteria of the 9 criteria were evaluated. At the end, the score of each criterion will be expressed as a percentage and there will be an overview of the areas to improve/improvement actions.

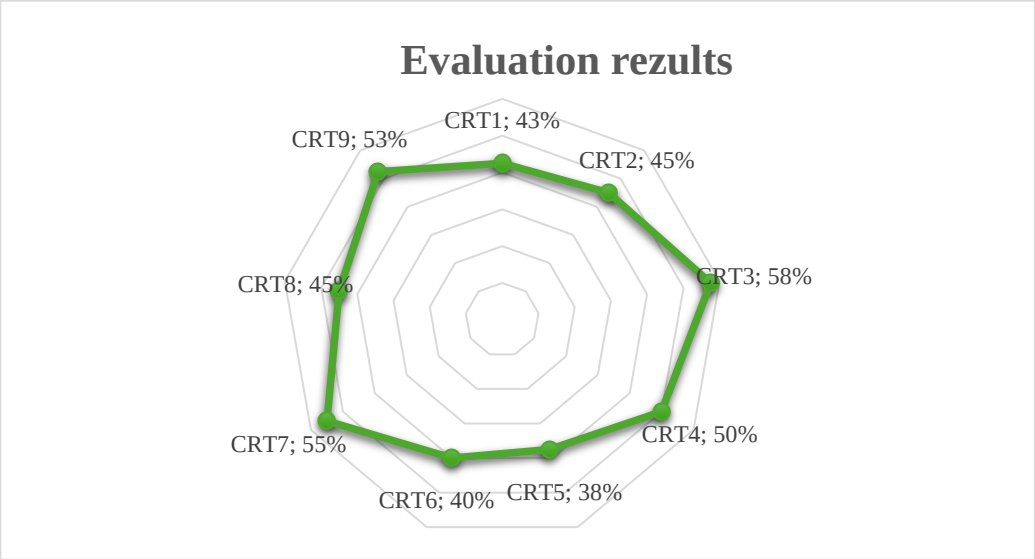

Fig. 1.

As it can be observed, criteria number 5 “Processes” obtained the lowest score, which is why improvement actions will be developed for this criterion.

3.DESCRIPTION

The improvement project will be carried out using the 6Σ method, this method presupposing the performance of certain steps:

1. Preparing the organization for 6Σ through awareness, training and training of project teams;
2. Identifying the main processes and key customers;
3. Defining customer requirements, both internal and external, as well as the deliverables provided;
4. Measuring current performance;
5. Prioritization, analysis and implementation of the improvement project;
6. Extension and integration of the 6Σ system.

Next, the project will be structured in 5 distinct phases, according to Fig. 2:

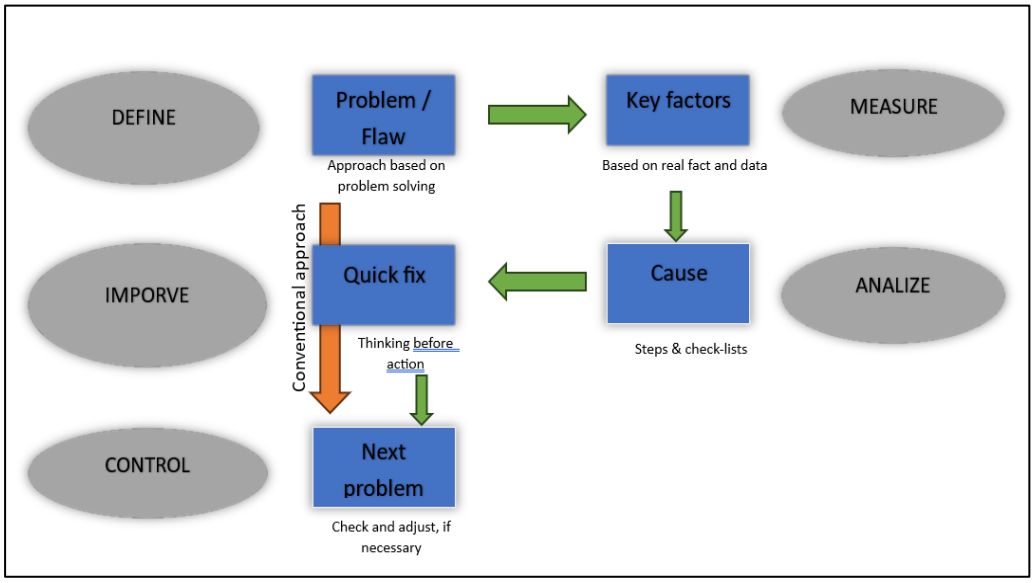

Fig. 2.

DEFINITION – involves defining the targets of the improvement project, phase in which the bases for planning the activities within the project will be established, defining the objectives and limits of the project and identifying the aspects that must be acted upon in order to obtain an improved sigma level**.**

Currently, the process of transmitting data to the business structures subordinate to the organization takes place decentralized through the following steps:

Step no. 1: the business structure receives a request to draw up a statement regarding various situations (annual, semi-annual reports, budget analyses, etc.);

Step no. 2: the business structure techno edits an "address" in which they state the reasons underlying the data request, as well as the exact definition of the information they require;

Step no. 3: The "address" is printed on paper and follows the circuit of obtaining signatures, in hierarchical order: compiler, head of services / office / behavior, deputy general manager (if applicable) and general manager;

Step no. 4: The "address" is assigned a registration number from the issuing department/service/office/compartment (as applicable);

Step no. 5: In this step the "address" can be transmitted to the organization. Transmission is done by e-mail, with prior scanning, or physically;

Step no. 6: Receiving the "address" and registering it within the organization;

Step no. 7: Analyzing the "address" by the general manager, assigning it to one of the sub-directorates and sending it by e-mail. This allocation is made in accordance with its specifics and the areas of activity of the sub-directorates;

Step no. 8: Receiving the "address" at the level of the competent sub-directorate, analysis by the director of the sub-directorate and its distribution to the service / office / department;

Step no. 9: Receiving the "address" at the service/office/compartment level and distributing it, by the head of the service/office/compartment to one or more persons, referred to as the person responsible for resolving the "address";

Step no. 10: The responsible person or persons responsible will deal with the design of the computer script to extract the information requested by "address", the export of the information in a file .xlsx, .pdf, .txt, .csv, .docx, etc. And the transmission of information, by e-mail, to the requesting structure.

MEASUREMENT – refers to the measurement of the existing or initial state, where the period of analysis will be considered from the 1^{st} of June 2023 until December 31^{st}, 2023, during this time frame approximately 500 unique "addresses" were received and registered.

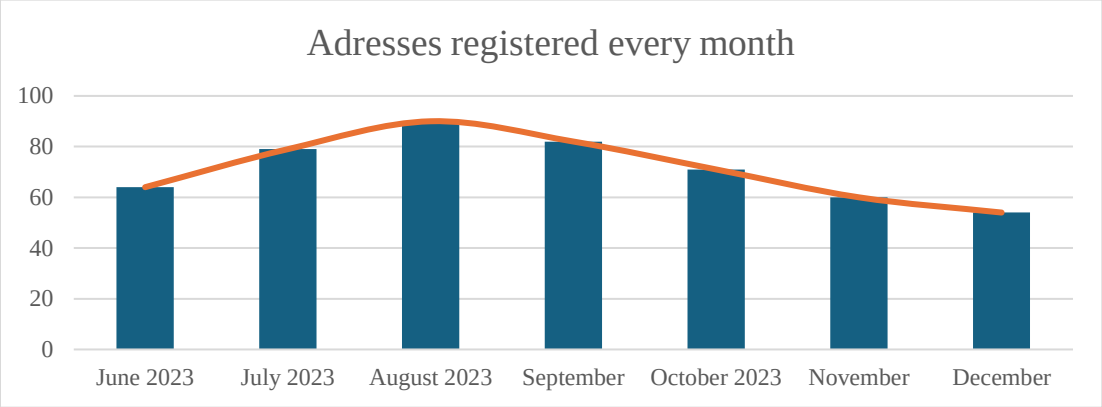

Fig. 3.

Analyzing figure 3, it can be observed that in the July-September period there is a sharp increase in the number of addresses resolved in a period longer than the ceiling period, which is 30 days, due to the specific nature of the vacation period, during which the number of staff is reduced. Consequently, although all received addresses were resolved, the number of those resolved within the legal term of 30 days is much higher than the number of addresses resolved within the legal term (Fig. No. 4), resulting in a weight of 70% of resolved addresses overdue and 30 of the addresses resolved within the deadline.

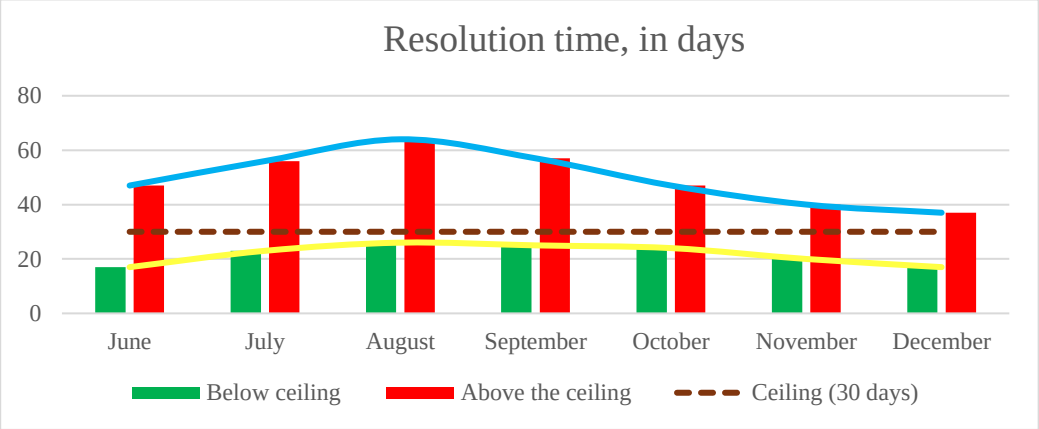

Fig. 4.

Next, the 6Σ method will be applied in order to improve the share of addresses solved in the overdue period, from the current 30% to a percentage of 60%, by developing the theoretical histogram (Fig. 5) and the practical histogram (Fig. 6). In accordance with SR EN ISO 90001/4.9. consideration will be given to conducting the process under controlled conditions. Corroborated with the legislation in force but also with the particular situations through which business structures require data in a very short time interval, the transmission time should be of the order of a few days. 30 days and 10 days reference settlement term will be considered as the legal settlement term for addresses.

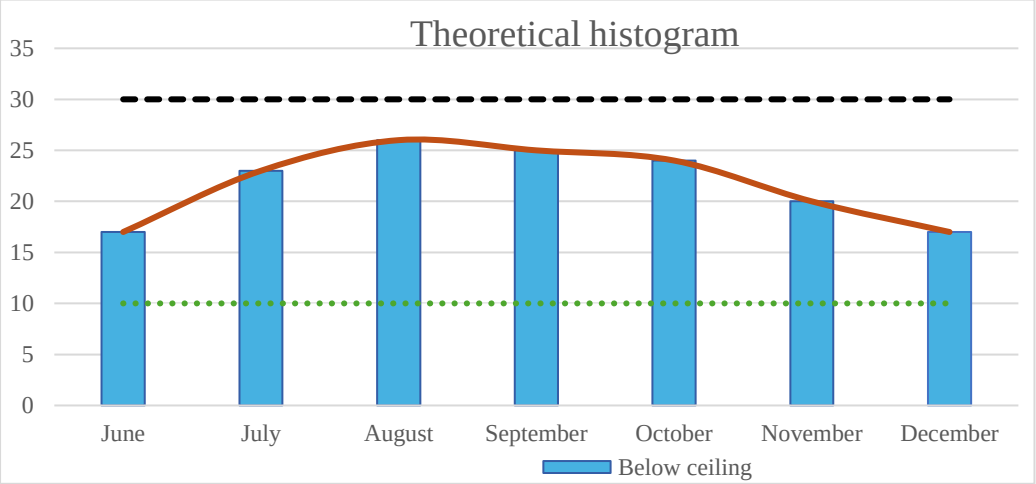

Fig. 5

For the elaboration of the practical histogram, the ceiling of 30 days was taken into account, by which, the number of addresses resolved in less than 30 days, the number of addresses resolved in more than 30 days and a reference resolution term of 10 days.

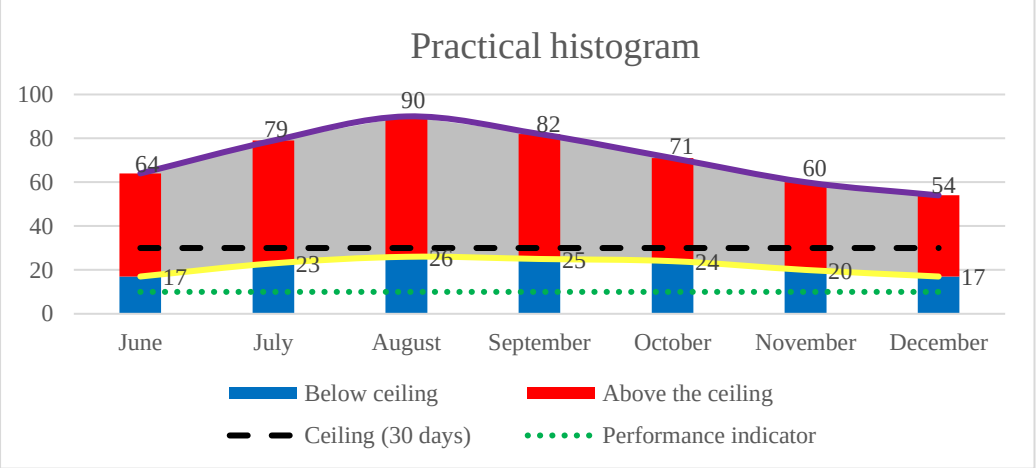

Fig. Nr. 6

ANALYSIS - in this phase, the necessary data will be analyzed to identify ways to close the gap between the current performance of the process and the desired target. In order to be able to identify the causes that lead to the delay in addressing the addresses, a Pareto diagram will be drawn up (Fig. No. 7). The data transmission process to the business structures subordinate to the organization will be analyzed and the steps that cause the delays will be taken into account (Fig. No. 8).

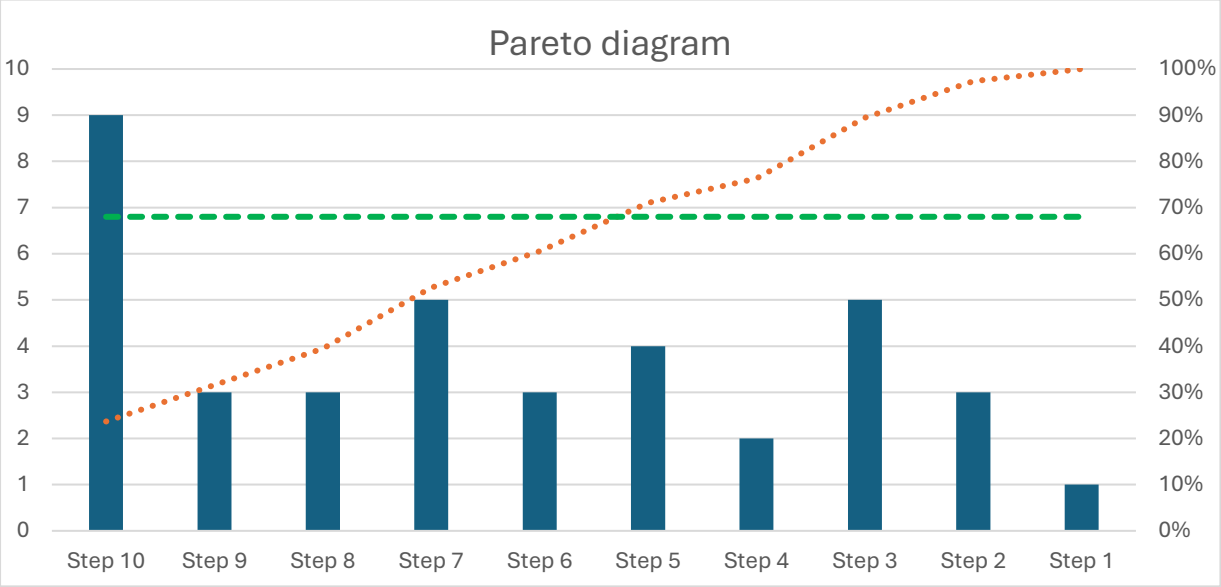

Fig. No. 7

Steps	Days late	Weight
Step No. 1 - receipt of business structure request	1	3%
Step No. 2 - technical drafting of the business structure request	3	8%
Step No. 3 - printing and obtaining signatures	5	13%
Step No. 4 - registration number assignment	2	5%
Step No. 5 - transmission to the organization, for resolution	4	11%
Step No. 6 - reception and registration	3	8%
Step No. 7 – analysis and distribution to subdirectorates	5	13%
Step No. 8 - reception within the sub-directorate and assignment to service/office/compartment	3	8%
Step No. 9 - reception within the service/office/compartment and distribution to those in charge	3	8%
Step No. 10 - settlement and transmission to the issuing structure	9	24%
TOTAL	**38**	**100%**

Fig. 8

At the end of the analysis phase, an Ishikawa diagram (Fig. 9) will be created in order to be able to determine which are the causes that lead to long delay times, which are equally generated both by business structures and by the organization .

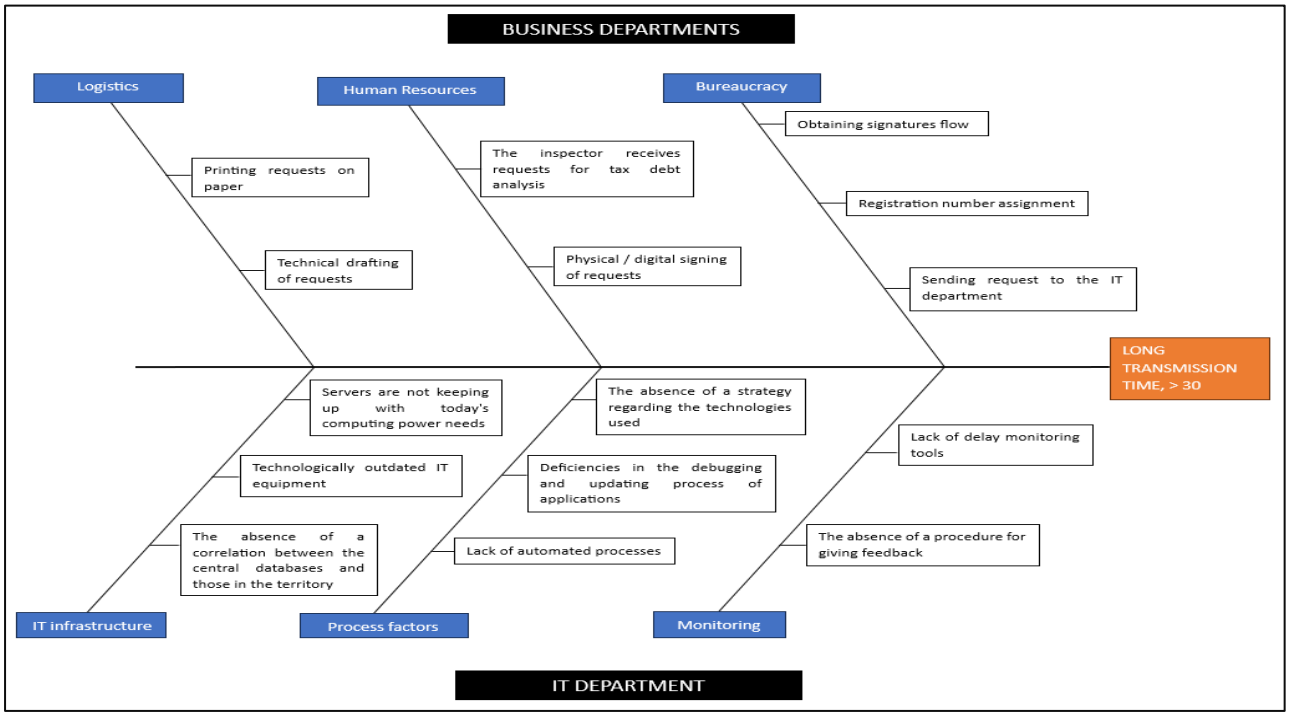

Fig. 9

IMPROVEMENT - process. During this phase, a technical solution will be implemented that aims to reduce the number of late addresses. The technical solution is constituted in the form of an IT application, which will automate the entire data transmission process to the business structures subordinate to the organization. With the help of this solution, all the steps involved in the current transmission process will be eliminated, logistical resources, human resources and most importantly the time required to obtain information will be substantially reduced.

The development of the application will take 6 months and will be done in stages, as follows:

- In the first stage, the application will be designed so that it meets the needs and requirements of business structures - 1.5 months;
- The second stage represents the construction of the application, with its components, the database, the component responsible for the functionality and the client interface - 3 months;
- The third stage: testing and validating the application, stage in which the functionality of the application and the behavior of the client interface will be tested – 1.5 months.

The application will be of the web application type, it will run inside a web browser and will be hosted on the institution's internal servers. Access to the application will be done using a internal link, but only employees within business structures will be able to use the application.

CONTROL - keeping the new solution under control. The application will benefit from tools and technologies with which the application's performance will be tested and monitored. Among these we find Postman - A.P.I. development software. (application programming interface), testing, documenting and analyzing the performance of the Services; Docker - open platform for developing, distributing and running applications in containers. Using Docker, one can package all the dependencies of an application into a container, making the application portable and easy to distribute and run on different environments; Minu - application that helps

to develop and manage Oracle databases. It provides a comprehensive set of tools and functionality for database development, management and optimization.

4. RESULTS AND DISCUSSIONS

After the implementation of the improvement project, the real histogram has been recreated and will be compared to the original real histogram. After analyzing the two histograms, it can be observed that the number of late requests, called "Exceeded legal term" from the initial real histogram, is drastically reduced in the final real histogram (Fig. No. 10) throughout the analyzed period, approaching " The reference period' of 10 days. This is possible due to the fact that by implementing the application, the need to go through the 10 steps of the data transmission process has been eliminated, this process being, now, fully automated. Consequently, the improvement project led to a considerable decrease in the number of delays in the transmission of data to business structures, reduced the consumption of logistical resources (printing paper, printer toner), reduced the human resource component (for the process of obtaining of all signatures) and most importantly the time required to obtain the data by the requesting structure.

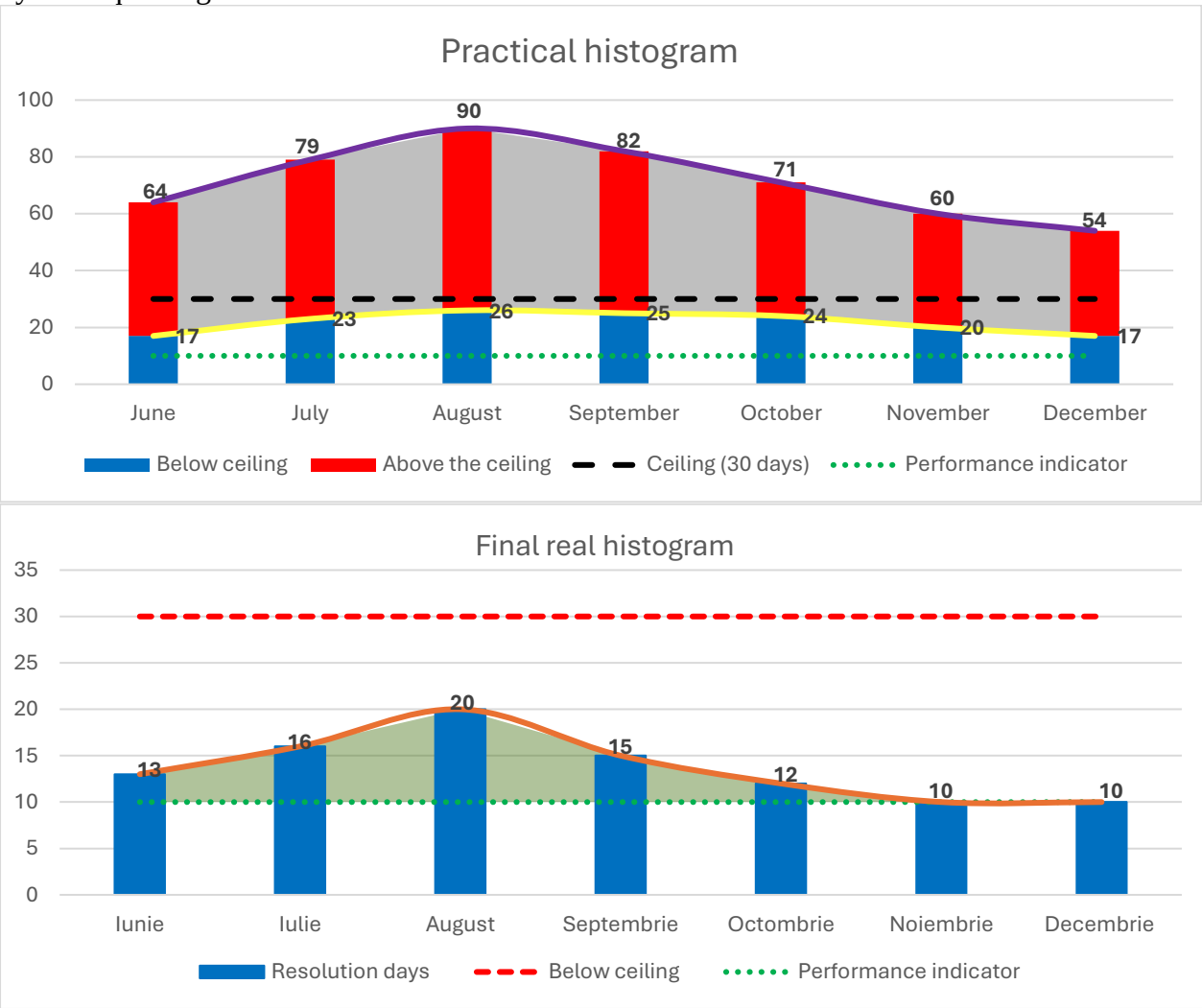

Fig. 10

Also, the share of addresses resolved within the ceiling, compared to those resolved (exceeding the ceiling of 30 days), was appropriate, according to figure 11.

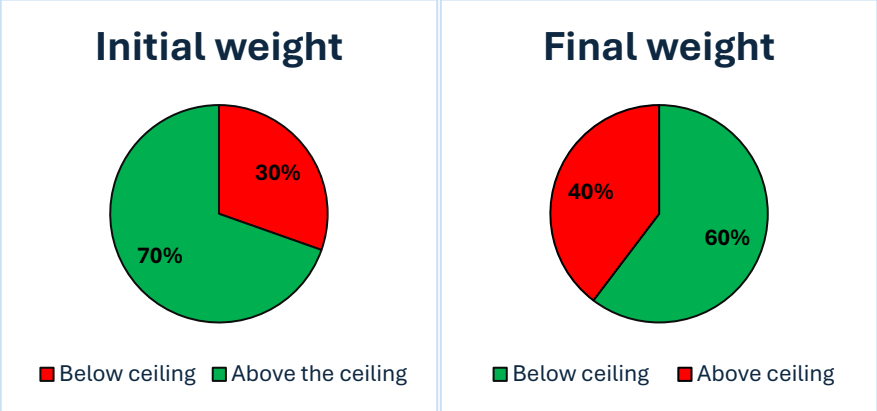

Fig. 11

5. CONCLUSIONS AND FUTURE RESEARCHES

In conclusion, by implementing the application, the old process used to request and send data was replaced and the efficiency of obtaining de data was greatly improved. Furthermore, the IT personnel now can focus on developing more solutions that can respond to similiar problems and the business departments cand now elaborate their business specific analyses much faster.

In the future the organization aims to closely monitor all the areas that require or may require a digital transformation or automation solutions in order to support the organizations departments acheive best results and efficiency.

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IMPROVING CUSTOMER COMMUNICATION IN COMPLAINT MANAGEMENT IN THE RETAIL SECTOR

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ABSTRACT: This paper presents an analytical study aimed at implementing quality management principles in students' lives. One of the fundamental principles of the ISO 9001:2015 standard is stakeholder relationship management; thus, the study focuses on the process of complaint management with customers in the retail and telecommunications sectors. The chosen customer for the study is the student, and the organization is eMAG (a retail company). To improve the complaint management process, a QFD analysis was conducted based on the reviews posted by students on the organization's platform. The interpretation of the results will show the efficiency and effectiveness of the quality management system in meeting the primary customer's needs and expectations.

KEYWORDS: student, customer, organization, complaints, QFD, results

1. Introduction

The ISO 9001 quality management system is one of the most important international standards that contain requirements to help companies or organizations be more efficient and effective in increasing customer satisfaction. Organizations must meet the requirements contained in ISO 9001, implement them, and maintain the applied system so that these requirements can be continuously met. The rigorous structure of the standard helps organize processes and maintain improvement in a wide variety of contexts, including students' lives.

The main component of the SR EN ISO 9001:2015 standard is customer orientation. This principle emphasizes the importance of understanding and meeting customers' needs and expectations. Through this approach, organizations can set clear objectives and align their processes and resources to meet customer requirements effectively.

The tools used in the complaint handling process according to the basic standard are: Ishikawa diagram (cause-effect), 5 Whys, root cause analysis, use of performance indicators (KPIs), and eMAG complaint form.

The aim of this research paper is to analyze how the organization eMAG manages the handling of student complaints, the primary customer. To achieve this goal, customer complaints on the eMAG application were analyzed to identify the customer's voice, supplemented by the application of the QFD function, which includes managing student needs.

2. Analysis and Interpretation of Customer Complaints

Following the analysis of the reviews posted by students on the eMAG platform, the customer's voice was identified. Figure 1 presents customer complaints from the site specifically dedicated to posting reviews after purchasing products.

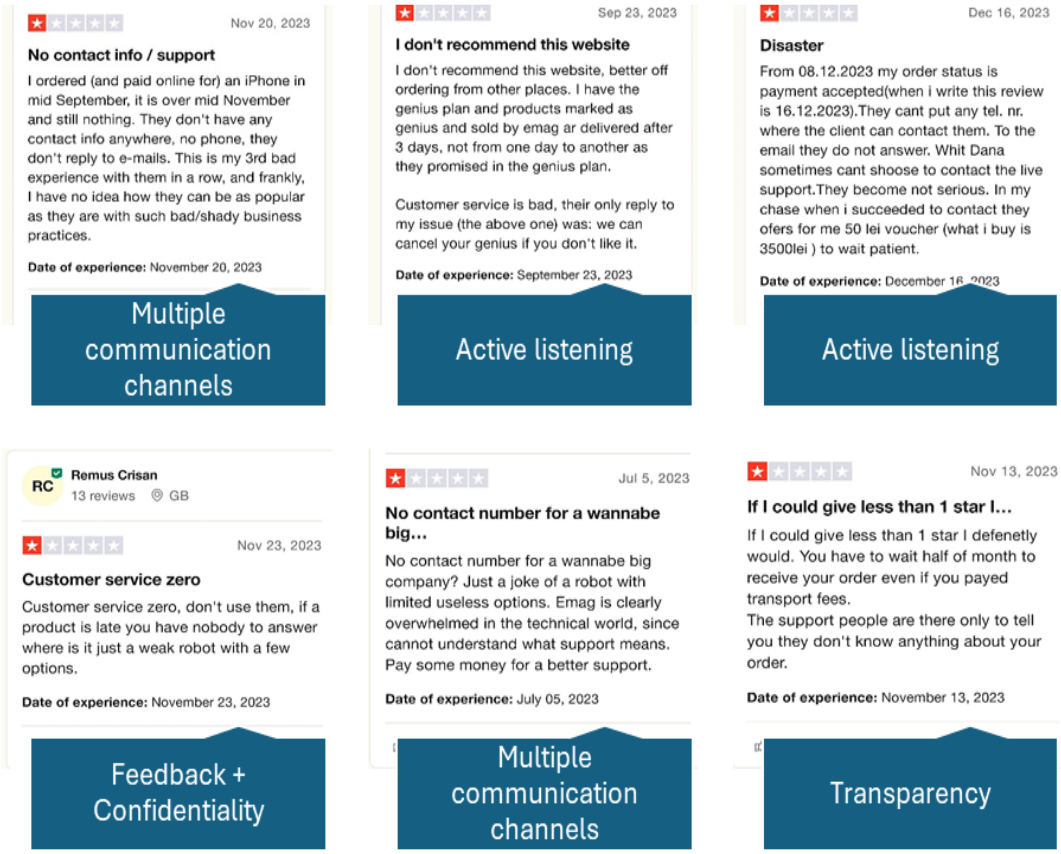

Fig. 1. Customer Complaints

3. Case Study

To better illustrate the customers' needs and to observe the various factors, we propose a model for applying the QFD function. Therefore, we chose to apply this function within the eMAG company. From customer complaints, we discovered VC, namely what they desire from the complaint communication service, and their needs are listed below:

- Active listening (empathy and understanding)
- Quick and efficient response
- Transparency
- Multiple communication channels
- Feedback + Confidentiality

Next, we listed a series of solutions through which customers' needs could be satisfied (HOW?):

- Well-established IT system
- Training for call center operators
- Communication methods tailored to each customer

From the reviews given by customers on the eMAG application, we identified the customer's voice, specifically what they desire from the complaint communication service.

Quality characteristics (How?) / Customer requirements (What?)	Importance score for the customer	Well-functioning computer system	Training sessions for call center operators	Tailored communication channels for each client	
Active listening (empathy and understanding)	2	−	+	−	22
Quick and efficient response	5	+	+	+	75
Transparency	3	+	−	−	15
Multiple communication channels	4	+	−	+	76
Feedback + Confidentiality	5	+	+	+	105
Total		118	68	87	

Fig. 2. House of quality

LEGEND:

9 = strong correlation +

3 = medium correlation +

1 = weak correlation −

Once the requirements were listed, we were able to construct the QFD function ("House of Quality"). Thus, before starting the calculations, based on customer responses, we were able to find the importance score given to each of the five needs (on a scale from 1 to 5, where 1 represents a very low interest in that need, and 5, a high interest). After the importance scores were established, we determined the methods by which the needs could be satisfied. Then, we correlated each need with the methods to fulfill them and observed the degree of correlation between needs and solutions. After establishing the correlation degrees according to the above grid, we made a total and obtained certain scores. From the obtained totals, it can be observed that the highest score, and thus the most important need for customers, is Feedback + Confidentiality, through a well-established IT system (score of 118).

4. Flow Diagram – Process Sheet "Handling Complaints"

In the retail industry, effective complaint management is crucial for maintaining customer satisfaction and loyalty. A flowchart for customer communication in the complaint handling process starts with receiving the complaint through various channels (phone, email, online, in-store) and documenting it in the management system.

The next step is acknowledging receipt, where the customer is informed about the details and the estimated resolution time. The complaint is then evaluated, classified, and analyzed to determine the necessary actions. Resolution involves concrete measures such as product replacement or refund, all properly documented.

Continuous communication with the customer is vital, providing updates on the complaint status and requesting feedback to assess their satisfaction. The process concludes with confirming the resolution and generating a final report.

This systematic approach ensures clarity, efficiency, and continuous improvement of services, enhancing customer satisfaction and fostering trustful relationships.

Following the QFD performed in the case study, a process sheet for handling complaints for the eMAG organization is proposed. With the help of the flow diagram, important stages in the complaint handling process are not omitted, thus it is conducted in a systematic manner. The implementation and efficiency of the quality system for handling complaints are illustrated in Figure 3.

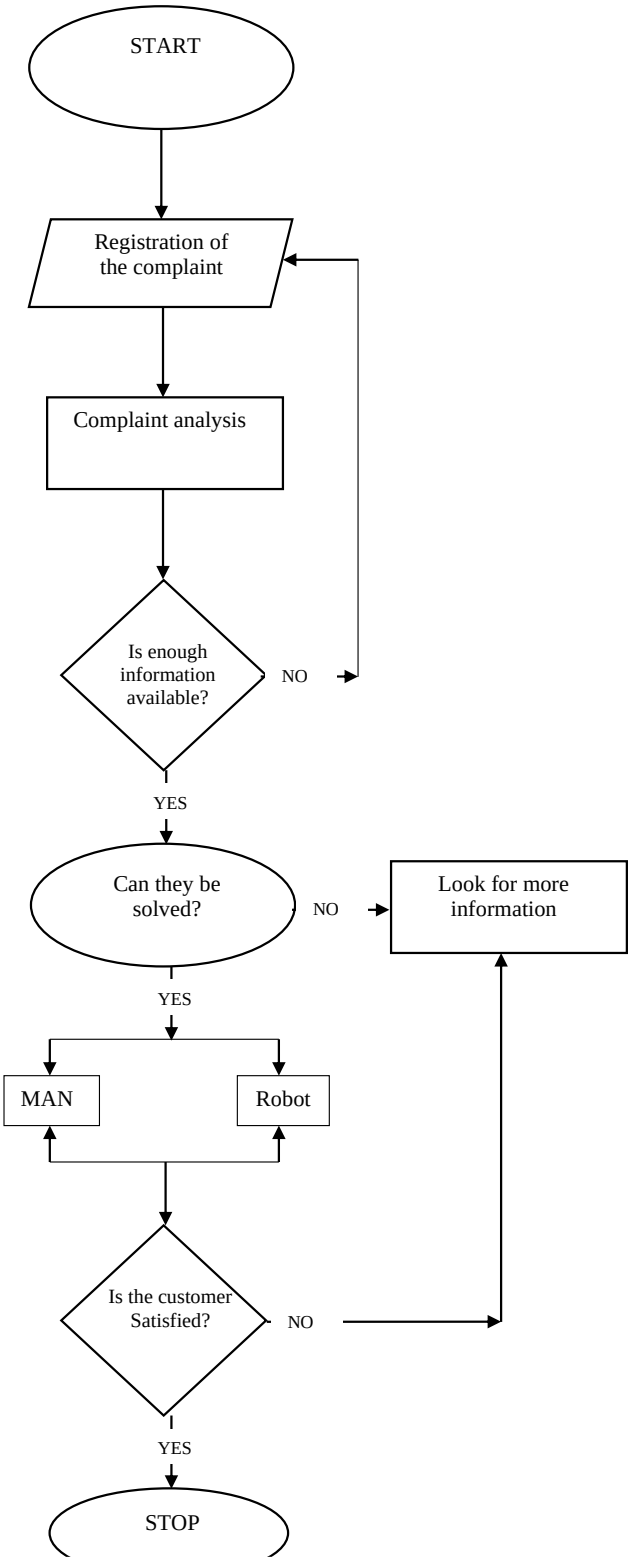

Fig. 3 Complaint Handling Process Sheet

5. Conclusions

To improve customer communication in the complaint handling process, negative reviews posted by users were analyzed and interpreted. Following the analysis, the customer's voice was identified. The needs identified through the customer's voice were highlighted through the application model of the QFD function. From the total analysis, the most significant score, revealing the most important customer need, is related to Feedback and Confidentiality, with a score of 118, especially when it comes to an efficient and well-developed IT system.

To streamline the complaint handling process, a process sheet based on the results of the QFD analysis is proposed. For long-term improvement of the process, it is considered to reapply the QFD analysis ("House of Quality").

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COMPARATIVE ANALYSIS OF SOME COMPANIES IN THE ENERGY FIELD USING THE EFQM EXCELLENCE MODEL

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ABSTRACT: In today's business environment, companies prioritize enhancing efficiency and productivity to reduce costs and save time. However, it's crucial to consider the negative impacts of actions that neglect sustainable concerns. Given the significance of conducting business activities in a sustainable manner that doesn't harm the environment, economy, or society, governments and global organizations have increasingly emphasized this aspect. Acknowledging this necessity, the present paper seeks to analyze various companies in the energy sector regarding sustainability. To ensure a comprehensive analysis, we utilized the criterions of EFQM Excellence Model as a framework for structuring and guiding the examination of sustainability within companies.

KEYWORDS: sustainability, EFQM Excellence Model, environment, responsibility

1. Introduction

Sustainability and excellence in organizational practices are paramount for companies operating in the energy sector. As the world grapples with the challenges of climate change and environmental degradation, the energy industry faces increasing scrutiny to adopt sustainable business practices while maintaining operational excellence. In this context, the EFQM Excellence Model emerges as a powerful framework for evaluating and benchmarking organizational performance across various sectors, including energy.

This paper presents a comparative analysis of select companies in the energy field, leveraging the EFQM Excellence Model as a guiding framework. Specifically, it was examined how three market leaders operating in different regions approach sustainability and excellence within their organizational contexts. By employing the EFQM Excellence Model as our analytical tool, we aim to provide insights into the best practices of these companies in integrating sustainability into their business strategies.

As the literature said, for a long period of time organizations improved their organizational attitude regarding the environment just through operational and technical activities and just a few of them incorporate sustainability as a strategic thinking to develop in a structured way the environmental management system [A].

Another study highlights that focusing on a green development of the the organization is a sustainable competitive advantage [A] that more and more companies should consider it.

Literature claims that sustainable development is formed on three major points of view, like presented in Figure 1, namely social, economic and environmental and the sustainable progress of organizations is realized when all of these three areas are integrated [D]. It is also said that are three different approaches to sustainable development that are articulated: "the economic which maximizes income whilst maintaining capital stock, the environmental which seeks to preserve biological and physical systems and the sociocultural which encompasses equity and participation" [D].

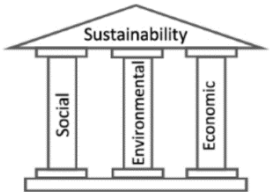

Figure 1. The three pillars of sustaiability adapted by [C]

Since the EFQM Excellence Model addresses all three pillars of sustainability and offers the possibility to conduct an exhaustive analysis of companies, it was chosen to use it in this work with the focus on the "Taking Responsibility for a Sustainable Future" principle.

2. Research methodology

In the current paper, three companies, market leaders in the energy producing industry, were approached, namely Siemens Energy, General Electric and Mitsubishi Power. These three companies are among the largest and most influential players in the global energy sector, providing a wide range of products and services for power generation, transmission and distribution. Each of these companies is headquartered in a distinct region—Europe, the USA, and Asia, respectively. They were chosen in this way to capture, through the prism of different cultures, the ways in which these organizations approach and implement the theme of sustainability, each within its own framework. Also, the EFQM Excellence Model was used to guide and structure the information and to be the tool that provides the criteria for companies' analysis. Thus, it started by presenting the principle Taking Responsibility for Sustainable Future from the EFQM Excellence Model in Table 1 and adding the three companies taken for the case study.

Tabel 1. The last principle of the EFQM Excellence Model and its sub-criteria

Taking Responsibility for sustainable future			
Criterion \ Companies	Siemens Energy	General Electric Power	Mitsubishi Power
	Europa	U.S.A.	Asia
1 Leadership	1.a. Leaders develop the Mission, Vision, Values and ethics and act as role models. 1.b. Leaders define, monitor, review and drive the improvement of the organization's management system and performance. 1.c. Leaders engage with external stakeholders. 1.e. !		
2 Strategy	2.c. Strategy and supporting policies ae developed, reviewed and updated.		
3 People	3.d. People communicate effectively throughout the organization. 3.e. People are rewarded, recognized and cared for.		
4 Partnership & Resources	4.c. Buildings, equipment, materials and natural resources are managed in a sustainable way		
5 Processes, Products & Services	5.d. Products and Services are produces, delivered and managed.		
6 Customer Results	-		
7 People Results	-		
8 Society Results	8.a. Perception 8.b. Performance Indicators		
9 Key Results	-		

Next, the three companies chosen according to the criteria of the model were analyzed and for each criterion the related sub-criteria were described, as can be seen in Table 2. After this, information about each company was extracted from public sources and this information was structured according to the subcriterion to which it corresponded. For each criterion, around two examples of good practices were presented for each individual company. After completing the table, some conclusions were drawn and some comparative results were obtained for the good organizational practices analyzed in relation to EFQM Excellence Model

Tabel 2. The sustainable good practices of each company according to the criteria of EFQM Excellence Model

Siemens Energy	General Electric Power	Mitsubishi Power
1.a. Leaders develop the Mission, Vision, Values and ethics and act as role models.		
Leaders of Siemens Energy develop the organisation's mission, vision and culture through a sustainable view, namely they push the organisation to reduce green house emission and make renewable energy, they empower to afford decarbonization through technology and to combat the lack of social inclusion and also to create tomorrow's sustainable energy solutions though partnerships. Leaders develop and role modelling values, ethics and public responsibilities that support the culture by attending, organizing and reward projects like climate-neutrality, eco-efficiency, zero pollution, circular economy and zero harm. Siemens Energy Leaders set and communicate the clear direction of the organization on sustainability by disseminate the three key areas: low- and zero- emission power generation, efficient transmission and storage of electricity and reducing CO2 emissions from industrial processes. These three key areas are in the strategy of the Siemens Energy.	Leaders of General Electric Power set and communicate a clear direction and strategic focus on sustainability like sustain integrity, continuous improvement of their people, communities and the planet. Leaders develop ethics and responsibilities in order to create a culture of integrity. Leaders acts as an active role models in sustainability programs due to their implication for developing and brining back into use the delirect properties of the community.	Leaders of Mitsubishi Power develop and set a clear Mission of the company in order to contribute to sustainable society through their business activities, likely: *Care for the planet, Create a more harmonious society and Inspire the future.* Leaders of Mitsubishi Power communicate the Mission, Vision and Values to the employees and stakeholders through site, rapports (Sustainable Rapports), meetings, workshops, visible papers etc.
1.b. Leaders define, monitor, review and drive the improvement of the organization's management system and performance.		
Leaders of Siemens Energy had integrated a management system for Business Area, Regional Hubs and Corporate Functions [B] to speed up the services, to simply processes and for transparency in order to implement an ESG approach Siemens Energy Leaders help in the design and implementation of an establishment, developing and reviewing process of the organizational management system Leaders ensure the minimization of the impact on the environment through environmental management system and they implement the approach of product stewardship by including all the environmental aspects, the focus on climate change adaptation and resources efficiency Leaders aligns the structure of the organization in support of the policy and strategy according to an integrated management system covering quality (ISO 9001), environment (ISO 14001) and health and safety (ISO 45001) [B]	Leaders of General Electric Power emphasize the development for the next suite of engine technologies that offer at least 20% additional improvement in fuel efficiency compared to today's performance. Leaders of General Electric Power develop and improve the organization's management through creating platforms and intelligent applications necessary to accelerate electrification and decarbonization along the entire energy system.	Leaders of Mitsubishi Power define and a improve a *Sustainability Promotion System,* with a *Sustainability Committee* which has as a general objective promoting a management that takes into account sustainability in all the activities of the company. Leaders of Mitsubishi Power review their sustainability system through the *Materiality Council,* where problems regarding the progress, project examples and questions/ opinions are discussed.

1.c. Leaders engage with external stakeholders.		
Leaders of Siemens Energy develop and sustain the usage of the Net Promoter Score (NPS) to evaluate and measure customer satisfaction Leaders' analysis of organizational performance in relation with to the satisfaction of customer requirements by evaluating this NPS score Siemens Energy Leaders use customer communication platforms to collect feedback Leaders conduct materiality analysis in order to establish the Sustainable Program and for that they engage with selected internal and external stakeholders' groups such as customers, investors and partners Leaders promote, support and engage in activities and collaborations with stakeholders in order to improve the sustainable improvement of the organization and also to foster the environment and society	Leaders promote sustainability programs like bringing back unused properties which helps an economic growth and a community development. Leaders of General Electric Power identify strategic and operational partnerships based on organizational and strategic needs, complementary strengths and capabilities because GE is a member of the GridWise Alliance, which represents the broad and diverse stakeholders that design, build and operate the electric grid is USA and educate key industry stakeholders on the critical need to modernize the national electricity system. M]	Leaders of Mitsubishi Power maintain a transparent and clear communication with their stakeholders and transfer to them their sustainability priorities and principles, expectations and business activities following a *CSR Action Guide.* Leaders of Mitsubishi Power engage with their stakeholders through a *Basic Policy on Environmental Matters and Action Guidelines* to promote environmental initiatives and maintaining dialogues with their stakeholders.
1.e. Leaders ensure that the organization is flexible and manages change effectively.		
Leaders organize training sessions for new employees in order to understand the mission, ethics, vision of the organization from the point of view of sustainability. Leaders are distinguished by outstanding performance becoming a motivational engine for their employees, they always seek to exceed their potential and promote employee involvement through direct questions during meetings.	Leaders have ensured throughout the 130 years of company history that they adapt and face all the challenges and changes of the organizational environment through the programs that sustains company sustainable goals (e.g. Driving Sustainability Through Transformative Technologies, Lowering Emission with Additive Manufacturing) Leaders ensure that the organization is flexible and manages change effectively due to their kaizen spirit of continuous improvement, they undertake to regularly review their measures and processes to adapt to changes in the external and internal environment.	Leaders of Mitsubishi Power inform themselves and are continuously adapting to changes in the society, trying to adapt sustainable AI or digital products to the needs of the company; using digitalization appropriately to manage in a sustainable way the demands of their customers; focus their employees on creativity in their activities. Leaders of Mitsubishi Power build *a flexible, robust and labour saving system* [E] which help them to contribute to a sustainable society.
2.c. Strategy and supporting policies ae developed, reviewed and updated.		
The Siemens Energy strategy is designed, developed and reviewed in accordance with the organization's Mission and Vision in the direction of sustainability The Siemens Energy strategy is reaffirmed through the focus on decarbonization and transformation of green energy. Siemens Energy's strategy balances the needs and expectations of stakeholders in the short and long term in order to be able to reach its sustainability targets Siemens Energy has identified its critical success factors through annual sustainability reports.	General Electric Power's strategy and polices on sustainability are communicate to external stakeholders through the annual Sustainability Report. General Electric Power's strategy is formed on six Sustainability Priorities, namely *Driving Decarbonization Through the Energy Transition, Smarter and More Efficient Future of Flight, Environmental Stewardship, Commitment to Human Rights, Lifting Up Our Communities, Safety of Our People*	Strategies and supporting policies are continuously developed and updated by the *Chief Strategy Officer* and *Chief Sustainable Officer* among with the *Sustainable Committee*, sustain and empower a growth of the company with *fairness*, *integrity* and *responsibility to society.* Strategies and supporting policies are reviewed continuously *based on the results of the effectiveness evaluation of the company* [E] and approved by the Board of Directors.

Siemens Energy adopts effective mechanisms to understand future scenarios such as the resulting climate outcomes and a detailed annual forecast four their CO_2 emission footprint of products and management strategic risks		
3.d. People communicate effectively throughout the organization.		
The Siemens Energy strategy is reaffirmed through the focus on decarbonization and transformation of green energy. Siemens Energy makes the internet available to employees to find structured and useful information about the company Siemens Energy promotes real communication between departments of the organization and between employees in the same department and promote a way of solving problems by helping each other through support each other There are training sessions for vision, mission that are held periodically	General Electric Power enable and encourage the sharing information, knowledge and best practices due to their collaboration with Universities like Boston University and MIT. General Electric Power communicate a clear direction and strategic focus for their people through the GE Human Rights Statement of Principles.	People in Mitsubishi Power communicate effectively in the organization through a well-established management of the organization; there is a *Chief Sustainable Officer* who is responsible with the sustainable direction of the company, namely *to make management level decisions related to how to address sustainability* In Mitsubishi Power is enable and encouraged the sharing of information and best practices throughout dialogues thanks to the *MHI Power Human Rights Policy* that contains the following: *Comply with Laws and Regulations on Respecting Human Rights, Targets and Education, Responsibilities on Respecting Human Rights, Human Rights Due Diligence, Dialogue and Consultation, Information Disclosure)* [E]*issues* like ESG initiatives [E]
3.e. People are rewarded, recognized and cared for		
Siemens Energy ensure an organizational culture through which it is promoted the diversity of people Siemens Energy ensure a safe and healthy working environment for their people through the physical safety of the workplace, but also through regular trainings on EHS Siemens Energy invests in employees' professional growth through training programs, workshops, and educational opportunities demonstrates a commitment to their long-term success.	One of General Electric Power's top Priorities is the effort to make the health and well-being of their employees and in recognition to their work, the company received The 2022 Best Employers: Excellence in Health and Well-Being Award from the Business Group on Health. At General Electric Power people are rewarded, recognized and cared for through respecting workers' rights to freedom of association, privacy, collective bargaining, immigration, working time, wages and hours, and prohibits forced, compulsory and child labor and employment discrimination in new business operations and partnerships.	People, both from internal and external, in Mitsubishi Power are encourage to participate in activities that contribute to wider society such as: *Science classes, Factory tours with hand-on learning, Career education, Sports coaching, Study support* and *Sponsoring of Scholarships.* In Mitsubishi Power it is ensured an embracement of diversity for they people through the *MHI Power Human Rights Policy* and through their principle *of act with integrity and fairness, always resecting others* [E].
4.c. Buildings, equipment, materials and natural resources are managed in a sustainable way		
Siemens replace some of their old equipment such as electric motors of exhauster, vacuum systems, air conditioners, air compressor etc. with the one more efficient in order to energy saving and to obtain less negative environmental impact Siemens Energy demonstrate its actively implication in reducing the negative impact of their work on the environment and its focus of producing green energy.	General Electric Power bases its exploitation of resources on the circular economy to allow their management in a sustainable way. General Electric Power uses their resources in a way to protect the environment, namely they use lost materials, redirecting them back to the economy instead using virgin materials.	Mitsubishi Power optimize the use and effectively manage the lifecycle of their resources and assets and the impact of them in the try to alleviate burden on the environment in all aspects of company business activities, *from product R&D and design to procurement of raw materials, manufacture, transport, usage, servicing and disposal, through pollution prevention, conservation of*

Siemens Energy develop strategy and supporting policies for managing		*resources, energy saving, and waste reduction* [E].
buildings, equipment and overall materials in a sustainable way Siemens Energy sustain their less negative impact on sustainability by equipe products (such as ground robots) with environmental sensors that can asses air and water quality Siemens Energy opted for helping the production of steel with equipment like electric arc furnace instead of coal-fires furnace Siemens Energy implement energy-efficient measures such as insulation, efficient HVAC systems, and LED lighting can result in excessive energy consumption and greenhouse gas emissions. Siemens Energy upgrade machinery and equipment to newer, more energy-efficient models even when they are available		Mitsubishi Power implement appropriate policies and approaches to preserve the environment and *contribute to solving environmental and energy challenges* [E].
5.d. Products and Services are produces, delivered and managed.		
Siemens Energy support through their products customers in their transition to a more sustainable world Siemens Energy manage products through their entire lifecycle, including reusing and recycle where appropriate, considering the impact on sustainability. Siemens Energy help in reducing negative impact on environment through sold their products Siemens Energy incorporate environmental sustainability principles into product design, manufacturing processes, and supply chain management to minimize environmental impact.	General Electric Power manage products and services throughout their entire lifecycle by their ambition to a more circular economy. They also consider the lifecycle of their engines. Currently, there are more than 23,000 total repairs in their catalogs to restore worn GE and CFM International 15 engine parts to serviceable conditions. Additionally, GE and CFM International15 industrialized more than 1,700 repairs in 2022, increasing repair capability. As a result, GE globally repaired approximately 2.3 million engine components in 2022. General Electric Power produce and deliver products and services to meet or exceed customer needs through currently having 100% H2-capability across some of its gas turbine offerings and is expanding capability with industry-leading, efficient HA gas turbines to 100% by 2030 to meet customer needs to future-proof investments as hydrogen becomes available.	Mitsubishi Power optimize the use and effectively manage the lifecycle of their resources and assets and the impact of them in the try to alleviate burden on the environment in all aspects of company business activities, *from product R&D and design to procurement of raw materials, manufacture, transport, usage, servicing and disposal, through pollution prevention, conservation of resources, energy saving, and waste reduction* [E]. Mitsubishi Power implement appropriate policies and approaches to preserve the environment and *contribute to solving environmental and energy challenges* [E].
8.a. Perception		
for global approaches of EQS Siemens Energy establish ongoing communication channels with stakeholders through various means such as surveys, focus groups, interviews, forums, social media, and dedicated websites.	General Electric Power initiate measures following the questionnaires for the areas of environmental impact and for social impact.	obtained *Incentives Toward Management Activities Related to the Issue of Climate Change* [E].
8.b. Performance Indicators		
Siemens Energy sets specific energy efficiency targets for its turbines and power generation equipment, regularly monitoring and optimizing performance to	General Electric Power is using Performance Indicators on Sustainability in order to predict and improve the performance of the	Mitsubishi Power uses internal measures and indicators in order to monitor, understand and improve the performance of the company regarding

achieve these goals. They track metrics such as heat rate improvements and fuel consumption reductions to drive efficiency gains Siemens Energy implements leading safety indicators such as Total Recordable Incident Rate (TRIR) and Lost Time Incident Rate (LTIR) to measure and improve safety performance across its operations. They conduct regular safety audits and provide ongoing safety training to employees. Siemens Energy use metrics like NPS (Net Promoter Score) and customer retention rates to measure and improve customer satisfaction, promptly addressing any issues or concerns raised. Siemens Energy utilizes operational efficiency metrics such as equipment uptime, maintenance costs, and production throughput to optimize plant performance and maximize productivity. They leverage data analytics and predictive maintenance technologies to proactively identify and address inefficiencies. Siemens Energy tracks financial performance indicators such as revenue growth, profit margins, and return on investment (ROI) to assess business performance and financial health.	organization (e.g. of categories Human rights: Supplier Responsibility Program, Environmental Stewardship, Diversity and Inclusion, Safety, Lifting Our Communities) General Electric internal indicators give a clear understanding of the efficiency in the different approaches adoptive such as sustainable progress across its supply chain and individual sustainable performance.	societal and environmental responsibilities, such as *Reduce CO2 emissions, Number of optimal energy infrastructures, Level of employees' awareness, Increase the ratio of women on the Board of Directors, Reduce the number of accidents etc.* [E]. Mitsubishi Power's indicators give a understanding of the approaches adopted and their impact on society and environment such as *Reduction in CO2 emissions, Reduction in water usage, Reduction in waste generation*

3. Results and Evaluation

As it can be seen above, all three companies have sustainable strategies and policies applied on their business. These organizations have also some differences in the ways in which the principle of Taking Responsibility for Sustainable Future of EFQM can be evaluates in them. Since this principle and its criterions are the underlying guidelines for this paper, it can be obtained the following results divided in three categorizes, namely emphasis on the specifications of the region in which they activate (First), they approach on using new technologies and solutions (Second) and the level of collaboration with their stakeholders (Three).

First. Each of these companies operates in different regions and therefore faces specific market requirements and conditions in terms of sustainability. For example, Siemens Energy in Europe have a greater focus on renewable energy integration and implementing processes for decarbonize energy systems, according to European standards and targets, while General Electric Power in the USA have a greater focus on carbon capture and storage technologies, due to policies and local requirements. Asia's Mitsubishi Power, on the other hand, is more geared towards innovations in energy efficiency and advanced power generation technologies to meet the growing energy needs of the region.

Second. Each company have a different approach to the portfolio of technologies and solutions to promote sustainability. For example, Siemens Energy is focusing more on the development and deployment of renewable energy solutions such as wind and solar, while General Electric Power may have a more diversified portfolio that includes both renewable energy solutions and technologies nuclear energy or low emission hydrocarbons. At the same time, Mitsubishi Power could place greater emphasis on advanced combustion and turbine technologies to improve efficiency and reduce emissions in existing power plants.

Third. Regarding the approach with the stakeholders, Siemens Energy adopt a collaborative approach through strategic partnerships with governmental and non-governmental organizations, as well as other energy companies. For example, they work with local governments to develop renewable energy and energy efficiency policies and initiatives. They also form partnerships with NGOs to implement community and sustainable development projects in underprivileged regions. Through these partnerships, Siemens Energy improve its impact on the environment and society and promote a faster transition to a more sustainable economy. At the same time, General Electric Power takes a similar approach, but with a strong focus on innovation and technology. The company develop partnerships with universities and research centers to accelerate the development and implementation of clean and energy efficient technologies. It also works with other energy companies to promote higher sustainability standards and practices. Through these partnerships, General Electric Power drives innovation and progress in sustainable energy. As far as Mitsubishi Power is concerned, it adopts an innovative and collaborative approach in developing and implementing sustainable energy solutions. The company forms partnerships with local governments and other companies in the region to develop integrated energy projects that improve energy efficiency and sustain human rights and equity in the community. It also works with local communities to identify and address specific energy needs and promote access to clean and secure energy. Through these partnerships, Mitsubishi Power contributes to the sustainable development of the regions in which it operates and reduce its impact on the environment and communities.

4. Conclusions

Therefore, this paper presents sustainability measures implemented by various companies in the energy sector. The approaches analysed were structured based on the EFQM Excellence Model and evaluated according to its criteria to achieve a comprehensive analysis of these companies' sustainability practices. The companies examined in this study were Siemens Energy, General Electric Power, and Mitsubishi Power, each operating in Europe, the USA, or Asia respectively. These three companies are market leaders in their respective regions within the energy sector, warranting a thorough analysis encompassing their operational practices and regional influences on sustainability implementation.

Analyzing these companies through the lens of sustainability principles according to the EFQM model contributes to both theoretical and practical advancements in evaluating organizational practices. This occurs in an environment increasingly prioritizing sustainability, thereby providing a framework for the quest for more effective methods of managing processes, products, and systems within the energy production industry

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IDENTIFYING THE ROOT CAUSES OF NON-CONFORMITIES OF AN INDUSTRIAL COLD WATER TAP PRODUCT USING FMEA

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ABSTRACT: This paper proposes the use of the new method for conducting FMEA (Failure Mode and Effect Analysis) for a product, which was approved in 2019 by the German Association of the Automotive Industry, Verband der Automobilindustrie (VDA), and the Automotive Industry Action Group (AIAG) from America, for a product that is not part of the automotive industry. An Industrial Cold-Water Tap, representative of the hydraulic industry, was chosen as the product for analysis, on which the failure modes, their effects, and their criticality were analyzed.

KEYWORDS: FMEA, non-conformity, subassembly, product

1. Introduction

Failure Mode and Effect Analysis (FMEA), known in Romanian as Analiza modurilor de Defectare, a Efectelor și a Criticității acestora (AMDEC), determines the predictive reliability of a technical system by identifying its potential failure modes, their effects, and by evaluating the severity of possible consequences, the probability of occurrence, and the probability of detection for each identified failure mode, thus assessing the criticality of defects. The analysis also includes the necessary preventive and corrective actions to reduce or correct the failures and their effects. The main objective of the analysis is to achieve optimal quality for a technical system, production system, or services.

FMEA is based on Murphy's Law, which states, "If something goes wrong, it will certainly go wrong at the most inconvenient time."

The two main types of FMEA analysis are: Design FMEA (DFMEA) and Process FMEA (PFMEA)

2. Current State

FMEA was developed by the U.S. military under the name Military Procedure MIL-P-1629 and dates back to November 9, 1949. It was used as a reliability evaluation technique to describe the effects of system and equipment failures. Failures were classified according to their impact on success, people, and equipment safety.

In 1963, NASA developed "Failure Mode and Effects Analysis" (FMEA) for the Apollo project. By 1965, the aerospace engineering sector had adopted this method. Around 1975, this method was implemented in nuclear engineering, among other fields. FMEA was first implemented in the automotive industry by Ford Motor Co. (USA) in 1977 for preventive quality assurance. In Germany the method was applied under the name of DAMUCK in 1980. Widely applied in the automotive field, the method becomes essential for the implementation of 6 sigma in the USA in 1986. In 1990 a common application of the method appeared in many fields: health services, telecommunications, and household appliances

In 2019, AIAG and VDA improved the FMEA method by organizing it into seven steps.

The paper aims to apply the latest advanced version of the FMEA methodology, specific to the automotive industry, to a product not associated with this industry.

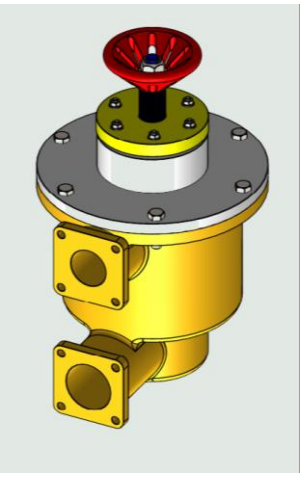

Figure 1: Industrial Cold Water Tap

The product chosen for analysis is an Industrial Cold Water Tap, which is part of the hydraulic industry. The functional role of the industrial cold water tap is to allow the release of overpressure generated in the sanitary installation in which it is inserted or to open at a certain pressure. It functions in regulating the water flow within the installation, directing the liquid, and ensuring the system's tightness by eliminating accidental liquid leaks. During use, no additional protective measures are necessary, as the working pressure of the liquid is a maximum of 10 bar. The entry of foreign bodies is sufficiently prevented by the design of the tap, so no additional preventive elements are required.

3. FMEA Analysis

The FMEA process unfolds in seven steps. These seven steps provide a systematic approach to conducting a Failure Mode and Effects Analysis and serve as a record of the technical risk analysis.

3.1 Step 1: Planning and Preparation

The purpose of the planning and preparation stage of DFMEA is to define which FMEAs will be conducted for a project and to define what is included and excluded in each FMEA based on the type of analysis developed, i.e., system, subsystem, or component.

The main objectives of planning and preparing DFMEA are:

- Project Identification
- Project Plan: Intent, Timing, Team, Tasks, Tools
- Analysis Boundaries: What is included and excluded from the analysis
- Identifying FMEA based on lessons learned

Identifying the DFMEA project includes a clear understanding of what needs to be evaluated. This involves a decision-making process to define the DFMEAs that are necessary for a program intended for customers. What to exclude can be as important as what to include in the analysis.

During the planning and preparation stage, the DFMEA document header needs to be completed. The header can be customized to meet the organization's needs. The header includes some of the basic information of the DFMEA domain, as follows:

PLANNING & PREPARATION (STEP 1)

Company Name:	HIDRO Terra	Subject:	HT 123 Industrial Cold Water Tap	DFMEA ID Number:	DFMEA_HT_ICWT
Engineering Location:	Bucharest, Romania	DFMEA Start Date:	20.04.2024	Design Responsibility:	Marinescu Victor-Marian Ploaie Roxana-Gabriela
Customer Name:	HIDRO Terra	DFMEA Revision Date:	10.05.2024		
Model Year/Platform:	2024 HT123	Cross-Functional Team:	See team list	Confidentialitu Level:	Confidential

Figure 2: Planning and Preparation

3.2 Step 2: Structure Analysis

The purpose of the design structure analysis is to identify and breakdown the FMEA domain into system, subsystem, and component parts for technical risk analysis.

The main objectives of a design structure analysis are:

• Visualizing the analysis domain

• Structure tree or equivalent: block diagram, boundary diagram, digital model, physical parts

• Identifying design interfaces, interactions, close distances

A system structure is composed of system elements. Depending on the scope of the analysis, the system elements of a design structure may consist of a system, subsystems, assemblies, and components.

A system element is a distinct component of a functional element, not a function, requirement, or characteristic.

The structure tree arranges the system elements hierarchically and illustrates the dependency through structural connections. The clear and structured illustration of the complete system is ensured by the fact that each system element exists only once to prevent redundancy.

The structures arranged under each System Element are independent substructures, as shown in Figure 4.

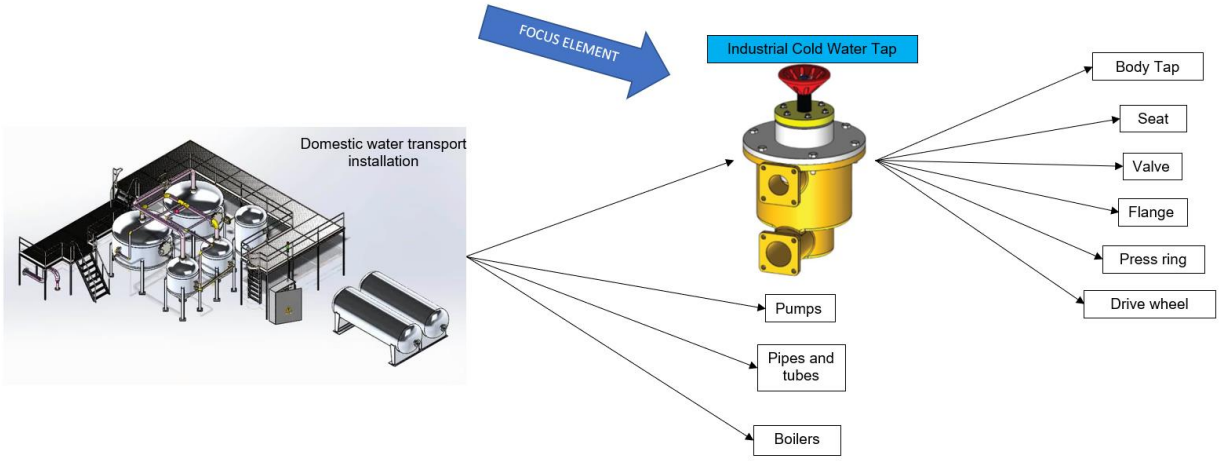

Figure 3: Structural Analysis - Structure Tree

The system structure can be created in the Structural Analysis section.

STRUCTURE ANALYSIS (STEP 2)

1. Next Higher Level	2. Focus Element	3. Next Lower Level or Characteristic Type
Domestic water transport installation	Industrial Cold Water Tap	Body Tap
		Seat
		Valve
		Flange
		Press ring
		Drive wheel

Figure 4: Structural Analysis (Step 2)

3.3 Step 3: Functional Analysis

The purpose of design function analysis is to ensure that the functions specified by requirements/specifications are properly allocated to the system elements. Regardless of the tool used for generating DFMEA, it is essential that the analysis be written in functional terms.

The main objectives of a design function analysis are:

• Visualizing the functions of the product or process

• Linking requirements or characteristics to functions

The structure provides the basis for each System Element to be analyzed individually regarding its functions and requirements. Comprehensive knowledge about the system and its operating conditions and environmental conditions is required, such as heat, cold, dust, water splashes, salt, ice, vibrations,

electrical failures, etc. The interactions of the functions of multiple system elements are to be demonstrated, for example, as a function tree.

The purpose of creating a function tree is to incorporate the technical dependency between functions. Therefore, it supports the later visualization of failure dependencies. When there is a functional relationship between hierarchically related functions, then there is a potential relationship between associated failures. Otherwise, if there is no functional relationship between hierarchically related functions, there will be no potential relationship between associated failures.

For the logical linkage of the function structure, the following questions are recommended:

- How is the higher-level function activated by the lower-level functions? (Top-down)
- Why is the lower-level function necessary? (Bottom-up)

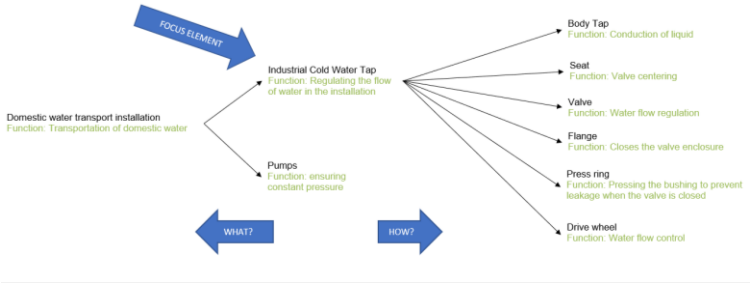

Figure 5: Function Analysis Structure Tree

The function structure can be created in the Functional Analysis section.

FUNCTION ANALYSIS (STEP 3)		
1.Next Higher Level Fuction and Requirement	2.Focus Element Function and Requirement	3. Next Lower Level Function and Requierment or Characteristic
Transportation of domestic water	Regulating the flow of water in the installation	Conduction of liquid
		Valve centering
		Water flow regulation
		Closes the valve enclosure
		Pressing the bushing to prevent leakage when the valve is closed
		Water flow control

Figure 6: Functional Analysis (Step 3)

Fully defining the functions (in positive terms) will lead to a comprehensive analysis in step 4 of failures, as potential failures are ways in which functions could fail (in negative terms).

3.4 Step 4: Failure Analysis

The purpose of design failure analysis is to identify the causes, modes, and effects of failure and to show the relationships between them to enable risk assessment

The main objectives of a design failure analysis are:

- Establishing the failure chain

• Potential effects of failure, failure modes, failure causes for each product function.

• Basis for documenting failures in the FMEA form sheet and the Risk Analysis step

There are three different aspects of failures analyzed in an FMEA:

• Failure Effect (FE)
• Failure Mode (FM)
• Failure Cause (FC)

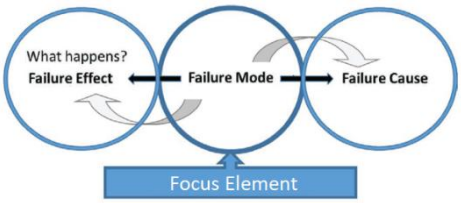

Figure 7: Theoretical Model of the Failure Chain

A failure effect is defined as a consequence of a failure mode.

A failure mode is defined as the way in which an item could fail to perform or provide the desired function.

A failure cause is an indication of why a failure mode may occur. The consequence of a cause is the failure mode. Identify, as far as possible, each potential cause for each failure mode.

To link Failure Causes to a Failure Mode, the question should be "Why does the Failure Mode occur?"

To link failure effects to a failure mode, the question should be "What happens in the event of a failure mode?"

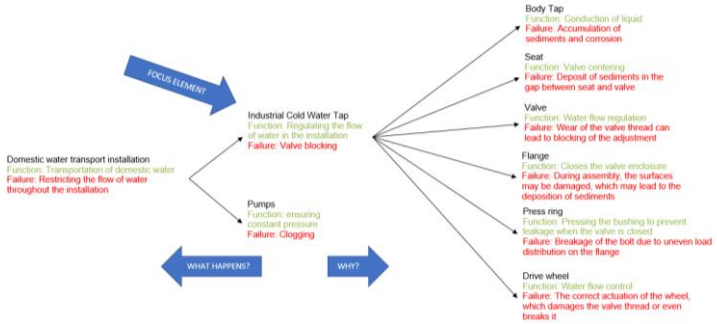

Figure 8: Functional Analysis Structure Tree

The failure structure can be created in the Failure Analysis section.

FAILURE ANALYSIS (STEP 4)			
1. Failure Effects (FE) to the Next Higher Level Element and/or Vehicle End User	Severity (S) of FE	2. Failure Mode (FM) of the Focus Element	3. Failure Cause (FC) of the Next Lower Element or Characteristic
Restricting the flow of water throughout the installation	10	Valve blocking	Accumulation of sediments and corrosion
			Deposit of sediments in the gap between seat and valve
			Wear of the valve thread can lead to blocking of the adjustment
			During assembly, the surfaces may be damaged, which may lead to the deposition of sediments
			Breakage of the bolt due to uneven load distribution on the flange
			The correct actuation of the wheel, which damages the valve thread or even breaks it

Figure 9: Failure Analysis (Step 4)

3.5 Step 5: Risk Analysis

The purpose of designing risk analysis is to estimate risk by evaluating severity, occurrence, and detection and prioritize the need for actions.

The main objectives of design risk analysis are:

• Assigning existing and/or planned controls and assessing failures
• Assigning preventive controls to failure causes
• Assigning detection commands to failure causes and/or failure modes
• Evaluating severity, occurrence, and detection for each failure chain
• Evaluating Action Priority
• Basis for the optimization step

Each failure mode, cause, and effect relationship are evaluated to estimate risk. There are evaluation criteria for risk assessment:

Severity (S): represents the severity of the failure effect

Occurrence (O): represents the occurrence of the failure cause

Detection (D): represents the detection of the occurred failure cause and/or failure mode.

Evaluation numbers from 1 to 10 are used for S, O, and D, where 10 represents the highest contribution to risk.

Once the team has completed the initial identification of failure modes, failure effects, failure causes, and controls, including evaluations for severity, occurrence, and detection, they need to decide whether additional efforts are needed to reduce risk. Due to inherent limitations of resources, time, technology, and other factors, they must choose how to best prioritize these efforts.

The Action Priority (AP) method recognizes all 1000 possible combinations of S, O, and D. It was created to place more emphasis first on severity, then on occurrence, and then on detection. This logic follows the intent of failure prevention of FMEA. The AP table provides a high-medium-low priority for action. Companies can use a single system to evaluate action priorities instead of multiple systems requested by multiple customers.

Risk matrices can represent combinations of S and O, S and D, and O and D. These matrices provide a visual representation of analysis results and can be used as input for prioritizing actions based on criteria established by the company.

Since the AP table was designed to work with severity, occurrence, and detection tables, if the organization chooses to modify the S, O, D tables for certain products, processes, or projects, the AP table should also be carefully reviewed.

High Priority (H):

- Highest priority for review and action. The team must either identify appropriate actions to improve prevention and/or detection controls or justify and document why current controls are adequate.

Medium Priority (M):

- Medium priority for review and action. The team should identify appropriate actions to improve prevention and/or detection controls or, at the company's discretion, justify and document why controls are adequate.

Low Priority (L):

- Low priority for review and action. The team may identify actions to improve prevention or detection controls.

The results of Steps 1, 2, 3, 4, and 5 of the 7-step FMEA process are used to determine if additional design or testing actions are needed. Design evaluations, customer reviews, management reviews, and inter-functional team meetings lead to Step 6, optimization.

FAILURE ANALYSIS (STEP 4)				RISK ANALYSIS (STEP 5)				
1. Failure Effects (FE) to the Next Higher Level Element and/or Vehicle End User	Severity (S) of FE	2. Failure Mode (FM) of the Focus Element	3. Failure Cause (FC) of the Next Lower Element or Characteristic	Current Prevention Control (PC) of FC	Occurrence (O) of FC	Current Detection Controls (DC) of FC or FM	Detection (D) of FC/FM	DFMEA AP
Restricting the flow of water throughout the installation	10	Valve blocking	Accumulation of sediments and corrosion	Erosion Simulation	6	Ultrasonic testing	6	H
			Deposit of sediments in the gap between seat and valve	Wear Simulation	3	Measuring the closing and opening force 15daN-20daN	4	L
			Wear of the valve thread can lead to blocking of the adjustment	Wear Simulation	5	Measuring the closing and opening force 15daN-20daN	1	M
			During assembly, the surfaces may be damaged, which may lead to the deposition of sediments	Measuring the hardness of the two surfaces	3	Dimensional control	6	M
			Breakage of the bolt due to uneven load distribution on the flange	Dimensional control during initial assembly	4	Dimensional control	6	H
			The correct actuation of the wheel, which damages the valve thread or even breaks it	Mode simulation for operating the rosette	2	Dimensional control	6	M

Figure 10: Failure Analysis (Step 4) & Risk Analysis (Step 5)

3.6 Step 6 Optimization.

The purpose of Optimization is to determine risk mitigation actions and assess the effectiveness of those actions.

The main objectives of design optimization are:

• Identifying actions needed to reduce risks

• Assigning responsibilities and deadlines for implementing actions

• Implementing and documenting the actions taken, including confirming the effectiveness of implemented actions and evaluating the risk after the actions have been taken

• Collaboration between the FMEA team, management, customers, and suppliers regarding potential failures

• Basis for refining product requirements and prevention and detection controls

The main goal of Design Optimization is to develop actions that reduce risk and increase customer satisfaction by improving design. In this step, the team reviews the results of the analysis of risk and assigns actions to reduce the probability of failure cause occurrence or increase the robustness of Detection Control to detect Failure Cause or Failure Mode. Additionally, actions that improve design but do not necessarily decrease risk assessment can be assigned. Actions are not intended to be used for activities that are already planned, as these are documented in Prevention or Detection Controls and are already considered in the initial risk analysis. Each action should have a responsible person and a target completion date (TCD) associated with it. The person responsible ensures that the status of the action is updated. If the action is confirmed, this person is also responsible for implementing the action. The actual completion date of preventive and detection actions is documented, including the date the actions are implemented. Target completion dates should be realistic (i.e., in line with the product development plan, before process validation, before production starts).

Open

No action defined

Completed

Completed actions have been implemented, and their effectiveness has been demonstrated and documented. A final evaluation has been made.

Not implemented

The Not Implemented status is assigned when a decision is made not to implement an action. This may occur when risks related to practical and technical limitations exceed current capabilities.

RISK ANALYSIS (STEP 5)					OPTIMIZATION (STEP 6)										
Current Prevention Control (PC) of FC	Occurrence (O) of FC	Current Detection Controls (DC) of FC or FM	Detection (D) of FC/FM	DFMEA AP	DFMEA Preventive Action	DFMEA Detection Action	Responsible Person's Name	Target Completion Date	Status	Action Taken with Pointer to Evidence	Completion Date	Severity (S)	Occurrence (O)	Detection (D)	DFMEA AP
Erosion Simulation	6	Ultrasonic testing	6	H	Filtration		Non-destructive testing engineer	yy/mm/dd	In progress		yy/mm/dd		6	3	H
Wear Simulation	3	Measuring the closing and opening force 15daN-20daN	4	L	n/a		Non-destructive testing engineer	yy/mm/dd	Initial		yy/mm/dd		3	4	L
Wear Simulation	5	Measuring the closing and opening force 15daN-20daN	1	M	Screw treatment		Non-destructive testing engineer	yy/mm/dd	În curs		yy/mm/dd	10	5	1	M
Measuring the hardness of the two surfaces	3	Dimensional control	6	M		The tightness test	Non-destructive testing engineer	yy/mm/dd	In progress		yy/mm/dd		3	6	M
Dimensional control during initial assembly	4	Dimensional control	6	H	Tightening the bolts with a torque wrench (6 daN)		Non-destructive testing engineer	yy/mm/dd	In progress		yy/mm/dd		4	6	H
Mode simulation for operating the rosette	2	Dimensional control	6	M	n/a		Non-destructive testing engineer	yy/mm/dd	In progress		yy/mm/dd		2	6	M

Figure 11 Risk Analysis (Step 5) & Optimization (Step 6)

3.7 Step 7 Documenting the Results

The purpose of documenting the results stage is to summarize and communicate the outcomes of the FMEA activity.

The main objectives of documenting the design results are:

• Communicating the analysis results and conclusions

• Establishing the documentation content

• Documenting the actions taken, including confirming the effectiveness of implemented actions and evaluating the risk after the actions

• Communicating the actions taken to reduce risks, both within the organization and with clients and/or suppliers, as applicable

• Recording the risk analysis and the reduction of risk to acceptable levels

4. Conclusion

The use of the DFMEA method according to AIAG and VDA proves its utility not only in the automotive industry but also in other industrial domains by:

Providing a comprehensive contextualization of non-conformities by correlating them from individual components to assemblies.

Offering clear prioritization of action plans to control high and medium-high level risks, where severity is the primary criterion in decision-making, followed by occurrence frequency, and detectability being the criterion with the least weight in decision-making.

5. Bibliography

[1]. AIAG & VDA. (2019). FMEA Handbook: AIAG VDA FMEA Handbook 1st Edition, Automotive Industry Action Group.

[2]. AIAG. (2008), „ Potential Failure Mode & Effects Analysis FMEA Reference Manual (4th Edition)

S.C. MACHINE NOISE REDUCTION AQUA VITALIS S.R.L.

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ABSTRACT: The acoustic pressure levels produced by the external equipment of AQUA VITALIS SRL were measured. The obtained values were processed and entered into the software Predictor-LimA version 2021.1. An action plan containing measures to reduce noise was made.

KEYWORDS: acoustic pressure, noise, sound barriers.

1. Introduction

The AQUA VITALIS company contacted the CLEAR SRL company to carry out a noise level evaluation study and the elaboration of the noise dispersion/propagation map, as well as a proposal for the positioning of some sound-absorbing panels. For this, contract no. 10/March 10, 2023 was signed.
The following stages were carried out:
-Measuring the level of noise generated by the equipment
-Identification of sources of noise generation and establishment of maximum noise values, both in the premises and at the reception position of the neighboring buildings.
-Realization of a calculation model of acoustic zoning (emission and dispersion of sound waves).
The first stage of the study, the realization of noise meters, was carried out on March 23, 2023.

2. Current status

In the location of the AQUA VITALIS SRL Bodoc factory there is a series of noise-generating equipment: chillers and fans. The map of noise sources is shown in Fig. 1.

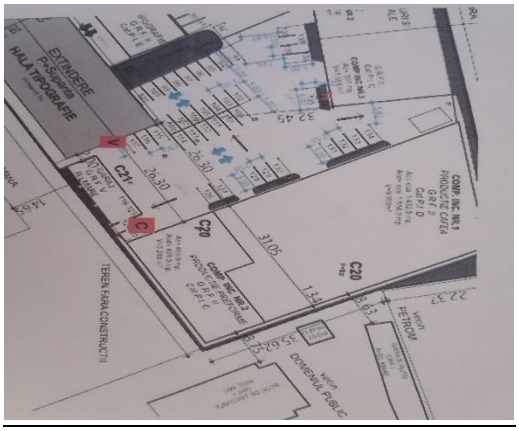

Fig. 1. Map of noise sources at SC AQUA VITALIS SRL

The factory is located in Bodoc, str. Carpati no. 46, Harghita district. The studied noise sources are located on the east side of the AQUA VITALIS SRL factory. On the east side, the factory is bordered by a vacant land belonging to the Romanian Patriarchate and a block of flats located at a distance of 8.75m from the factory. The height of the block is 14m.

3. Work methodology

The stages of the realization of such a project are:
-Requesting the necessary input data [area situation plan, technical data, noise sources, topography of the area] from the beneficiary.
-Making measures of the noise level for the calibration of the created acoustic model.
-Realization of an acoustic mapping that includes both the noise sources and the affected receivers.
-Preparation of an acoustic map of the location, which also includes the potential affected receivers.
-Identification of areas where exceedances of the maximum allowed noise level are recorded and the proposal of noise reduction measures.
- Creation of a noise map of the location containing the effects of noise reduction measures.
The acoustic measures carried out by CLEAR SRL were carried out to establish the noise level at the receivers and for the acoustic characterization of the sources.

3.1 Site characterization

The studied location is assimilated to an industrial area. For the acoustic modeling, a software specialized in creating noise maps was used, Predictor-LimA v.2021.1. The input data has been received from the beneficiary.

3.2. Measurement of noise sources and legislation

Noise sources were measured with a Bruel&Kjaer 2245 sound level meter, class 1, calibrated and metrologically verified. The human ear does not perceive all frequencies with the same intensity and is more sensitive to frequencies between 500 and 8000Hz. In order to measure the same level of noise perceived by the human ear, sound level meters have incorporated electronic filters to correspond to the different sensitivities of the ear. This filtering is called type A weighting and the measured values are denoted by Dba.
The maximum allowed values of the ambient noise are established in several technical standards and in the regulations or orders of the various ministries.
Ministry of Health
Romanian legislation, O.M.S. no. 119/2014, modified by O.M.S. no. 994/2018, establishes that:
"ART. 16
(1) The dimensioning of the sanitary protection zones is done in such a way that in the protected territories the limit values of the noise indicators are ensured and respected, as follows:
a) during the day, between the hours of 7.00-23.00, the A(LaeqT) weighted equivalent continuous acoustic pressure level must NOT exceed the value of 55dB outside the house;
b) during the night, between 11:00 p.m. and 7:00 a.m., the A-weighted equivalent continuous sound pressure level (LAeqT) must not exceed the value of 45 dB outside the home.
c) 50Db for the peak level, in the case of the acoustic measurement performed outside the home during the night in order to compare the result of this measurement with the limit value specified in letter b).
(2) If an objective is located in an area in the vicinity of a protected territory where the external background noise prior to the location of the objective does not exceed 50dB(A) during the day and 40dB(A) during the night, then the dimensioning sanitary protection zones is done in such a way that in the protected territories the limit values of the noise indicators are ensured and respected, as follows:
a) a) during the day, between 7:00 a.m. and 11:00 p.m., the A(LaeqT) weighted equivalent continuous sound pressure level must NOT exceed the value of 50dB outside the house;
b) during the night, between 11:00 p.m. and 7:00 a.m., the A-weighted equivalent continuous sound pressure level (LAeqT) must not exceed the value of 40 dB outside the home.
c) 45dB for the peak level, in the case of the acoustic measurement performed outside the home during the night in order to compare the result of this measurement with the limit value specified in letter b).

(3) The location and operation of small production, commercial and service capacity units specified in paragraph (1) are prohibited inside protected territories with the exception of residential areas.
(4) The location and operation of units with small production capacity, commercial and service provision specified in art. 5 paragraph (1), inside residential areas, are done in such a way that the noise from their activity does not lead when the following limit values are exceeded:
a) 55 dB for the continuous equivalent weighted sound pressure level A(LAeqT), outside the homes, during the day, between 7:00 a.m. and 11:00 p.m.
b) 45dB for the continuous equivalent weighted sound pressure level A(LAeqT) outside the houses, during the night, between 11:00 p.m. and 7:00 a.m.
c) 50 Db for the peak level, in the case of the acoustic measurement performed during the night outside the home in order to compare this measure with the limit value specified in letter b).
(5) As an exception to the provisions of ali. (3), the location and operation of commercial units with restaurant activity in parks are allowed, with an operating schedule during the day, between 7:00 a.m. and 11:00 p.m., if the noise coming from their activity does not lead to exceeding the following limit values:
a) 55 db (A) for the weighted equivalent continuous acoustic pressure level A(LAeqT), at a distance of 15 meters from the perimeter of the unit.
b) 60db (A) for the peak level, in the case of the acoustic measurement carried out at a distance of 15 meters from the perimeter of the unit, in order to compare the result of this measurement with the limit value specified in letter a).
(6) In the case of various types of units with small production capacity and providing services, as well as commercial units, especially those of the type of restaurants, bars, clubs, discotheques, etc., which, on the date of entry into force of these norms, carry out their activity on the ground floor/basement of residential buildings, the operation of these units is done in such a way that the noise from their activity does not lead to exceeding the following limit values, for any of the homes located both in the building on the ground floor/basement which the respective unit operates, as well as in the neighboring residential buildings.
55 db(A) for the A-weighted equivalent continuous acoustic pressure level (LAeq T), outside the house, during the day, between 7:00 a.m. and 11:00 p.m.;
45db(A) for the continuous equivalent weighted acoustic pressure level A(LAeqT), outside the house, during the night, between 23.00 and 07.00;
35db(A) for the continuous equivalent weighted acoustic pressure level A(LAeqT), inside the home, during the day, between 7:00 a.m. and 11:00 p.m.;
30 db for the continuous equivalent weighted sound pressure level A(LAeqT), inside the house, during the night, between 11:00 p.m. and 7:00 a.m.;
35db for the peak level, in the case of the acoustic measurement performed during the night inside the home in order to compare the result of this measurement with the limit value specified in letter d).
(7) Public authorities that have noise laboratories in their own structures or that are responsible for carrying out acoustic measurements outside and/or inside homes have the obligation to develop noise measurement procedures that comply with the provisions of SR ISO 1996/1-08 SI SR ISO 1996/2-08.
(8) The Ministry of Health and the central public authority for the protection of the environment will provide in the regulatory acts that they will issue the necessary technical and/or administrative measures so that the location and operation of units with low production capacity, commercial and service provision, as well as the dimensioning of sanitary protection zones must be carried out in compliance with paragraphs (1)-(6), as the case may be.
Ministry of the Environment
The SR 10009-2017 standard provides that the admissible limit of the noise level in the functional space "Industrial premises and spaces with activities assimilated to industrial activities" is 65db(A)[tab.1]

Table 1. Maximum limits allowed according to SR 10009-2017

	Maximum value	Maximum allowed value [dBA)
Functional space	Day	Night
Industry	65	65
Residential buildings with more than two floors	50	50

The measured values were used to calculate the acoustic power level of the noise sources[tab.2].

Table 2. Noise sources located in the premises of SC AQUA VITALIS SRL

Noise source	Sonorous Power Level
Noise sources SC AQUA VITALIS SRL	
Chiller	91,64 dBA
Fan	89,80 dBA

3.3 Acoustic modelling

The noise sources modeled in table no. 1 were added to the Predictor-LimA model. The heights of the industrial buildings were taken from the site plan in fig.2. The equipment was considered at a height of 1 meter - the chiller and at a height of 6 meters - the fan.

The receptions, the residences near the factory, were considered to be 14 meters high. Assessment points were placed at the property boundary to calibrate the existing model. To create the noise maps, specialized software for acoustic mapping was used, Predictor-LimA, software recognized at the level of the European Union for accuracy and calculation speed.

The standard for which the Noise Map of the industrial source was created is the ISO 9613-2 standard for the evaluation of industrial noise, provided for in the European Directive 49/2002/END regarding the acoustic mapping of industrial sources.

4. Modeling results

4.1 Normal Operation

Measurements were made of the noise level at the property boundary during the normal operation of the facilities. The charge level was 99% throughout the measurement period[tab.3].

Table 3. Comparison between measured and estimated values

Measuring point	Measured Sound Pressure Level	Calculated Sound Pressure Level
ZG1- block	57,4	72
ZG2- noise sources	72,3	64

The measured values exceed the maximum values allowed for the industrial space - 65 dBA next to the preform production chiller[fig.1]

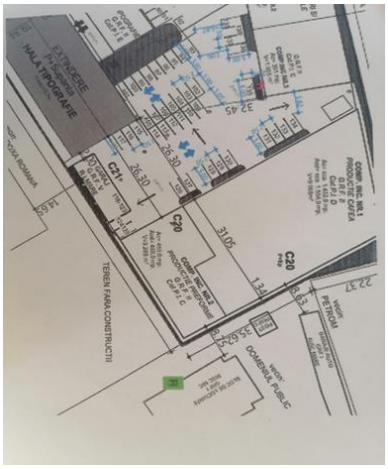

Fig. 2. Location of assessment points.

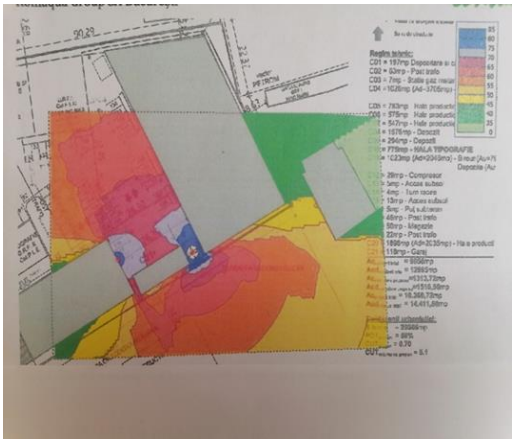

Fig. 3. Noise map for normal operation at a height of two meters - 2D view.

5. Variants of noise reduction

A noise reduction variant was simulated, with the aim of reducing the level of noise generated by the normal operation of the factory. The proposal consisted in the successive application of two measures, first sound barriers to the chiller and then, sound barriers to the fan, if it is need. The most acoustically efficient option is to add sound barriers near the noise sources, isolating them from nearby receivers.

5.1 Phase 1. Sound barriers

The installation of an anti-noise barrier near the chillers was simulated, with a total height of 4 meters. Dimensions: 2 meters perpendicular and 3.5 meters parallel to the existing fence.

Table 4. Comparison between the initial values and those estimated after mounting the panels.

Evaluation Point	Sound Pressure Level Without Panel	Sound Pressure Level With Panel
ZG1-2m	45,65	36,57
ZG2-4m	45,95	37,11
ZG3-6m	47,02	38,86
ZG4-10m	49,28	41,93

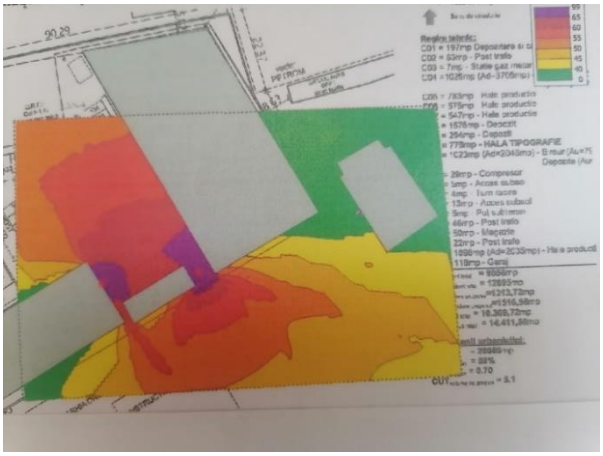

Fig. 4. Noise map after installing the sound-absorbing panels at the chiller

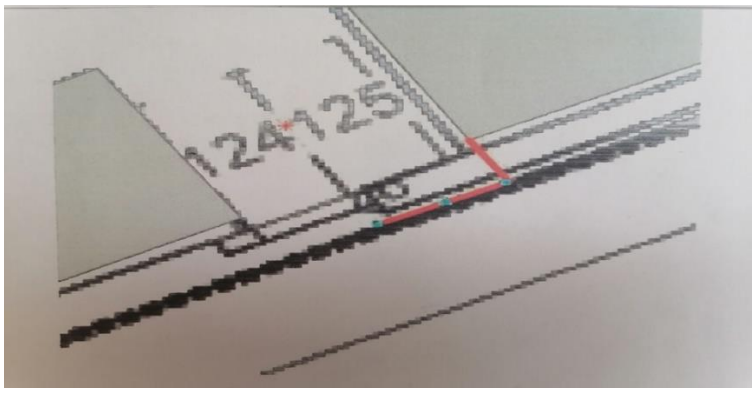

Fig. 5. Placement of sound panels

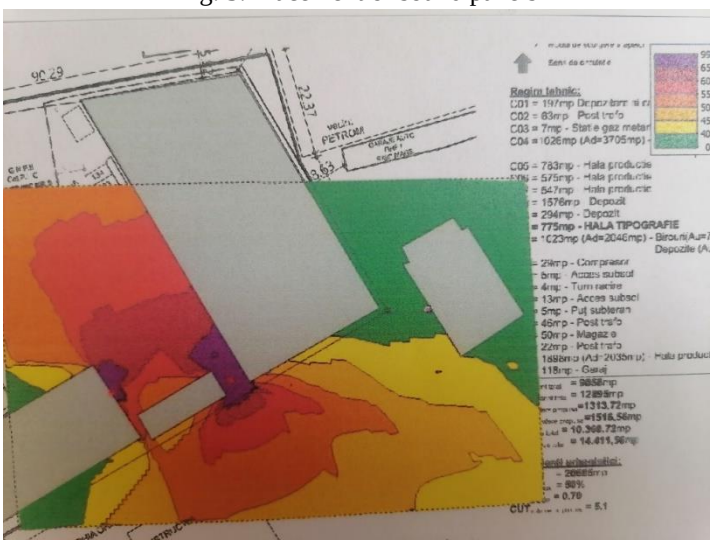

Fig. 6. Noise map after the installation of sound-absorbing panels at the chiller and fan.

5.2 Phase 2. Fan noise barriers

In addition, sound panels will be mounted to the fan, 2 meters away from the source.

Table 5. Comparison between the initial values and those estimated after mounting the panels.

Evaluation Point	Sound Pressure Level with Panel / Chiller	Sonorous Pressure Level With Panel/ Chiller and Fan
ZG1-2m	36,57	36,18
ZG2-4m	37,11	36,39
ZG3-6m	38,86	36,75
ZG4-10m	41,93	38,78

6. Conclusions

1. SC CLEAR SRL was contacted by SC AQUA VITALIS SRL to carry out an acoustic study and propose measures to reduce the noise coming from the production equipment.
2. Noise measurements were made to define the noise level at the level of nearby residences and for the acoustic definition of the noise sources.
3. A noise map was made for the initial situation.
4. The installation of a barrier with a total height of 4 meters was simulated, from a height of one meter above the ground, one meter away from the noise sources (chillers).

The noise level at ground level (2 meters) is below the maximum allowed values for the residential area.

7. Bibliography

[1] AQUA VITALIS internal documents
[2] O.M.S. no. 119/2014, modified by O.M.S. no. 994/2018, art. 16
[3] Standard SR 10009-2017.

EXPLORING STRESS AND MENTAL HEALTH AMONG STUDENTS

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ABSTRACT: The research paper focuses on analyzing the level of stress experienced by students in the faculty and the various influences on their mental state. We investigate the impact of adapting to the university environment, academic pressure, the evaluation process, and the relationship with professors on students' stress levels and mental health. Through a comprehensive study utilizing questionnaire research methods, we aim to evaluate the variables associated with academic and psychological stress in the university setting. The results of this research have the potential to bring understanding and clarity regarding the needs and challenges of students, aiding in the development of more effective educational and mental health policies and services tailored to the specificities of each higher education institution. By identifying stress factors and management strategies, this paper makes a significant contribution to promoting the well-being and academic success of students.

KEYWORDS: students, university, adaptation, stress, mental health.

1. Introduction

Within the academic university environment, the stress and mental state of students have become increasingly relevant and concerning topics in recent years. Adjusting to university life, managing multiple academic and emotional challenges, and maintaining a balance between personal and academic life are essential aspects for the well-being and success of students. In this research paper, we aim to explore in-depth the level of stress among students and the multiple influences on their mental state.

Our objectives are manifold. Firstly, we aim to investigate the impact of adapting to the university environment on students' stress levels. Secondly, we intend to analyze academic pressure and the evaluation process and how these influence students' mental health. Additionally, we will examine students' relationships with professors and the impact of this relationship on their stress and psychological well-being.

To achieve these objectives, we will employ a research approach that includes collecting and analyzing primary and secondary data to assess the level of stress and mental state of students. By identifying stress factors and management strategies, we aim to contribute to promoting a healthier academic environment and improving students' academic success.

2. Method Used

The questionnaire was developed using the Google Forms platform to assess students' stress levels, academic pressure, and their relationship with professors. It consisted of 15 questions with "Yes/No" responses, covering aspects related to academic and emotional stress, difficulties in managing academic pressure, and perceptions of the relationship with professors.

1. "Have you ever felt stressed about not knowing which field to pursue in your career?" - This question aims to assess the uncertainty related to the student's future career and possible pressures associated with choosing a specialization.

2. "Did you find it easy to transition from high school to college?" - This question explores the experience of transitioning from pre-university education to university education and adapting to academic and independent life requirements.

3. "Have you ever felt that you haven't chosen the right college/field?" - This question investigates possible doubts or regrets regarding the choice of college or specialization.

4. "Have you adapted to the new learning environment?" - This question examines the student's level of adaptation to the university academic environment and its specific requirements.

5. "Have you adapted to living conditions with someone/alone?" - This question refers to adaptation to dormitory life or independent living and managing interpersonal relationships in these environments.

6. "Have you integrated well into the class community?" - This question explores the degree of social integration and interpersonal relationships of the student within the academic environment.

and so on, each question addressing different aspects of the student's academic and personal life that may influence their level of stress and mental health. These questions are designed to gather essential information for understanding and addressing academic stress and the specific needs of students.

Participants were selected from university centers across Romania. To be eligible, they had to be university students enrolled in higher education institutions from various counties of the country.

The link to the questionnaire was distributed online through social media platforms and specific discussion groups within the student community. Participants completed the questionnaire voluntarily and anonymously. Data collection took place from March 4th, 2023, to March 18th, 2024.

Methodology:

The collected data were processed in Excel spreadsheets, where we obtained graphs corresponding to the responses obtained from the questionnaires. The data collected from the questionnaires are related to the area, accommodation in the university environment, the relationship between student and professor, and extracurricular activities, thus obtaining risks regarding mental health status, followed by the elaboration and implementation of solutions.

The action plan will be implemented and monitored to see if the expected effects have been obtained, followed by another questionnaire for the same sample of individuals.

The research was conducted in accordance with relevant ethical principles and respecting the confidentiality of participants' personal data. Participation in the study was voluntary, and participants' personal information was kept anonymous.

3. The interpretation of the responses

The figure below represents the total distribution of participants according to their place of origin. It can be observed that the majority of participants come from Bucharest, followed by Constanța, Brașov, and Sibiu, while other locations (Timișoara, Iași, Pitești, and Suceava) have a smaller number of participants (see Figure 1).

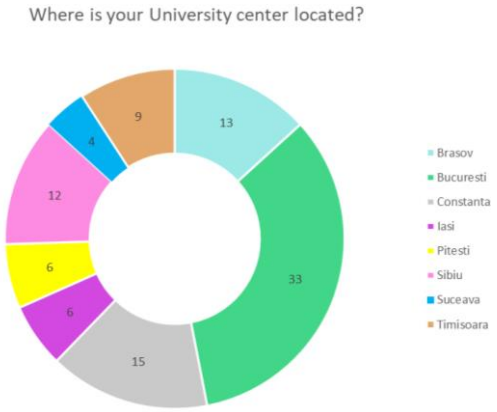

Fig. 1. The total distribution of participants according to their place of origin

Graph 1 highlights the percentage of participants who responded "yes" or "no" to the question regarding stress related to uncertainty about career field choice. It can be observed that a significant percentage of participants indicated experiencing stress regarding this issue (see Figure 2).

Graph 2 illustrates the distribution of "yes" and "no" responses to the question regarding feelings of unease regarding the choice of college or field of study. The results show that a significant percentage of participants have experienced such doubts regarding their academic choices (see Figure 3).

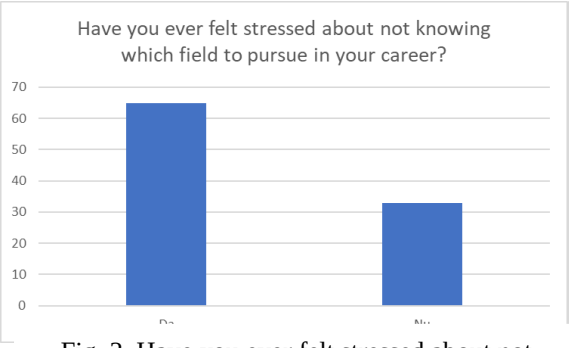

Fig. 2. Have you ever felt stressed about not knowing which field to pursue in your career?

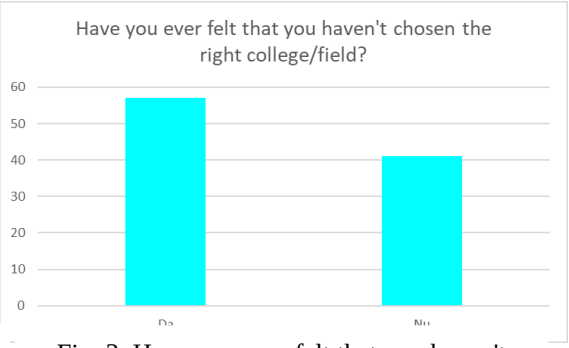

Fig. 3. Have you ever felt that you haven't chosen the right college/field?

Graph 3 presents the distribution of responses regarding the level of stress related to university education. It can be observed that a significant percentage of participants indicated feeling stressed during their university studies, thus emphasizing the importance of proper management of this aspect (see Figure 4).

Graph 4 highlights the distribution of responses regarding the pressure and overload caused by the volume of schoolwork. The results suggest that a significant percentage of participants indicated feeling pressured or overloaded by the volume of school tasks, which can represent a major source of stress for them (see Figure 5).

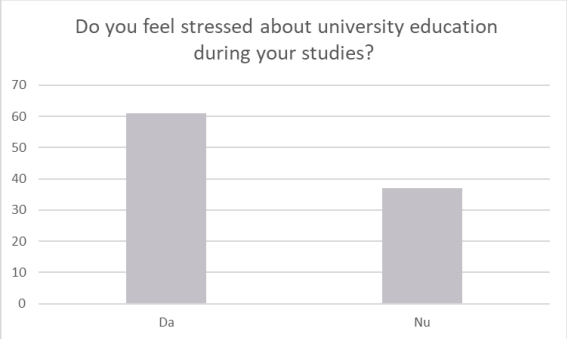

Fig. 4. Do you feel stressed about university education during your studies?

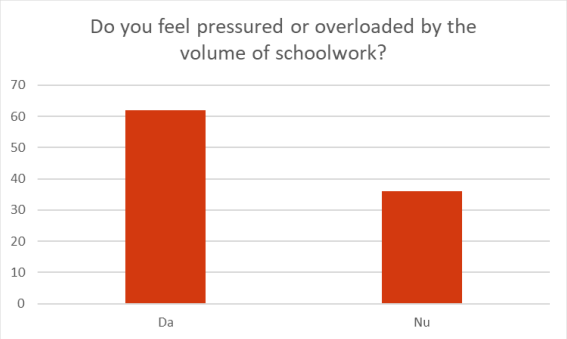

Fig. 5. Do you feel pressured or overloaded by the volume of schoolwork?

Graph 5 presents the distribution of responses regarding difficulties in concentration and maintaining attention during classes or study sessions. It is observed that a significant percentage of participants indicated having such difficulties, which can negatively influence academic performance and contribute to the level of perceived stress (see Figure 6).

Graph 6 highlights the distribution of responses regarding communication and provision of details by professors regarding activities within and outside of the faculty. It is observed that a significant percentage of participants indicated that professors do not provide sufficient details, which can influence students' perception and contribute to the level of stress (see Figure 7).

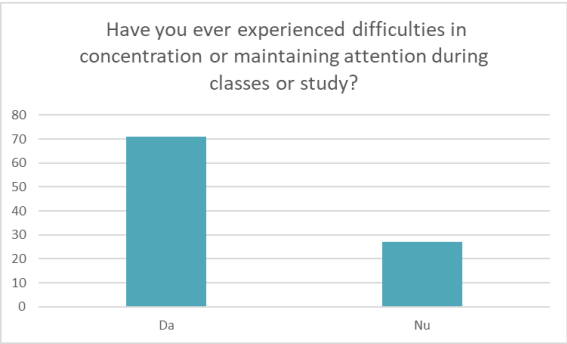

Fig. 6. Have you ever experienced difficulties in concentration or maintaining attention during classes or studv?

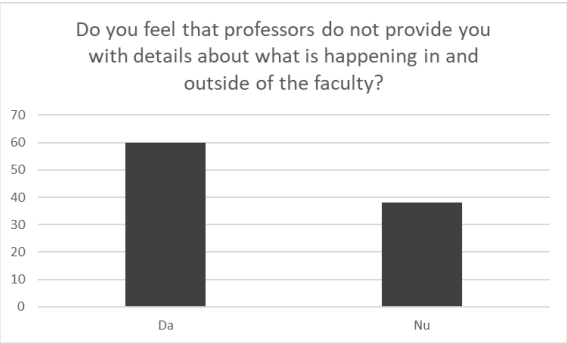

Fig. Do you feel that professors do not provide you with details about what is happening in and outside of the faculty?

Graph 7 presents the distribution of responses regarding students' comfort in discussing their mental health issues with professors. The results show that a significant percentage of participants indicated that they do not feel comfortable having such discussions with their professors, which can be a negative aspect for accessing the necessary resources and support for students' mental health (see Figure 8).

Graph 8 illustrates the distribution of responses regarding the discomfort caused by students not passing certain subjects and how this can influence their emotional balance. The results show that a significant percentage of participants indicated experiencing such feelings of discomfort and emotional imbalance, thus emphasizing the importance of a sensitive approach from educators in managing these situations (see Figure 9).

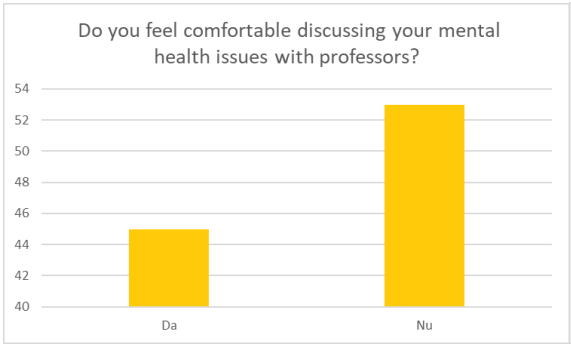

Fig. 8. Do you feel comfortable discussing your mental health issues with professors?

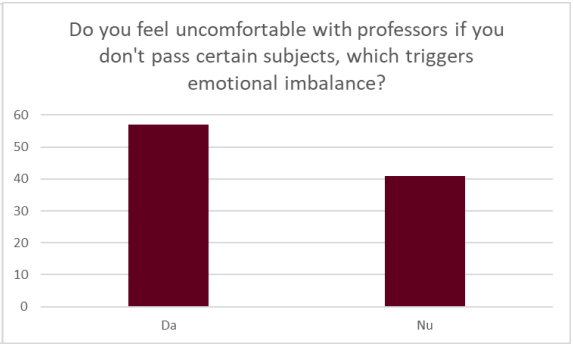

Fig. 9. Do you feel uncomfortable with professors if you don't pass certain subjects, which triggers emotional imbalance?

4. Conclusions

Through the investigation and optimization of occupational risk assessment and related objectives, this research has provided a solid foundation for supporting the working hypothesis and for further development of research in this direction. In the context of increasing concerns regarding occupational health and safety, the results obtained demonstrate the importance of effective occupational risk assessment and the necessity of applying appropriate methods and techniques in this regard.

Therefore, this research represents not only a significant contribution to understanding and optimizing occupational risk assessment but also a solid foundation for further development in this research field. The implications of this work are particularly relevant for promoting a safe and healthy work environment, both for employees and employers, and for improving practices and policies in the field of occupational health and safety.

Thus, this research offers a significant contribution not only at the theoretical but also at the practical level, by providing arguments and recommendations for optimizing the assessment and management of risks related to psychosocial risks that arise during the transition from high school to university education.

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OPERATIONAL CONTROL OF THE QUALITY OF THE WORKING ENVIRONMENT

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ABSTRACT: In the work, a summary presentation and other general elements are made regarding the establishment of the workplace environment factors for monitoring and keeping them under control, for creating a well-being of the worker at the workplace with a higher yield of the work performed.

KEYWORDS: industrial microclimate, physical factors, UTI, biological factors, Covid-19

1. Introduction

The conditions in which the employee carries out his activity constitute a separate category of factors that can influence his performance and attitudes. The most important factors (other than the psychosocial and salary ones) are the physical, chemical and biological ones.

The work environment factors are constitutive, structural-functional elements of the workplace, in an interdependent relationship with the other components of the man-machine-environment system and being of great diversity .

2. Work environment factors

- Physical factors
- Biological factors
- Physico-chemical factors
- Chemical factors

2.1. Physical factors

One of the most important physical factors at work is:

The industrial microclimate: (Temperature, Humidity, Air currents)

a) Temperature is a factor of the environment with effects on the state of health, effort and work results of the performers.

We become aware of the temperature of the environment when we feel cold or hot, which is triggered by the imbalance between the thermal conditions of the environment and those of our body.

Maintaining a constant body temperature depends on maintaining the balance between thermogenesis (heat production) and thermolysis (heat loss):

- if the temperature drops, the body reacts both by peripheral vasoconstriction resulting in the reduction of heat loss, and by intensifying thermogenesis, increasing muscle tone, shivering from the cold;

- if the temperature rises above the upper limit of the thermal neutrality zone, this causes an adaptive reaction that consists in - increasing sweat flow up to 1.3 kg/h. If the respective liquid is not replaced, a state of water deficit can be reached (during working hours, up to 6% of the body mass). Along with sweating, other constituents are also lost (sodium, vitamins, etc.), the activation of the circulation with the increase of the circulatory flow and the increase of the respiratory frequency.

The temperature of the working environment influences the health and performance of employees through:

- the combination of temperature and humidity;

- duration of exposure to thermal conditions outside the comfort zone, in which case acclimatization is necessary;

- the temperature of the objects and tools used; large differences (object temperature above 43°C or below 0°C) between the temperature of the body and that of the tools can produce the sensation of pain or even tissue destruction.

b) Ambient humidity - is the amount of water vapor in the atmosphere (water droplets or ice crystals) is expressed as a percentage by the ratio between the amount of vapor in the air at a given moment and the maximum possible (when the air is completely saturated). Organic comfort is in the 30-70% range:
- below 30%, there are negative repercussions on the structures and functions of the respiratory mucosa that ensure the elimination of impurities (including germs) from the inhaled air;
- over 70%, under the conditions of hard work, has a negative effect on the thermolysis process (up to caloric shock).

ITU calculation, (temperature-humidity index or/and accentuated thermal discomfort):

Thermal discomfort in the hot season occurs when the air temperature value exceeds the threshold of 37 degrees Celsius or when the temperature-humidity index (ITU) reaches and exceeds the value threshold of 80 units. The human body is not genetically prepared for these situations, feeling them as a state of aggressive stress, with extremely negative, sometimes lethal effects.
ITU is calculated based on measurements from weather stations, including two factors: the air temperature in degrees Celsius (which is taken in the shade, at the standard height of 2.00 meters), this if it exceeds 35 degrees Celsius (+35°C) we speak of heatwave (on the opposite side we speak of frost if the temperature drops below -10°C); the relative humidity (humidity) of the air is defined by the water vapor content existing in the atmosphere at a given moment, measured in percentages -%- with special direct-reading devices called psychrometers and hygrometers ("hygro" from water vapor, " hygro" comes from water, salt is hygrometric, it absorbs water vapor from the air).

The following calculation formula for ITU is used:

$$ITU = (T \cdot 1{,}8 + 32) - (0{,}55 - 0{,}0055 \cdot H)[(T \cdot 1{,}8 + 32) - 58] \qquad (1)$$

Where:
T = air temperature in °C;
U = relative humidity in %.

Comfort, alertness and discomfort:

ITU for values lower than 65 is considered a state of comfort, between 66-79 a state of alertness, and over 80 is considered a state of discomfort. Example: if we make a calculation at a humidity of 50%, we find that just under 20°C, the ITU is acceptable, and if at the same humidity we calculate the ITU at 31.5°C, we get a value of 80 units.

The explanation lies in the fact that through sweating, the person removes the excess heat from the body, and if the humidity is high, with saturated air, it no longer naturally removes the excess water.

Stare de disconfort ITU > 80	
Stare de alertă 66 < ITU < 80	
Stare de confort 66 > ITU	

Fig. 1. Comfort, alertness and discomfort

Legislatively, Government Emergency Ordinance no. 99/2000, which refers to the measures to be applied during periods of extreme temperatures by employers for the protection of employees (above 37°C or with conditions related to humidity, above 80 ITU units) or below -20°, or correlated with wind conditions.

At the level of our company, the Internal Prevention and Protection Service monitors daily the temperature and humidity in the production space and based on them we calculate the thermal comfort index (ITU) on the form "Temperature, humidity monitoring and determination of the thermal comfort index" form.

The data obtained are periodically presented in the meetings of the CSSM and in the Analysis carried out by the management, and in case of discomfort, measures are proposed to improve the working conditions according to the provisions of the Government's Emergency Ordinance no. 99/2000. Thus, if we refer to extremely high temperatures, minimum mandatory measures are required to improve working conditions (from reducing the intensity and pace of physical activities, ventilation, alternating work and rest periods) to maintaining the health of employees, (2-4 liters of mineral water/person/exchange [3], protective equipment, showers) and, if it is not possible to apply these measures, a mutual agreement is reached with the unions or the representatives of the employees, to reduce the working day, to stagger it in two less burning periods, even the collective interruption of work with the maintenance of employment contracts and seniority.

For example , in the month of July 2023, the highest temperatures of the year 2023 were recorded. At 2:30 p.m. [the] entries were as follows:

3) PIVOTI (PSB)		LUNA IULIE-2023	
ZIUA	[°C]ora14,30	UMIDITATEA [%]	ITU
1			
2			
3	30.0	41	76.9
4	31.0	45	78.8
5	31.0	47	79.1
6	31.0	46	78.9
7	31.0	47	79.1
8			
9			
10	32.0	37	78.7
11	31.0	44	78.6
12	32.0	45	80.0
13	33.0	49	82.0
14	32.5	40	79.8
15			
16			

Fig. 2. Register monitoring temperature, humidity and determining the thermal comfort index

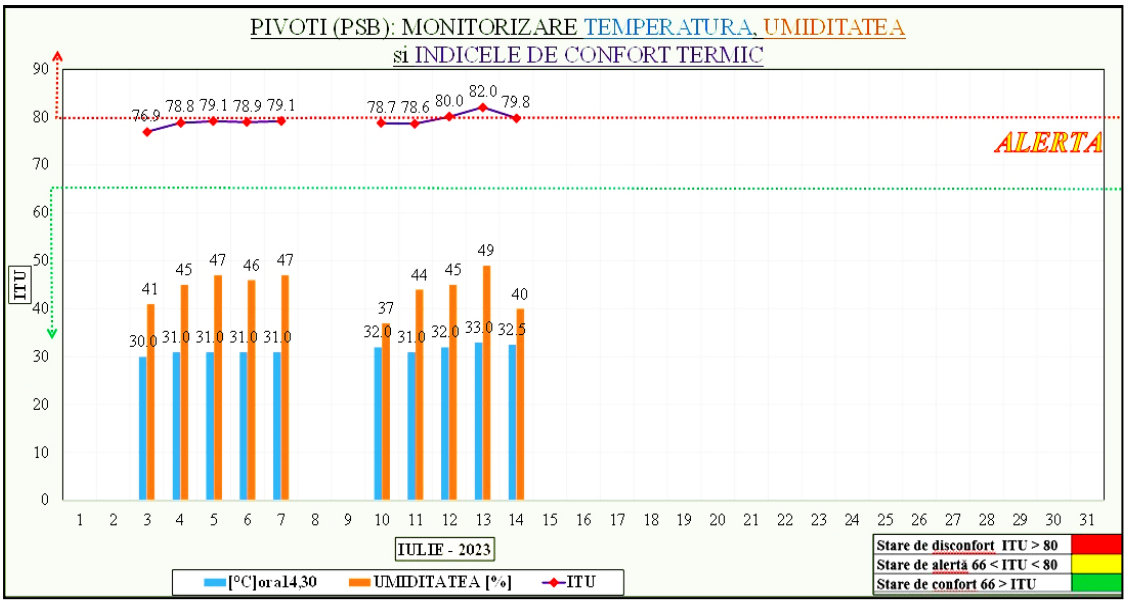


Fig. 3. Graphs for monitoring temperature, humidity and determining the thermal comfort index

Considering the extreme temperatures recorded, in order to ensure working conditions in the department, the following measures were taken to improve working conditions and maintain the health of employees:

- ensuring ventilation at workplaces with existing equipment;
- alternating work periods with rest periods in shaded places as needed;
- provision of adequate mineral water, 2 liters/worker/shift;
- providing first aid through the trained staff of the own office;
- providing individual protective equipment.

According to the National Meteorological Administration, the estimate of the evolution of thermal values and precipitation in the interval July 10-14, 2023 for Muntenia will be as follows:
"Throughout the interval, the weather will be warm, with average maximum temperatures of 32...34 degrees, but there will also be hot periods, especially in the plains (July 13-14), when the average daily values will be around of 37...38 degrees."

Proposals for other short-term measures:

- Identification of space/room where to ensure an adequate temperature where operators have the possibility to alternate work periods with rest periods;
- Equipping the dining room in the production area with a refrigerator.

2.2. Biological factors in the context of the Covid 19 pandemic – Case study

During January 2020, the China CDC reported a novel coronavirus as the causative agent of an influenza outbreak, a virus that, from a phylogenetic point of view, is in the same class as SARS-CoV.

The disease associated with the new coronavirus was called COVID-19 and the symptoms associated with this disease initially start as a flu, characterized by runny nose, sneezing, coughing, chills, fever, muscle pain, loss of smell and taste, and the complications arising from infestations with various strains of the virus caused the death of millions of people during the 2 years of the pandemic.

Since the emergence of the virus in Wuhan, China, on December 19, 2019, until March 11, 2020, approximately 120,000 cases of COVID-19 have been reported worldwide, in more than 100 countries.

As of the end of February 2020, the majority of reported cases were from outside China, with an increasing majority of those reported from EU/EEA countries and the UK [5].

The speed of the spread of the virus, the lack of medical equipment needed to protect the population and the medication needed to treat such a large number of people forced the authorities to declare a state of pandemic worldwide.

The Director General of the World Health Organization (WHO) declared a pandemic with COVID-19 on March 11, 2020.

The state of alert entered into force in Romania by DECISION no. 24 of May 14, 2020 regarding the approval of the establishment of the state of alert at the national level and of infection prevention and control measures, in the context of the epidemiological situation generated by the SARS-CoV-2 virus [6].

Based on the risk assessment issued by the National Center for Surveillance and Control of Communicable Diseases and the measures to prevent contamination with the new SARS-CoV-2 coronavirus [7], the employer initiated a plan of concrete measures to limit employee illnesses and sanitize the premises contaminated by the presence of employees found positive in the Covid antigen tests.
In this sense, the plan of measures provided for two important measures regarding prevention among employees:

- Testing staff with Covid-related symptoms with rapid antigen tests (self-control)
- The purchase and use of a sanitizing and air purifying device in the offices and spaces used by the company's employees, including the cars used by the company's staff.

Following a thorough analysis of the sources of sanitization of the premises (UV lamps, ozone generators, disinfection with chemical substances), the ozone GENERATOR based on electric discharge, in a completely controllable way, was chosen as the optimal measure and without other contraindications for employees.

Ozone is the most powerful oxidant known and effectively removes toxins from the air (nitrates, sulfates, car emissions, etc.). At the same time, it ranks 2nd in the world as a sterilization power and can be used to destroy bacteria, viruses and odors. With the help of ozone produced by ozone generators, bacteria, viruses, fungi, mold, odors are completely eliminated and destroyed.

Ozone is an efficient way to sanitize the home, office, car, water and food. At the same time, it also has an extremely important industrial utility: it is currently used in factories, work halls, the food industry, etc. Ozone destroys bacteria, fungi and viruses, removes color and odor from water.

Eliminates the unpleasant odors of old furniture, toilets, smoke and fire, rotten meat, cooked food, cigarettes, sweat. And so on Destroys pathogens: E-coli, Listeria, mold and mold spores.

Sanitizes the car's air conditioning system and removes odors from the passenger compartment.

The device used is manufactured in Romania and is called **OZON FIX** , it is an ozone generator using OTC Tube technology through the corona effect.

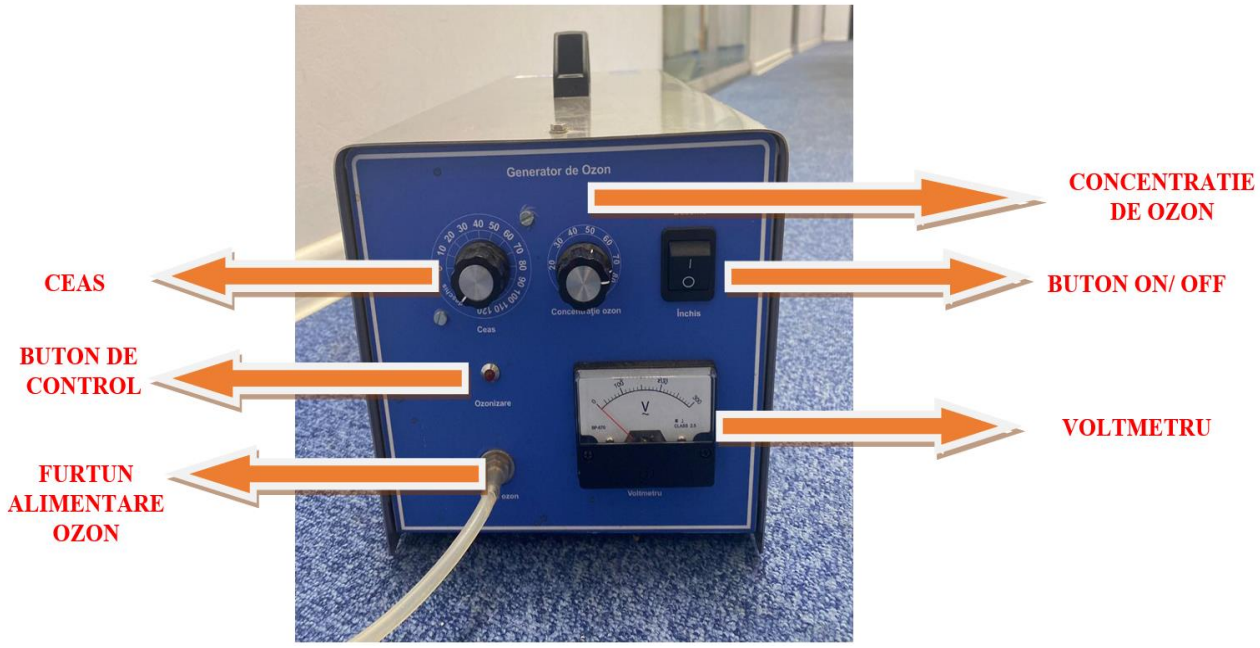


Fig. 4. Components of the OZON FIX device

Fig. 5. OZON FIX device (front view)

Fig. 6. OZON FIX machine (rear view)

Fig. 7. OZON FIX device (side view)

In the USA, OHSA regulates 2 levels of exposure to ozone, respectively:

- 0.1 PPM time-weighted average for an 8-hour day;
- 0.3 PPM for a period of 15 minutes.

In the instruction manual of the product, its components are presented, as well as the operating times of the device in relation to the size of the space to be disinfected.

For example , an office with dimensions L= 10 m, l= 5 m, h= 3 m, in which an employee infested with covid stayed, requires 20 mg ozone/ m^3 for air purification.

We use an Ozonfix 3 device, which generates 3 gr of ozone/hour, which means 30 g/h.
The ozone requirement is 10 x 5 x 3 x 20 mg = 3000 mg ozone.
The time required to obtain 3000 mg of ozone (300 gr) is 1 hour at a concentration of 100.
The advantage of this device is that it can be programmed and turns off automatically.

CONDITIILE AMBIENTALE ALE APARATULUI

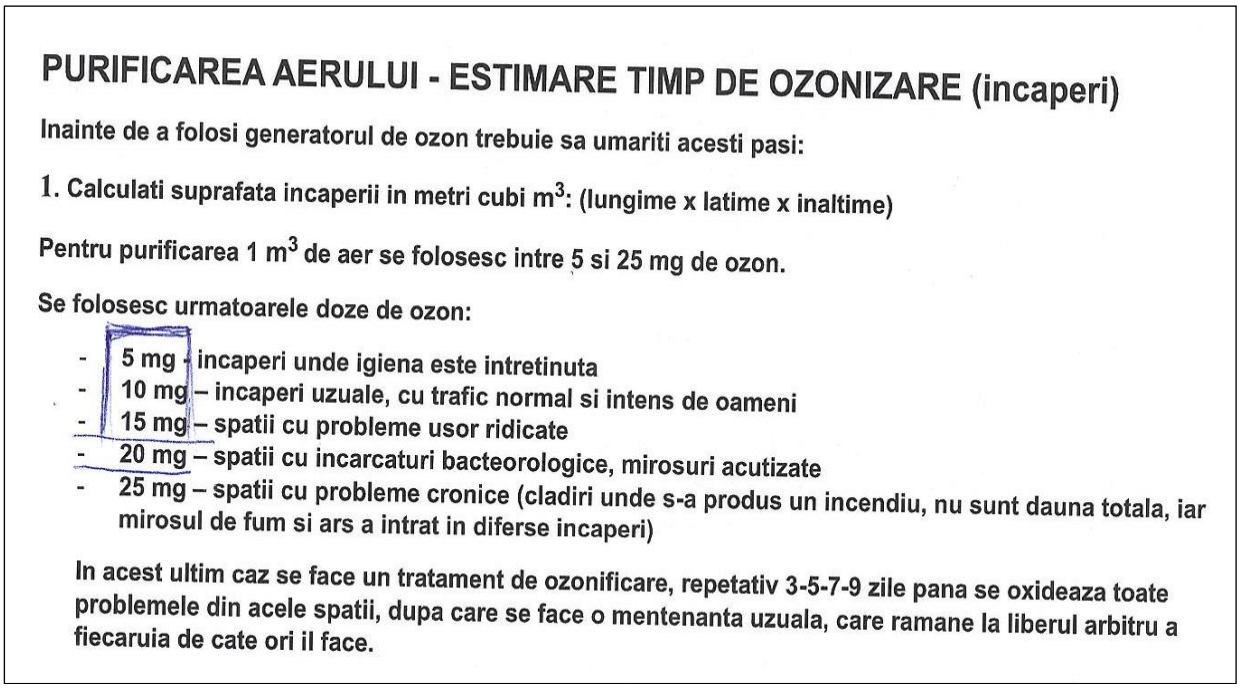
- Incaperea unde se amplaseaza Generatorul de Ozon trebuie sa fie bine oxigenata, fara gaze inflamabile care pot produce explozii! Este interzisa folosirea aparatului intr-un mediu cu praf.
- Tensiune de alimentare 220V/50Hz AC, 110V/60Hz (optional, trebuie să se specifice atunci când se comanda Generatorul de Ozon)
- Cerințe de temperatura a mediului ambient : intre +5°C si +35 °C
- Cerințe de umiditate a mediului: ≤ 60 % .

IMPORTANT: Ozonul este mai greu decat oxigenul, prin urmare se lasa jos la pardoseala.

Atunci când functioneaza generatorul de ozon in interiorul incaperilor, este necesar sa se instaleze un ventilator in incaperi (sau aerul conditionat sa fie functionabil) pentru ca ozonul sa intre in toate colturile si ungherele.

De retinut: Daca aveti aer conditionat este bine sa-l puneti pe temperatura cea mai joasa, deoarece ozonul rezista mai bine la temperaturi joase. La temperaturi ridicate se descompune inapoi in stadiul de oxigen.

Fig. 8. Ambient conditions of the device [8]



PURIFICAREA AERULUI - ESTIMARE TIMP DE OZONIZARE (incaperi)

Inainte de a folosi generatorul de ozon trebuie sa umariti acesti pasi:

1. Calculati suprafata incaperii in metri cubi m^3: (lungime x latime x inaltime)

Pentru purificarea 1 m^3 de aer se folosesc intre 5 si 25 mg de ozon.

Se folosesc urmatoarele doze de ozon:

- **5 mg - incaperi unde igiena este intretinuta**
- **10 mg – incaperi uzuale, cu trafic normal si intens de oameni**
- **15 mg – spatii cu probleme usor ridicate**
- **20 mg – spatii cu incarcaturi bacteorologice, mirosuri acutizate**
- **25 mg – spatii cu probleme cronice (cladiri unde s-a produs un incendiu, nu sunt dauna totala, iar mirosul de fum si ars a intrat in diferse incaperi)**

In acest ultim caz se face un tratament de ozonificare, repetativ 3-5-7-9 zile pana se oxideaza toate problemele din acele spatii, dupa care se face o mentenanta uzuala, care ramane la liberul arbitru a fiecaruia de cate ori il face.

Fig. 9. Estimation of ozonation time (rooms) [8]

For the calculation of the time required for ozone sanitization of a certain surface, the simple rule of 3 will be used, by multiplying the length x width x height of the hall/room and the ozone requirement per m^3, according to the table above.

How to use and safety precautions [8]

- The device is positioned in the space to be disinfected, programmed from the buttons on the control panel, respectively the time of use and the oxygen concentration level.
- The windows are closed hermetically.
- It turns on apart from the start button and immediately leaves the room.
- All persons leave the room.
- The access door is closed and a signal indicator " **ACCESS PROHIBITED WHILE THE OZONIZER IS OPERATING** " is displayed.
- After the ozonation period has passed, at approx. 15-20 minutes enter the room to open the window and let the space air out for another 30 minutes.
- Ozonation is considered completed when the space (office, room, changing room, etc.) gets a strong smell, like after a rain in the mountains and the device stops producing ozone.
- After ozonation and ventilation, the space can be used after the ozone smell has completely disappeared, turning it into oxygen.
- Preferably, the ozone sanitization operation is carried out at the end of the work schedule, and in the morning it is ventilated again, before starting work, for 30 minutes.

3. Conclusions

A safe working environment, without risks of employee illness, as stipulated by Law 319/2006, HG 1425/2006, General labor protection norms (2002), is a necessity through which the employer proves that he has taken all the necessary measures for so that employees have the certainty that the workplace is safe and healthy.

By monitoring the workplace environment factors we can keep them under control for creating a well-being of the worker at the workplace with a higher yield of the work performed.

Depending on the ambient temperature, the person, through the skin analyzer, develops the sensation of heat (caused by the action of objects with a temperature higher than the skin temperature), or

the sensation of cold (caused by the action on the receptors in the skin of objects with a temperature higher lower than that of the skin). The heat in the body is produced by the chemical transformations that take place inside the liver and by the transformation of the mechanical energy of the muscles.

The distribution of this (own) heat is not uniform, but it remains constant (about 37A°C) inside the brain, in the heart and in the organs in the abdomen, the constancy of the temperature at the level of these organs being a condition for the unfolding of vital processes.

The realization of a thermal environment corresponding to a physiological well-being of the body (subjective temperature) is based on a balance between the temperature and humidity of the environment.

During the entire period of the COVID 19 pandemic, as a result of the application of the plan of measures at the company level, especially the provision of antigen tests, disinfectants, protective masks, as well as the periodic sanitization of the work spaces with the ozone generator, to the staff employed as a result employees who went through the pandemic period without serious health problems.

Not one of the company's 270 employees died or required intubation due to infection with the Covid virus. A very small number of people required medical care in hospital facilities (5 people), and the rest of the employees infected with the COVID virus had symptoms specific to a common flu and were treated at home.

I estimate that the use of ozone sanitization drastically reduced the viral load of the COVID virus, but also of other types of bacteria, viruses, fungi present in the work spaces, which fully proved the usefulness of the OzonFix device used.

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[6] DECISION no. 24 of May 14, 2020 regarding the approval of the establishment of the state of alert at national level and the measures to prevent and control infections, in the context of the epidemiological situation generated by the SARS-CoV-2 virus
[7] ORDER no. 1731 of May 15, 2020 regarding the measures to prevent contamination with the new SARS-CoV-2 coronavirus and to ensure that activities are carried out under sanitary safety conditions in the economic field, during the state of alert
[8] OZONFIX Bussines 3 Ozone Generator User Manual

5. Notations

The following symbols are used throughout the paper:
ITU = temperature-humidity index;
T = air temperature [°C];
U = relative humidity [%];
L = length [m];
l = at times [m];
h = height [m].

INVESTIGATION OF ACCIDENTS AT WORK INVOLVING THE USE OF GOODS LIFTS

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ABSTRACT: This paper presents a presentation on the investigation of accidents at work involving the use of freight elevators. Definitions, a concrete case study, suggestive pictures and measures on workplace injuries using the freight elevator are presented. The authors believe that the measures applied should be accessible to all and should be respected by all employees.
KEYWORDS: work accident, victim, freight elevator, action, faculty of industrial engineering and robotics

1. Introduction

Preventing accidents at work is fundamental to ensuring the safety and health of workers in the workplace. Despite prevention efforts, such incidents can occur at any time and can have serious consequences, including temporary incapacity for work, disability or even death. It is therefore crucial that employers provide adequate training, appropriate protective equipment and implement workplace safety measures. Workers should also be aware of the specific risks of their job and act responsibly to prevent accidents. A proactive approach and the involvement of all stakeholders is key to reducing the number and severity of accidents at work.
Accident at work, as defined in LG 319/2006, art. 5, lit. G means - violent injury to the body, as well as acute occupational intoxication, which occurs during the work process or in the performance of work duties and which causes temporary incapacity for work of at least 3 calendar days, disability or death;

2. Research objective:

The purpose of the investigation of the events is to establish the circumstances and causes that led to the occurrence of the event, the legal regulations violated, the responsibilities and the measures to be taken to prevent other similar cases and to determine the nature of the accident occurred on 20.05.2023, around 12:15, involving worker X - Vegetable-fruit seller, employee of a supermarket - Satu Mare work point, located in Mun. Satu Mare, Str. Milcov, nr. T6, Jud. Satu Mare in accordance with section 2, chap. VII of the Methodological Norms for the application of the provisions of the Law on Safety and Health at Work no.
319/2006, approved by GD no. 1425/2006 amended and supplemented.

3. Detailed description of the place where the event occurred:

The event, which resulted in the injury suffered by worker X, occurred at the supermarket's working point, located in Mun. Satu Mare, respectively in the goods reception area of the store.
The shop employs 17 workers, working in two shifts.
The freight elevator operates on two up/down stations between the ground floor and the basement. It is fitted with two metal access doors, located on the basement and ground floor landings of the store where it connects.
On the basement and ground floor landings, the lighting is artificial and the contact surface is metallic.
The event took place on the ground floor while worker X used the hoist to move from the basement to the upper level with a forklift.

4. Detailed description of the work equipment:

The event, which resulted in the injury to worker X, involved a goods lift (see Fig. 1).

Fig. 1. Work equipment

Technical data lifting installation - freight elevator/self-loading material platform:

- Type: Hydraulic Compact Cargo Lift;
- Drive: electric;
- Number and year of manufacture of the lifting machine: 014641.14/2014;
- Maximum load capacity: 1000 kg.;
- 2 lift stations, between basement and ground floor;
- Fitted with 2 external metal doors on each landing;
- The lift car has no walls, only a metal platform for the goods to be transported;
- The lift control panel is located on the outside of the lift, to the left of the landing doors.

The work equipment - freight elevator/self-erecting material platform, was technically inspected on 15.03.2022 by the RSVTI Operator. Following the checks and tests carried out, appropriate results were recorded.
The deadline for the next verification has been set at 14.03.2023.
The work equipment - freight elevator/self-erecting material handling platform, is operated only by operating personnel trained by the RSVTI operator.

5. Detailed description of the circumstances:

Worker X, employed as a Fruit and Vegetable Salesman, reported to work at around 06:30, according to the work schedule for shift I.
After the morning meeting with the store manager, where the workers were given the work tasks to be carried out that day, as well as training on the occupational health and safety rules to be observed during work, worker X started work.
Until around 12:00 noon, Worker X carried out his duties as a fruit and vegetable seller in accordance with his job description.
At the same time, on 20.05.2023, at around 12:10, the company's representative came to the shop to carry out the periodic inspection of the goods lift, according to the maintenance contract for lifting equipment.
At the time of the event, Worker X was trained in occupational health and safety and was declared medically fit for work.

6. Detailed description of how the event occurred

From the statement of worker X, worker Y, the shop manager and the representative of the lifting equipment maintenance company, as well as from the report of the on-site inspection, it appears that:
On 20.05.2023, at around 12:00, worker X, employed as a Fruit and Vegetable Salesperson in the store, was working in the goods reception area in the basement of the store, where he was supposed to pick up goods to supply the fruit and vegetable section of the store.
According to his account, in the basement, after placing the goods on the trolley, he met with the representative of the lift maintenance company, who was present in the store for the regular check of the goods lift.

Worker X placed the goods trolley on the goods lift platform and then asked the representative of the lift maintenance company to operate the lift start button on the lift control panel to the left of the outside door in order to move the goods on the trolley to an upper level from the basement to the ground floor.
In view of the statements made by the maintenance man, before he pressed the start button on the installation,

he drew worker X's attention to the prohibition on using the lift to transport people and warned him of the position he should adopt when using it.
Knowing the dangers to which Worker X was exposed, the maintenance man stood by with his hand on the STOP button to activate it if necessary.
During the ascent, Worker X reported that he stuck his right hand out of the lift platform, intending to leave an empty box at the side of the platform, at which point he caught his right hand between the lift frame support rail and the nacelle frame.
Alerted by worker X's screams, the maintenance man immediately pressed the STOP button to shut down the plant.
The lift maintenance gentleman rushed to the upper level, ground floor, opened the lift with the service key provided and found Worker X "...holding his right hand with his left hand", where he was in pain.
Worker X was helped out of the lift car by the lift maintenance man, and then the shop manager arrived on the scene, who, after giving him first aid, called 112 and requested an ambulance.
Ambulance staff arrived at the scene, picked up worker X and transported him to the Satu Mare County Emergency Hospital for specialist medical investigations.

7. Aftermath and/or consequences suffered by the injured party

Following the event occurred on 20.05.2023 and following medical investigations carried out at the Satu Mare County Emergency Hospital, worker X was diagnosed with:
"Open fracture type II right humerus paddle"
Worker X was granted 35 days of sick leave from 20.05.2023 to 31.05.2023, according to his sick leave certificate, CCMAQ series no. 2685771 and from 01.06.2023 to 24.06.2023, according to his sick leave certificate, CCMAQ series no. 4712257.

8. Cause of the event

The cause of the event was the improperuse by worker X of a goods lift to move to a higher level of his position, contrary to the intended use and operation of the lift.
This action caused the event to occur, as a result of the right upper limb being pulled out of the lift platform while it was ascending, which led to the worker's right hand being caught between the support rail of the lift frame and the frame of the nacelle, resulting in the worker suffering a type II open fracture of the right humerus blade.
This violates the following requirements in the field of SSM, as follows:
-The provisions of para. 4, item 7.3.14, Section Use of Goods Lift, of IPSSM No. 12, on Handling, Carrying and Transport by Non-Mechanised/Mechanised Means and Storage of Materials, which states: "... the goods lift shall not be used for the carriage of persons;"
Corroborated with,
- Article 22 of Law no. 319/2006 (Law on safety and health at work), which states: "Each worker must carry out his work in accordance with his training and instruction and with the instructions received from his employer, so as not to expose his own person to the risk of injury or occupational disease...";
-Article 23, letter h, of Law no. 319/2006 (Law on Safety and Health at Work), which states: "In particular, in order to achieve the objectives set out in Article 22, workers have the following obligations: to understand and comply with the provisions of occupational safety and health legislation and their implementation measures;"

9. Other contributing causes

The investigation commission established another contributing cause:
-Triggering of the external control to start the goods lift by maintenance staff, for use of the installation for the purpose of transporting persons, and thus exposing worker X to risks of injury.
This action led to the event occurring as a result of Worker X's right hand getting caught between the lift frame handrail and the nacelle frame, injuring his right limb.
This violates the following requirements in the field of SSM, as follows:

-The provisions of Art. 1 of the IPSSM for the operation and maintenance of lifts for persons and goods, which states: "Every worker shall carry out his work .....in such a way as not to expose his own person or other persons who may be affected by his actions or omissions during the work process to the risk of

injury or occupational disease;
Corroborated with,
-Article 23, letter h, of Law no. 319/2006 (Law on Safety and Health at Work), which states: "In particular, in order to achieve the objectives set out in Article 22, workers have the following obligations: to understand and comply with the provisions of occupational safety and health legislation and their implementation measures;"

10. Persons responsible for breaching legal regulations

The event investigation commission appointed at company level has determined on the basis of the checks carried out, the statements of those involved and following analysis of the documents submitted on this occasion that:
In view of the circumstances, conditions and cause of the event, it has been established that the person responsible for the breach of the occupational safety and health requirements is worker X for those set out in point 8 and the maintenance staff for those set out in point 9.

11. Nature of the accident

Regarding the event under investigation, in view of:
-Sick leave certificates;
-The circumstances and causes of the event;
-The provisions of Law 319/2006:
Art. 5, letter g): "Accident at work - violent injury to the body, as well as acute occupational intoxication, occurring in the course of work or in the performance of work duties and causing temporary incapacity for work of at least 3 calendar days, disability or death";
Art. 31, lit. a): "Accidents at work are classified, in relation to the consequences produced and the number of persons injured, into: a) accidents causing temporary incapacity for work of at least 3 calendar days"
In conjunction with the provisions of Article 2, para. (5) of the Implementing Rules of Law 319/2006, approved by GD no.1425/2006, subsequently amended and supplemented:
Art. 2, para. (5) "Accident causing temporary incapacity for work (ITM) - accident causing temporary incapacity for work of at least 3 consecutive calendar days, confirmed by medical certificate or, where appropriate, by other medical documents, according to legal provisions", which is why the event suffered by worker X is classified as an accident at work, which caused temporary incapacity for work of at least 3 calendar days.

12. Measures in place to prevent similar events

1. Review the risk assessment, with regard to occupational safety and health at the workplace and update the prevention and protection plan based on the revised risk assessment, for the salesperson workstation.

Deadline: 30 working days from the approval of the research file.

2. Additional occupational health and safety re-training of worker X. Deadline: 2 days after resumption of work
3. Additional re-training of maintenance staff on the repair work of hydraulic passenger and goods lifts; Deadline: 30 working days from the approval of the research file

13. Comparison of the case with the possibility of an accident in the Faculty of Industrial Engineering and Robotics

In the Faculty of Industrial Engineering and Robotics, in the CE building, there is a freight elevator (see fig. 2.1 and fig. 2.2), similar to the one shown above. During the last weeks we have been watching carefully the people in the EC body and we have noticed that especially the students are curious to use it, not knowing the risks they are exposed to.

Fig. 2.1 Goods lift

Fig. 2.2. Lift buttons

Therefore, we propose the implementation of safety measures to be applied within the faculty:

- Appropriate training: All users of the freight elevator should receive regular training on how to use it correctly, including safety procedures and rules of conduct.
- Restricting access: Access to the freight elevator should be restricted to authorized and properly trained personnel only.
- Regular checks: The freight elevator should undergo regular inspections and overhauls to ensure that it is operating safely and that all components are in proper working order.
- Marking and signage: The goods lift should be appropriately marked and signposted, including instructions for use and visible safety warnings.
- Emergency communication system: The freight elevator should be equipped with an emergency communication system to allow users to call for help in case of need or in emergency situations.
- Video surveillance: Installing video surveillance cameras in the freight elevator area can help monitor its use and identify potential problems or unsafe behaviour.

14. Conclusion

The workplace accident under review highlights the seriousness of workplace risks and the need to pay greater attention to worker safety when using lifts. To prevent such incidents, immediate measures have been ordered, such as reviewing the risk assessment, re-training staff and implementing these measures in all organisations where the lift is used.

It is vital that all these actions are implemented immediately and rigorously to ensure a safe and healthy working environment for all employees and to avoid such events that were not foreseen in the risk assessment.

We made a safety notice about the prohibition of people using the freight elevator and placed it on the elevator door (see fig 3.1 and fig 3.2):

Fig. 3.1. Safety advertisement

Fig. 3.2. Lift door

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EMPLOYEE MOTIVATION, PSYCHOSOCIAL FACTOR IN THE WORK PROCESS

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ABSTRACT: Occupational health and safety are fundamental elements in maintaining a productive and motivating work environment. They not only ensure the physical well-being of employees, but also contribute to the creation of a positive work climate that can boost motivation and engagement. A safe and healthy work environment can reduce stress, prevent occupational accidents and occupational diseases, leading to increased employee satisfaction and productivity.

KEYWORDS: employee motivation, performance evaluation, OSH

1. INTRODUCTION

The human being is a complex biopsychosocial entity, therefore, regardless of the nature and the way of action of an external factor, whether harmful, aggressive or beneficial, the human individual, his body reacts as a whole on all levels of manifestation: physical, physiological, neuroendocrine, psycho-emotional, behavioural, social.

In this context, external factors, whether professional or existential, in so far as they come into contact with man and interact with him, causing (in all cases) complex reactions with a high degree of psychological involvement, have been called **psychosocial factors** (not in relation to their original nature, but to their transformation and development in contact with the person on whom they act).

In other words, psychosocial occupational factors, as factors of psychological stress, are the result of an interaction between ***occupational factors*** (work task - by its content, nature and characteristics, work environment, conditions of work organisation and workplace layout, interpersonal relations, managerial practices, conditions of employment, promotion and job retention, etc.) and ***individual factors*** (abilities, skills, needs, aspirations, level of education and culture, etc.)[2].

Psychosocial risks are defined as aspects of the design, organisation and management of work that can lead to psychological, social or physical harm.

2. PSYCHOSOCIAL RISKS

Throughout its existence, the human race has experienced a relatively limited number of work-related life transitions. The first occurred about 10,000 years ago, with the transition of nomadic tribes from hunting and fishing to agriculture. The next transition began only a few hundred years ago, with the rise of the industrial revolution. Today, we are in the midst of the third transition, to a post-industrial era, characterised by the information economy, but also by globalisation, corporate reorganisation, the introduction of new technologies (such as computerisation, robotisation and biotechnology), the introduction of new management philosophies, and the increasing diversity of the workforce and the expectations of that workforce [3].

Stress is sometimes either a risk factor (stressor), a mental or physical reaction to risk factors (stressor), or a psychosocial consequence of these reactions (Fig. 1).

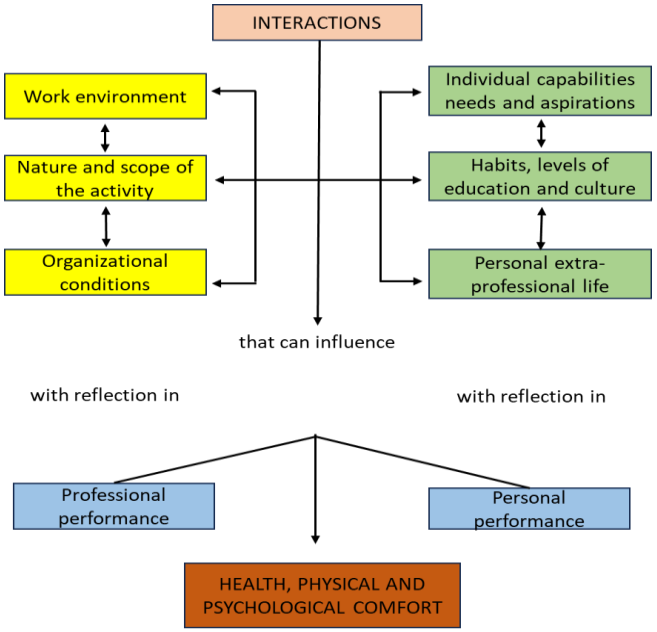

Fig.1. The relationship of health status in the dynamics between occupational and personal factors

The issue of stress is part of a much broader field of an interdisciplinary approach to the organization, namely "organizational pathology" which emerged from the need to address problems of great extent and severity encountered throughout the organization [4].
Stress is both active and cumulative. It builds up over time to a state of crisis, when physical (muscle tension, headaches, back pain, insomnia, hypertension, etc.) and psychological (irritability, anxiety, frustration, hatred, loss of concentration, etc.) symptoms appear.
Din diversitatea abordărilor conceptuale ale stresului, s-au mai reţinut câteva definiţii ale acestuia:
J.E. McGrarth defineşte stresul ocupaţional ca o stare de dezechilibru perceput între solicitări şi capacitatea individului de a răspunde la acestea, în condiţiile în care imposibilitatea de a defini aceste solicitări are consecinţe importante [5].
R.L. Kahn şi R.P. Quinn consideră că prin stres ocupaţional ne referim la orice factor negativ de mediu sau stresor (exemplu: conflictul de rol) care este asociat cu munca prestată şi care produce efecte negative asupra persoanei [6].
R.S. Lazarus şi S. Folkman văd stresul ca o relaţie particulară între persoană şi mediu care este evaluată de individ ca fiind costisitoare sau ameninţătoare pentru propria stare de bine [7].

From the diversity of conceptual approaches to stress, several definitions of stress have been retained:
J.E. McGrarth defines occupational stress as a state of perceived imbalance between demands and the individual's ability to respond to them, where the inability to define these demands has important consequences [5].
R.L. Kahn and R.P. Quinn consider that occupational stress refers to any negative environmental factor or stressor (e.g. role conflict) that is associated with the work being performed and that produces negative effects on the individual [6].

R.S. Lazarus and S. Folkman see stress as a particular relationship between the person and the environment that is assessed by the individual as costly or threatening to their own well- being [7].
Workplace stress is the natural reaction of people under intense pressure at work for a period of time. In general, many people are motivated by the challenges and difficulties associated with the demands of work and respond by improving performance. Meeting those challenges and overcoming difficulties leads to feelings of relaxation and satisfaction. When the pressure of work demands becomes excessive and prolonged, individuals perceive a threat to their comfort and interests and experience unpleasant emotions such as fear, anger or anxiety. These emotional symptoms, together with a range of cognitive and behavioural symptoms, characterise stress.

A general classification of the factors that can lead to psychosocial risks is as follows (Fig. 2):

Factors of the physical environment, which through direct action on the body can cause a series of negative effects both on the body in general, but especially on the central nervous system, the neuroendocrine system and thus can also have effects on the psychological level, causing possible mental disorders.
This first group also includes the risks of injury and occupational illness, which also have a dual action mechanism. For example, an employee's injury can lead not only to physical trauma but also to psychological trauma (e.g. post-traumatic stress disorder); and the very existence of the risk of injury causes the individual a quasi-permanent state of psychological stress.
Workload-dependent factors, these can mainly lead to different levels of demand: overload, underload or alternating situations.
Overload is the main stress factor, because it occurs when the demands of the job exceed the worker's individual capacities, and maintaining this state over a long period of time increases the risk of stress, even chronic stress.
Also, a permanent overload in the workplace can lead to burnout, with serious effects on the worker's health, efficiency and performance.
Underload is a stress factor because there is an innate (and socially enhanced) human need for affirmation, for enhancement, for highlighting one's own abilities, a need that can only be satisfied by a professional activity that demands an optimal level, corresponding to one's abilities [1]
The indicators used to assess the level of demands addressed by the task refer to:

- the complexity-speed ratio (number of routine or conscious choices; duration of a work cycle and number of choices per cycle, memorisation effort, speed required)
- level of attention (concentration, distributivity, etc.)
- degree of precision (e.g. very small parameters or objects)

All of these require intense mobilisation of conscious participation in the performance of the work task and thus represent a major factor of mental effort.

Temporary constraints, these are determined by: repetitive or non-repetitive nature of the operations; free or imposed rhythm; wage system (e.g. by agreement); time needed to reach the required work rhythm (time to enter the rhythm); break regime (organised or individual); possibility to leave the workplace outside breaks if necessary; daily, weekly, monthly, annual working time; shift regime.

The factors of organisation and management of activities, teams and the organisation as a whole are increasingly important in modern society, as evidenced by the frequency and extent of staff dissatisfaction and intra-organisational conflict.
These factors include: ambiguity of roles (of tasks assigned according to role and status in the organisation), conflicts between the different demands on staff (e.g. between production and safety or production and effort, safety and physical and mental comfort), lack of responsibility for other people and their safety, lack of consultation and participation in decision-making (excessive centralised or non-participatory management), unjustified restrictions on work behaviour, lack of control and self-control (in relation to the results of one's own work).
As such we can see ***role conflict*** and ***role ambiguity*** as central agents of organisational stress.
Role conflict can arise in situations where the person occupying a particular role is subject to conflicting, often incompatible, demands or pressures of a certain intensity and orientation, which either facilitate or hinder the exercise of the role. Faced with these pressures, the person can choose whether or not to comply, these pressures generating motivational (mobilising or resisting) psychological forces [1].
With regard to ***role ambiguity***, the person affected does not know exactly what the objectives and tasks are, the level of performance expected, the criteria for control, evaluation and sources of motivation. The source of ambiguity is often generated by information dysfunctions. The intensity of the stress generated by role ambiguity is marked by one's own personality characteristics and is closely related to the capacity for tolerance, which differs from one individual to another.

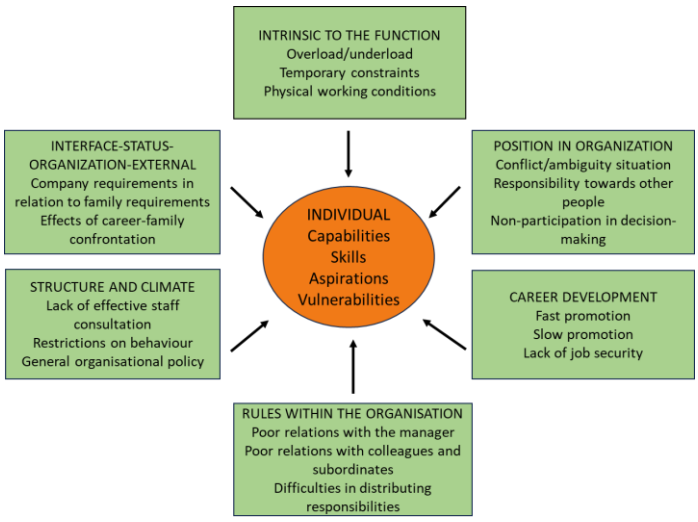

Fig. 2. Sources of stress

3. MOTIVATIONAL THEORIES

In the context of the current presentation, the following motivational theories are essential in the analysis of the research hypothesis.

Abraham Maslow's ***Hierarchy of Needs Theory*** is a psychological theory that proposes that people are motivated to fulfill certain needs in a hierarchical order. This is often presented as a pyramid, with basic needs at the bottom of the pyramid and higher needs at the top.

Basic needs, also known as physiological needs, include needs for air, water, food, shelter, sleep and reproduction. Once these needs are satisfied, people become motivated to fulfill safety needs, which include personal security, health and economic well-being [8], [9], [10], [11].

Once safety needs are met, people are motivated to meet social or belonging needs, which involve interpersonal relationships, friendship and love. The next level of the pyramid includes esteem needs, which involve self-esteem, recognition, and success.

At the top of the pyramid is the need for self-fulfilment, which involves realising personal and creative potential.

Frederik Herzberg's ***Dual Factor Theory*** is a theory of motivation that distinguishes between satisfaction factors (motivational factors) and dissatisfaction factors (hygiene factors). Motivational factors are related to the nature of work itself and include achievement, recognition, responsibility, advancement and personal development. These factors lead to satisfaction and motivation, but their absence does not necessarily lead to dissatisfaction.

Hygiene factors are related to working conditions and include pay, relations with colleagues, company policy and administration, working conditions, status and security. The absence of these factors may lead to dissatisfaction, but their presence does not necessarily lead to satisfaction [12], [13], [14], [15].

Daniel Pink's "***Motivation 2.0" Theory*** is presented in his book "Drive: The Surprising Truth About What Motivates Us". Pink argues that the traditional system of motivation, which he calls "Motivation 2.0", relies on external rewards (such as salaries or bonuses) and punishments (such as job loss or criticism). This system may be effective for simple and repetitive tasks, but not for complex and creative tasks that require critical thinking and innovation [16].

Pink compares society to a computer operating system. "Motivation 1.0" is the original operating system, based on primary biological needs such as food, water, shelter, and sex. This system was enough to keep the human species alive for most of our evolutionary past.

However, when humans created more complex societies, the concept of "Motivation 1.0" became

inadequate. So humans switched to a second operating system, "Motivation 2.0", which is based on reward seeking and punishment avoidance.

4. RESEARCH HYPOTHESIS

This chapter is dedicated to the increase in the number of minor accidents related to the work process in an automatic and semi-automatic machine tool manufacturing and assembly plant and the correlation of the period of increase in the occurrence of these incidents to the interval of evaluation of employee performance objectives in that organisation.
The analysis covers three years and is based on all the data recorded in the medical office at the plant. In this case, pathological and work-related attendances were separated. The latter are analysed in this material. As the information is confidential (name, surname, age, sex, etc.), the identity of the persons who are the subject of this study will not be revealed.

The work sample:

- employees working as automatic and semi-automatic machine tool operators performing their work tasks on manufacturing and assembly lines;
- their age range is between 18 and 62 years;
- the level of formal education being from 8 classes up to and including 12 classes;
- seniority in the factory, being between 6 months and 10 years.

5. WORKING METHODOLOGY

The recorded data reveal the following:

Tabel 1

Year 2021	INCIDENTS											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	8	4	4	3	12	15	3	6	4	5	4	4

Tabel 2

Year 2022	INCIDENTS											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	9	5	7	2	9	9	4	6	3	3	3	1

Tabel 3

Year 2023	INCIDENTS											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	2	3	3	3	10	11	6	6	3	5	1	3

According to Law 319/2006, Article 5, letter q), the definition of a minor accident is as follows: "minor accident - an event resulting in superficial injuries requiring only first aid and resulting in incapacity for work lasting less than 3 days" [17].
At the same time, within the organization, according to Law 53/2003 - Labour Code, the internal regulation provides that the employer shall establish individual performance objectives, as well as the criteria for evaluating their achievement [17]. In this context, in the current case, the organization established the period of evaluation of performance objectives in the period 1- 31 May, and the communication of the results of the evaluation at the end of the same month.
Analysing the data on minor accidents at work in factories, we observe that each May (Fig. 3), the number of such accidents increases significantly compared to the adjacent months. This phenomenon can be explained by the increased expectations of employees during the performance evaluation period. In general, employees anticipate feedback on their work and have high expectations in terms of recognition of their efforts, often subjectively.
By extrapolation, each year, the month of April, shows a significant decrease in workplace incidents. This

is due to increased attention to rules in general. Increased attention comes as a result of the expectation of employees that once they comply with rules related to work discipline, as a consequence, the perception of those involved in evaluating employee performance will also be positive towards high scores.
In comparison to April, we see a significant increase in work incidents in June, just after the performance review period. This phenomenon may be associated with decreased motivation of employees, who may feel disappointed by the feedback received or the lack of recognition, resulting in feelings of frustration and possibly rebellion. According to Maslow's Hierarchy of Needs Theory, job satisfaction is directly related to the fulfilment of higher-order needs, such as the need for recognition and self-fulfilment.

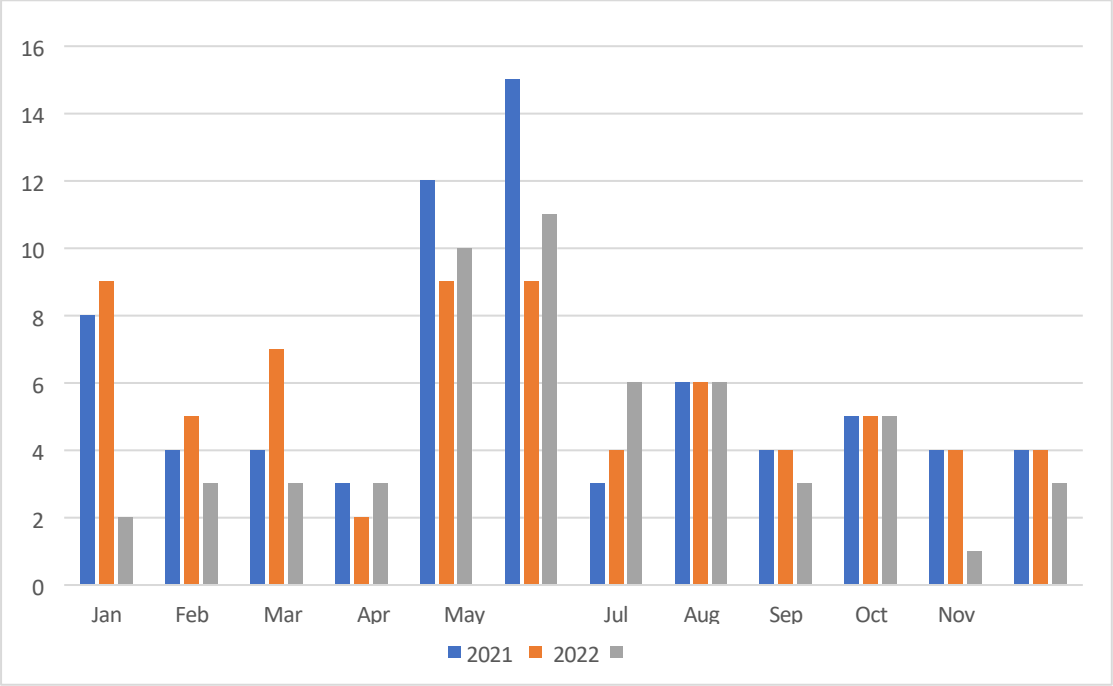

Fig.3. Correlation between incidence of minor accidents and performance evaluation period

There are several possible reasons why the incidence of workplace accidents may increase during the periods when the performance evaluation process is underway and in the month immediately following:
Performance pressure: During the performance evaluation period, employees may feel increased pressure to meet or exceed their goals. This pressure can lead to fatigue or stress.
Working in a hurry: Employees may be tempted to work faster to meet their goals, which can lead to neglect of safety measures and therefore a higher risk of injury.
Lack of concentration: The stress and anxiety associated with performance reviews can affect employees' ability to concentrate, which can increase the likelihood of making mistakes that can lead to accidents.
Neglecting training and protective equipment: In an attempt to save time, employees may skip training steps or fail to use proper protective equipment.
Human error: Human error is a common cause of workplace accidents. It can be magnified in times of stress or when employees are distracted by other concerns, such as performance evaluation.

The interpretation of the data in relation to the motivational theories of Maslow, Herzberg and Pink could be as follows:

Maslow's Theory: This theory suggests that human needs are arranged in a hierarchy, with physiological needs at the bottom, followed by needs for safety, belonging, esteem and self-actualization. In the context of workplace accidents, we can assume that employees' physiological and safety needs are not adequately met, which can lead to an increased number of accidents. Also, the pressure of performance evaluation can affect employees' stress levels, which can negatively affect their needs for belonging and esteem.
Herzberg's Theory: This theory distinguishes between hygiene factors, which can prevent job dissatisfaction, and motivational factors, which can increase satisfaction. Work accidents can be seen as a result of unsatisfactory hygiene factors, such as unsafe working

conditions. In addition, the pressure to evaluate performance can lead to a decrease in job satisfaction if

employees do not feel recognised or valued for their efforts.
Pink's Theory: This theory emphasises the importance of intrinsic motivation and suggests that extrinsic rewards, such as financial bonuses, may be less effective in motivating employees. In the context of accidents, this may suggest that motivation strategies based solely on extrinsic rewards, such as productivity bonuses, may have negative effects on workplace safety. In contrast, approaches that encourage intrinsic motivation, such as providing opportunities for personal and professional development, may be more effective.

6. PREVENTIVE MEASURES

There are several strategies that can be implemented to prevent an increase in the incidence of accidents during performance review periods:
Education and training: the employer must ensure that all employees are properly trained in workplace safety and are aware of all safety procedures.
Open communication: encourage employees to communicate any safety and wellness concerns or issues. This can help identify and address issues before they lead to accidents.
Stress management: finding resources to manage stress and continually ensuring employees have enough time to rest and recover.
Continuous monitoring and improvement: Constantly evaluating the effectiveness of safety programs and making adjustments where necessary.
Encourage incident reporting: create an organizational culture where employees feel comfortable reporting any minor incident for workplace safety and health. This can help identify and prevent potential risks before they lead to more serious accidents.

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DEVICE FOR CPR GUIDANCE IN THE CASE OF HEART ATTACK AND CARDIAC ARREST – HEART GLOVE

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ABSTRACT: The CPR method consists of a series of compressions applied on the chest of a heart attack or a cardiac arrest victim, with the goal of restarting the normal function of the heart. This procedure is a laborious one that needs special training in order to be carried out successfully.

The project that we have developed aims to help with the teaching of the CPR technique and guiding the one that performs it with indications that will improve their technique. By using 3D printing and small electronic components, we have managed to place the device directly in the line of sight of the rescuer, making it easy for him to see the suggestions from the OLED screen.

KEYWORDS: resuscitation, wearable devices, 3D Printing, CPR, medical training.

1. Introduction

Cardiac Arrests and Heart Attacks are some of the leading heart disorders that cause hundreds of thousands of victims per year [1]. Cardiac Arrest occurs when the heart suddenly stops pumping blood throughout the body, while a Heart Attack occurs when a part of the heart does not get enough blood. In both cases, the lack of blood circulation can lead to the death of the victim.

The administration of first aid techniques is vital for saving the victim and for preventing other complications to appear [2].

If CPR is performed on the victim quickly, the chances of survival rise dramatically, but few people know how to give this resuscitation method, and even fewer believe that they are able to administer it correctly [3].

The goal of our research is the creation of a device that can aid the resuscitator by giving them feedback on the technique that they are using. The project that we have developed consists of a glove that has an accelerometer and a screen attached to it via a 3D printed case. This would be worn by the resuscitator and monitor, with the help of different sensors, the compressions and decompressions of the CPR procedure.

2. Market Research

After conducting a market research, we have found other two similar products. The first one was developed by two students from McMaster University [4] in Canada in 2006. This device was measuring the depth and frequency of the CPR compressions and then display the data on a digital screen.

The second product is being produced by the company Laerdal Medical and consists of a device that is mounted on the chest of the victim [5] and displays information about the state of the victim on a paired phone app.

3. Design and Concept

The device designed by our team primarily aims to ease the administration of cardiac massage, making it as user-friendly as possible. The assistance glove consists of two components: the data acquisition and display unit (on the glove) and the control unit (on the forearm). The setup involves putting on the glove and attaching the control unit to the forearm.

After putting on the glove, the routine for cardiac massage begins. The first step is selecting the type of victim, as CPR procedures have different parameters for adults and children. After adjusting the values for the compression rate and depth according to the previous selection, the user is guided through the procedure of administering cardiac massage via the screen. After the instructions are completed, a start command is awaited to begin the cardiac massage. During the procedure, the device provides real-time feedback to adjust the administration method. After completing 30 compressions, the algorithm waits a preset duration for the two mouth-to-mouth respirations. For starting a new set, the user is asked if he wish to continue.

The developed project uses a Raspberry Pi Zero W as the control unit, which has multiple modules and peripheral devices for visual feedback and data acquisition are attached via GPIO and USB. A USB microphone is used for data input from the rescuer, utilizing a voice recognition library called PicoVoice Rhino, which transforms specific predefined phrases into multiple intents that can be processed in the Python program. For displaying information to the user, the device uses an OLED screen that communicates with the development board via the I2C protocol. The sensor used for detecting compressions is an ADXL345 accelerometer. The glove is powered by a 9V battery connected through a variable regulator set to 5V, supplying power to the Raspberry Pi.

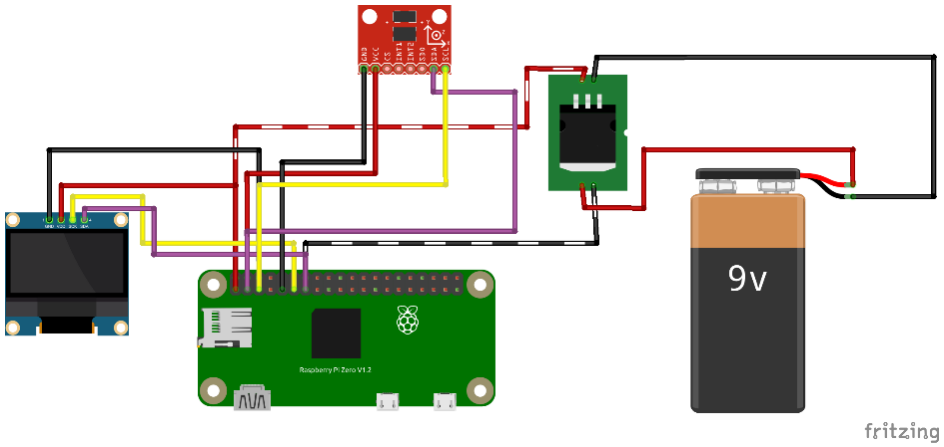

Fig.1

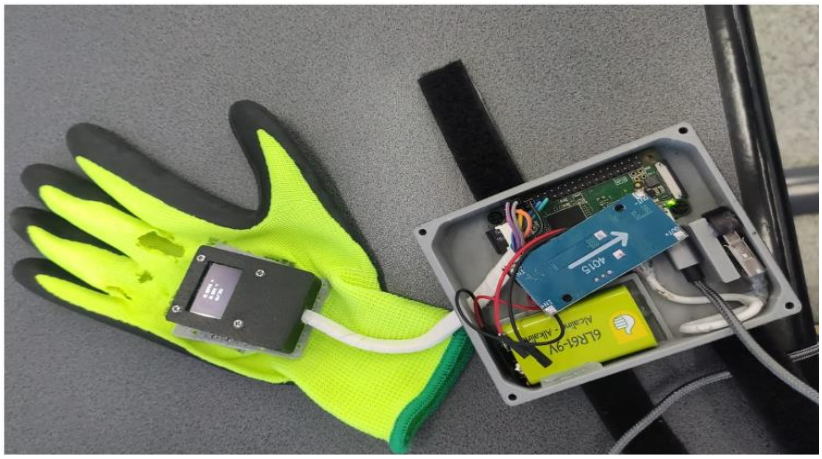

Fig.2

4. Implementation and Technologies Used

The device manufacturing process consisted of two stages: developing the electrical circuit and producing the casing. The electrical circuit was designed using software to visualize the connections. The casing was designed using computer-aided design (CAD) programs (SolidWorks and Onshape), based on the shape of a human hand and considering the components and their placement to minimize dimensions. Subsequently, the casing was produced through an additive manufacturing process with a 3D printer using PLA filament. The display component is mounted on the glove, while the control component is attached to the forearm with two velcro straps and foam to follow the shape of the hand.

Press detection is achieved using an accelerometer mounted on the user's hand, and the calculations for recording amplitude and frequency are based on the assumption that to administer a correct press, the palm must be parallel to the ground, meaning the normal axis to the plane of the hand must be perpendicular to the ground. The mathematical model created checks for two consecutive local maxima points on the acceleration graph, which physically represents a compression and a decompression. For the period between peaks, the average acceleration is calculated and the duration is recorded. Using these two variables, the depth of a press is calculated, and using the duration of the last three presses, the number of presses per minute is calculated.

$$d = a * t_{\mathrm{d}} \tag{1}$$

$$t = t_{\mathrm{a}} - t_{\mathrm{i}} \tag{2}$$

5. Feedback System and User Interface

The graphical user interface is made with the help of the Adafruit SSD1306 Raspberry PI library. With the use of the OLED screen, the resuscitator gets all the information that is needed in order to learn and improve how they administer the CPR procedure.

During normal operation, the first screen that is being displayed asks the operator for the type of victim, after getting the input from the user, the procedure adjusts either for adults or for children.

Fig.3

Fig.4

During the compression phase of the CPR procedure, by using the variables that are being calculated with the mathematical model described in the third section, the screen displays feedback to the user with suggestions on how to improve their technique. The three main fields of information are: compression depth, compression frequence and a compression counter. The feedback is displayed as a symbol next to the specific field that indicates if the number is too low (+), too high (-) or in the permitted range (=).

Fig.5

Fig.6

6. Testing and Validation

For testing the real world efficiency of our algorithm, we have developed a testing sequence that consists of comparing the readings from a 10cm ruler with the output from the device and timing the compressions using a stopwatch. This testing method allowed us to improve the algorithm.

One of the biggest problems that we have encountered during the development of our device were the bad connection between the accelerometer and the Raspberry PI, giving bad readings and crashing the program, this was solved by securing the cables, thus ensuring good operation.

7. Results and Discussions

Following the validation tests, we found that for measuring the pressing amplitude, the developed device has an error margin of approximately 5%. Additionally, for compliant compressions, the device may not count approximately two presses per hundred compressions.

The main advantages of the developed project are its low cost and small size, making it a potential aid for teams involved in cardiac massage training, especially when they use mannequins without sensors.

The necessary improvements to reduce the error and create a more comfortable user experience include: replacing the accelerometer with an IMU (this modification would help because, by using the gyroscope, the device could calculate the distance traveled without the need for the assumption described in point 3), adding a color screen (animations could be displayed on it to facilitate understanding of the process), adding an audio feedback system, and reducing the size of the device.

The possible improvements listed were observed during the product development and are intended to be implemented in a later version of the device.

8. Conclusions

In conclusion , we found that the hypothesis of a device to assist the person providing first aid in the event of a cardiac arrest or heart attack is valid, making it possible to develop a product certified by the relevant authorities for this purpose. Another conclusion that emerged from the development of the project was that the created glove can maintain critical parameters such as: frequency, amplitude, the number of compressions, and duration.

Besides the technological improvements mentioned in point 6, the completed project can be developed into a product ready for the demands of the medical industry and for commercialization on the market, following certification of its effectiveness.

Fig.7

9. Notes

d – distance [cm];
a – acceleration [cm/s^2];
t_d – compression time interval [s];
t – time [s];
t_a – current time [s];
t_i- compression start time [s].

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THE USE OF COFFEE GROUNDS AS A BASIC MATERIAL IN OBTAINING SMALL-SIZED CONTAINERS

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ABSTRACT: The research presented focuses on evaluating the importance of cups made from coffee grounds in an ecological context. The study analyzed the amount of cardboard used in a "to go" café and compared it with the ecological benefits of cups made from coffee grounds. Our materials and methods involved collecting data on cardboard consumption in the café and analyzing the ecological impact of the cups. The results show that, on average, each café uses a significant amount of cardboard every day. In contrast, cups made from coffee grounds contribute to waste reduction and conservation of natural resources. The findings underscore the importance of adopting cups made from coffee grounds to protect the environment.

KEYWORDS: coffee grounds, coffee, ecology, consumption, cardboard.

1. Introduction

In our era, environmental concerns have become a global priority, given the alarming increase in pollution and the increasingly evident impact of climate change. In this context, finding sustainable solutions to counteract the negative effects on the environment is essential. Among the industries with a significant environmental impact is the "to-go" coffee industry, which, although it brings many benefits to modern consumers, substantially contributes to cardboard waste production. All concerns regarding compliance with standards and directives framed within the 17 Sustainable Development Goals should lead to essential changes in the daily lives of the planet's population.

Single-use cups, ubiquitous in this industry, represent a major issue due to the massive deforestation they cause. International statistics show that approximately 0.016 trees are needed to produce a single cardboard cup. This reality underscores the need to seek sustainable and efficient alternatives to reduce the amount of waste generated by this industry.

In this context, cups made from recycled materials, specifically those manufactured from coffee grounds, become an attractive and promising option. By transforming coffee grounds, a common waste product in the coffee preparation process, into a raw material for making coffee ground cups, efforts are made to mitigate the negative effects on climate change. These cups offer an ingenious solution for reducing waste and conserving natural resources. Not only do they minimize the amount of cardboard used, but they also provide a sustainable and eco-friendly alternative for consumers in this industry.

In this research paper, we aim to evaluate the ecological importance of cups made from coffee grounds. We will investigate the amount of cardboard used in a "to-go" coffee shop operated by an economic entity and compare this information with the ecological benefits brought by using coffee ground cups. Our methodology will involve collecting and analyzing data on cardboard consumption in coffee shops, as well as assessing the ecological impact of the cups. Through this research, we aim to highlight the important role these sustainable alternatives can play in protecting the environment and promoting responsible and ecological consumption in the "to-go" coffee industry.

2. Materials and methods used

To evaluate the ecological impact of cups made from coffee grounds compared to single-use cardboard cups in the "to-go" coffee industry, a rigorous data collection and analysis methodology was used.

The 5 To Go coffee shop located in the Faculty of Industrial Engineering and Robotics at the National University of Science and Technology POLITEHNICA Bucharest was selected, and the amount of cardboard used daily was recorded over a one-week observation period. To determine the average number of cardboard cups used in a week, the total number of coffees sold each day of the week was calculated, taking into account variations in consumption based on the days of the week.

Thus, it was determined that, on average, each coffee shop uses a significant amount of cardboard each day, with a weighted average of 200 to 400 coffees sold per day, depending on the days of the week. Based on these data, it was estimated that the average number of trees cut down to produce the cardboard cups used in these coffee shops is approximately 3 to 7 trees each working day.

To calculate the number of trees cut down for producing the cardboard cups, a simple formula was used that took into account the average number of coffees sold each day and the amount of cardboard needed for a single coffee cup. The formula used was:

$$\textit{Number of trees cut down} = \textit{Average number of coffees} * \textit{Amount of cardboard required for a single cup of coffee} \quad (1)$$

Regarding reusable coffee ground cups, the production process was evaluated, and the amount of recycled coffee grounds needed for their manufacture was determined. By calculating that each cup requires a certain amount of recycled coffee grounds, it was found that using coffee ground cups instead of cardboard cups can significantly reduce environmental impact.

By comparing this data and analyzing the ecological impact of the two types of cups, a formula was applied to calculate the pollution index of cardboard cups compared to coffee ground cups. These methods allowed for a comprehensive analysis of the ecological impact of coffee ground cups, providing relevant data and significant results for further discussions on sustainability in the "to-go" coffee industry. The calculation formula is:

$$\textit{Pollution Index} = \textit{Total number of trees cut down} - \textit{Total number of trees saved} \quad (2)$$

where:

$$\textit{Total number of trees saved} = \textit{Total amount of recycled coffee grounds} \div \textit{Amount of recycled coffee grounds per cup} \quad (3)$$

3. Results and Discussions

Based on the analysis, it was estimated that on average, each café uses approximately 1,504 cardboard cups in one week, as shown in table 1.

Table 1. Presentation of the average coffee consumption over a 5-day period at a 5 To Go café

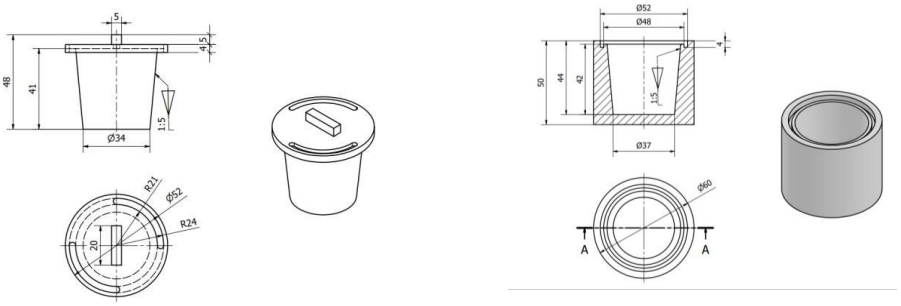
Days of the week	Monday	Tuesday	Wednesday	Thursday	Friday
Number of coffees / day	200	325	350	388	241
Total	**1.504**				

To determine the ecological impact of cardboard cups, a formula was applied that takes into account the average number of coffees sold and the amount of cardboard needed for a single cup of coffee. Thus, it was estimated that in one week, approximately 25 trees are cut down to produce the cardboard cups used in "to go" cafés (table 2):

Table 2. Determination of the number of trees cut down over a 5-day period

Number of trees cut down	Number of cardboard cups
0,016	1
X	1.504
25	

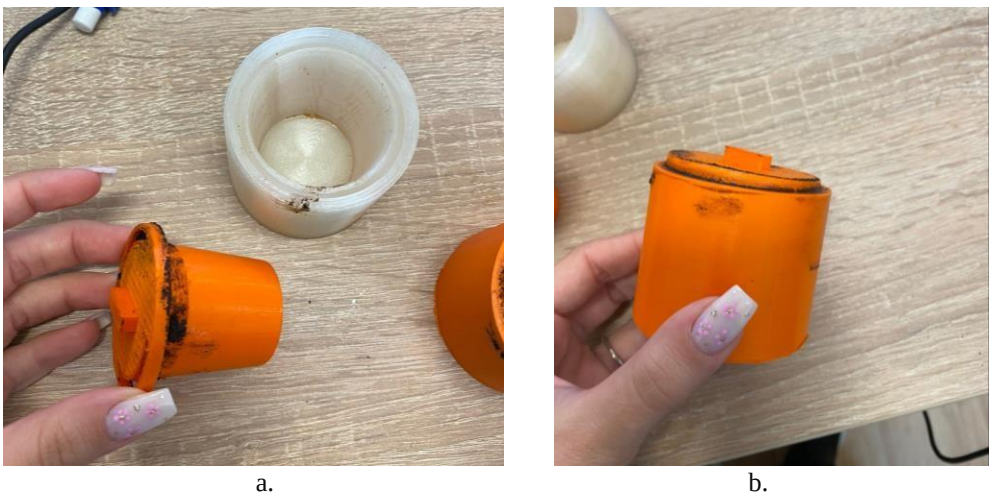
For the coffee ground cups, we investigated the production process and determined the amount of recycled coffee grounds needed to manufacture them. We estimated that each cup requires 50 g of coffee grounds, which means that in a week it amounts to 50 * 1,504 = 75,200 g of coffee grounds that can be used in making coffee cups.



a. b.

Fig.1. The drawing showing the execution of the mold elements used for making a coffee ground container; a.- bottom part of the mold; b. – Top part of the mold.

So, in this 5-day period, the pollution index is -1479. Since it is a negative number, this indicates that the actions and practices over those 5 days had a massively positive impact on the environment. In other words, it signifies an extremely beneficial impact. For the practical realization of the cups, two types of molds consisting of two parts were designed, presented in figures 1a and 1b.



a. b.

Fig. 2. Molds used in the production of coffee grounds containers; a - mold before use, b - mold destroyed by sticking of the composition to its walls.

The two parts of the mold are made of plastic through additive manufacturing using a 3D printer (figure 3).

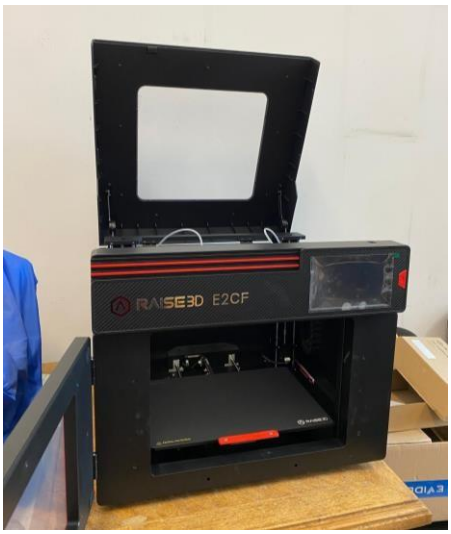


Fig.3. The 3D printer used in creating the mold for producing coffee ground containers.

To demonstrate the validity of the method for making coffee ground cups, a technology was devised in which:

- a layer of oil was applied to the two halves of the mold,
- both parts of it were covered with food wrap,
- the moist coffee grounds were mixed with a mixture of resin and hardener, which acts as the binder between the granules forming the grounds (figure 4).

Thus, in figures 4a and 4b, the application of the oil layer on the two parts of the mold is presented. In figures 4c and 4d, the stages of extracting 2 grams of resin and 1 gram of hardener, respectively, are shown, which will form the binder for the composite structure thus conceived. Figure 4e illustrates the introduction of coffee grounds into the cavity-shaped mold, while in figure 4f, the application of the second part of the mold is presented through pressing. The assembled mold is depicted in figure 4g. After approximately 20 hours, the two parts of the mold were disassembled, resulting in the product presented in figure 4h.

a.

b.

c.

d.

e. f. g. h.

Fig.4. The steps in making a coffee ground container
a. – applying a layer of technical oil on the first semi-mold; b. – applying a layer of oil on the second part of the mold; c. – extracting a quantity of 2 grams of resin; d. – extracting a quantity of 1 gram of hardener; e.- introducing the coffee grounds into the first semi-mold; f. – closing the two semi-molds; g. – assembling the two semi-molds; h. – resulting in the coffee ground container.

Unfortunately, the resulting product did not meet the desired quality because, from the analysis conducted, it was found that a significant amount of water from the grounds altered the chemical composition of the resin and hardener mixture, and the curing process did not occur properly.

4. Conclusions

This study investigated the ecological impact of cups made from coffee grounds compared to single-use cardboard cups in the "to go" coffee industry. Based on the data collected and analysis conducted, we can draw the following conclusions:

- the collected data showed that the use of cardboard cups in the "to go" coffee industry involves a significant amount of natural resources, especially wood, for their production. Additionally, the manufacturing process and disposal contribute to environmental pollution and waste generation.
- cups made from coffee grounds represent an ecological and sustainable solution. By recycling coffee grounds and using them in cup production, dependence on new resources is reduced, and the impact on ecosystems is minimized.
- in addition to ecological benefits, adopting coffee ground cups can bring economic and social advantages. Reducing costs associated with purchasing single-use cups and waste management can contribute to increased business profitability and promote a culture of responsible consumption.
- to maximize the positive impact of transitioning to coffee ground cups, collective commitment is necessary from businesses, consumers, and public authorities. Education and awareness about the benefits of using these cups should be a priority for promoting sustainable behavior.

In conclusion, adopting coffee ground cups over single-use cardboard cups is an important step towards a more sustainable and responsible "to go" coffee industry. Through collaboration and commitment from all parties involved, we can contribute to protecting the environment and building a more sustainable and equitable society for future generations.

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TEHNOLOGICAL ADVANCEMENTS OF METAL POWDERS

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ABSTRACT: Metallic powders have emerged as a crucial element in contemporary industrial processes, revolutionizing the way manufacturers approach product development and fabrication. These versatile materials have unlocked innovative solutions across various industries. As demand grows for high-performance, cost-effective manufacturing methods, research has focused on addressing potential challenges associated with metal powder processing, such as mitigating cracks, porosity, density issues, and thermal deformations.

KEYWORDS: metal powders, advanced processing, additive manufacturing, defect reduction, thermal control

1. Introduction

Metal powders have conquered an important position in modern industry due to their versatility and unique advantages. Recent studies focus on combating potential defects that can appear in parts made by metal powder processing technologies, such as cracks, porosity or insufficient densification, as well as preventing thermal deformations.

The present paper aims to present the different types of metal powders used in various fields, as well as the main technologies for their processing, with an emphasis on powder metallurgy and 3D powder printing. It will also address current challenges in the production of metal powder parts and present recent innovations in these areas that can help prevent potential defects and deformations.

Next, it will be presented: applications of metal powders, looking at 3D printing in the production of metal parts and the use of metal powders in metallurgy, challenges and weaknesses, recent technological advances in metal powder technologies and a case study addressing the defects and the risks that can occur in a part designed by pressing the metal powder as well as a simulation of the thermal defects of a part.

The paper will conclude with a synthesis of the concepts and observations presented, providing clear and concise conclusions regarding the various types of metal powders, their processing technologies and current challenges in the field.

2. Applications of metal powders in industry

Metal powders are finely divided base materials used in the production of metal parts. The particle size of most metal powders ranges from 5-200 μm. Most types of metals and their alloys are composed of metal powders, such as iron, aluminum, bronze, chromium, cobalt, tungsten, etc. [15].

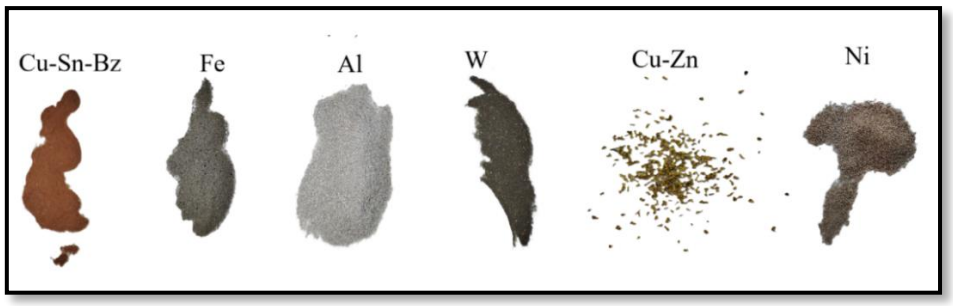

Fig. 1. Types of metal powders

In recent decades, various metal powder manufacturing processes have been designed, developed and applied, adapted to the distinct physical and chemical properties of different metal powders. Among

these processes, the most commonly used are: conventional powder metallurgy (pressing and sintering), metal injection molding, metal additive manufacturing and powder forging.

2.1. 3D printing in the production of metal parts

The main mechanism of additive manufacturing with metal powders involves the following steps:

- preparation of metal powder: metal powders with specific chemical compositions are prepared to be used in the additive manufacturing process;
- deposition of the layers: a laser or an electron beam melts and deposits the metal powder in successive layers, gradually building the final piece;
- layer consolidation: each deposited layer is consolidated by melting and solidification, creating a solid and durable structure;
- finishing and post-processing: after manufacturing, parts may require additional finishing operations, such as machining, heat treatments or other processes necessary to achieve the desired final properties and tolerances [6].

Laser additive manufacturing technology has seen exponential growth over the past two decades, conquering numerous industrial domains. Although traditional methods such as casting, forging, rolling and welding remain the most widely used methods, additive manufacturing is gaining ground in industries such as aerospace, automotive or medical for the production of prototypes, lightweight components and complex parts. Metal powder layer laser fusion is a rising trend that is expected to maintain a high growth rate over the next decade.

A brief history of 3D printing with metal powders can be summarized as follows:

• 1980s: Dr. Carl Deckard makes a key contribution to technological progress by creating the first 3D printer to use laser sintering on plastics. This groundbreaking invention laid the foundation for 3D printing with metal powders, paving the way for a new era of additive manufacturing.

• 1995: The Fraunhofer Institute in Germany files the first patent for laser melting of metals. This discovery sparked a race to perfect the technology, with companies like EOS and various universities playing a fundamental role in advancing the process.

• Accelerated development after 2000: Metal 3D printing has seen gradual but steady growth since the turn of the millennium. A significant change occurred after 2012, with the expiration of the original patents and significant investments by companies such as GE, HP or DM [16].

2.2. The use of metal powders in metallurgy

Powder metallurgy stands out as an advanced manufacturing method widely used in today's industry. This technique involves the use of metal powder, from which parts/components are manufactured, by applying pressure and heat. An advantage of this system is that the metal powder can be composed of a single metal, an alloy or a mixture of different metals and alloys. The main stages of the process of pressing and synthesizing the powders include:

- obtaining metal powders: metal powders can be obtained by various methods, such as atomization (spraying of molten metal), grinding (crushing of solid metal) or chemical precipitation;
- dosing and mixing: metal powders are dosed and mixed in the desired proportions, often with the addition of binders or additives, to improve the characteristics of the mixture;
- compaction: the mixture of powders is compressed under high pressure in molds to form the raw piece;
- sintering: preformed parts are heated to high temperatures (below the melting point of the metal) in a controlled atmosphere. This stage, known as sintering, leads to the consolidation of the part, by increasing the bonds between the powder particles;
- final processing: depending on the requirements, the sintered parts can be subjected to additional processing, such as mechanical processing or thermal treatments [3].

A major advantage of powder metallurgy is the speed and efficiency of production. The process allows for quick production of finished parts, significantly reducing manufacturing times. Moreover,

powder metallurgy stands out for its efficiency from an economic point of view, generating minimal material losses.

Due to these advantages, powder metallurgy has experienced significant growth in recent years. The annual turnover on the European market already exceeds 6 billion euros, and the global production of metal powder has reached one million tons [1].

3. Challenges and weaknesses

Among the challenges faced by metal powder metallurgy are:

● Powder quality: Inconsistencies in powder particle size, shape and flow can result in final parts with inferior structural characteristics. Variations in particle properties can lead to nonuniform compaction, density gradients, and nonuniform shrinkage during sintering, all of which can compromise the mechanical and physical properties of the final product.

● Limitations of traditional sintering: During high-temperature sintering, metal powder particles can increase in size, resulting in a coarser grain structure, which can adversely affect the mechanical properties of the part, such as strength, ductility, and service life. fatigue life. The high temperature sintering process can also cause many other undesirable changes in the microstructure of the part such as phase transformation or the formation of intermetallic compounds.

● Residual Porosity and Surface Roughness: Parts made from metal powders often have residual pores or small air cavities, as well as rough surface finishes. These characteristics can have a negative impact on part performance, such as reduced strength, increased wear, and poor surface appearance. In many applications, additional finishing operations such as machining, grinding, or polishing are required to improve part dimensional accuracy, surface quality, and functional properties.

Addressing the challenges in metal powder metallurgy requires a thorough analysis of the complex relationships between powder characteristics, compaction, sintering and final part properties [7].

Regarding the weaknesses of additive manufacturing processes with metal powders, issues have been frequently raised regarding:

- Limited design complexity: Common 3D printing techniques using metal powders have a limited ability to create complex geometric shapes.

- Cost and adaptability: Additive manufacturing processes with metal powders can have high costs and limitations in terms of large-scale production. This characteristic is one of the main factors preventing the widespread adoption of the technology [17].

- The extremely rapid cooling of the additive manufacturing process inevitably leads to internal stresses in the manufactured parts. These stresses can cause premature failure during prolonged use. In order to develop high-strength materials with a long lifetime, it is essential to understand the evolution of the hierarchical microstructure and the changes in properties that may occur during post-treatment.

Future research should focus on redesigning alloys, optimizing process parameters, and better understanding the micro-structural phenomena involved in additive manufacturing technology with metal powders [10].

4. Recent technological advances in metal powder technologies

In the metallurgical industry, the development of advanced powder atomization techniques has enabled the production of high quality metal powders with increased purity, control of particle size and morphology. Techniques such as gas atomization, plasma atomization, and centrifugal atomization have been refined to create powders with improved flowability, compressibility, and sinterability, leading to improved mechanical properties of the final sintered components [13].

In addition, the adoption of additive manufacturing or 3D printing technologies has revolutionized the way metal powders are used. The growth of 3D printing processes with metal powders (selective laser melting, electron beam melting), has determined the emergence, research and development of additional

technologies that help the processes of making parts printed with metal powders, such as: advanced thermal cameras that monitor the distribution temperature during printing, printing with high power lasers and multiple beams or laser beam shaping and modulation techniques [5], [9].

In the past two years, the industry has seen the emergence of new powder production methods, such as plasma-based atomization and cryogenic gas atomization, which provide improved control over particle size distribution, morphology, and purity. In addition, the integration of machine learning and artificial intelligence algorithms has enabled more efficient powder characterization, process optimization and quality control, further improving the capabilities of metal powder manufacturing [14] [11].

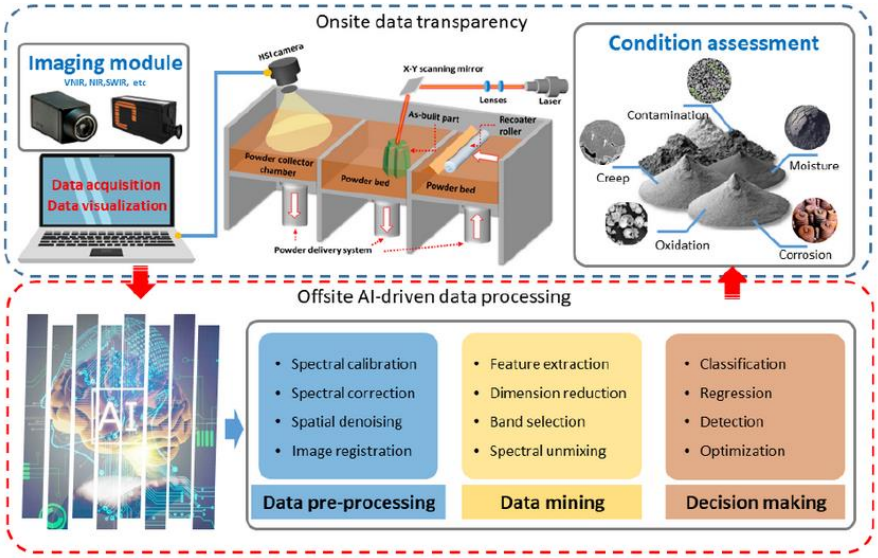

Fig. 2. Integration of artificial intelligence in metal powder purification processes [12]

The field of metal powder metallurgy and additive manufacturing has witnessed the emergence of several advanced metal powders in recent years. These innovative materials offer improved properties, enhanced performance and expanded applications compared to traditional metal powders. Among them are:

▪ High Entropy Alloys (HEA): HEAs are a new class of alloys composed of several principal elements in nearly equal proportions, challenging conventional design principles. These alloys exhibit exceptional properties, including increased strength, ductility and corrosion resistance, making them ideal for demanding applications in the aerospace, energy and biomedical industries. Examples:

- CoCrNiFeAl HEA (exhibits superior strength, ductility and wear resistance, making it suitable for aerospace and automotive components).

- AlCrCuFeNiSi HEA: (shows exceptional resistance to corrosion and high resistance to cryogenic temperatures) [4], [2].

▪ Nanostructured metal powders: nanostructured metal powders are characterized by their extremely small grains, usually on the order of nanometers. This unique microstructure confers exceptional properties including improved strength, toughness and electrical conductivity. Examples:

- Nanostructured Titanium Powder: This powder enables the manufacture of high-strength titanium components with improved ductility and fatigue resistance.

- Nanostructured copper powder: This powder facilitates the production of highly conductive copper components with improved thermal conductivity and electrical efficiency [8].

▪ Biocompatible metal powders: Biocompatible metal powders are designed specifically for use in implants and medical devices. Examples:

- Titanium alloy powder: This powder is widely used for orthopedic implants due to its excellent bio-compatibility, strength and corrosion resistance.

- Cobalt-chromium alloy powder: This powder is another popular choice for orthopedic implants due to its high strength, wear resistance and bio-compatibility.

These advanced metal powders are revolutionizing the field of metal additive manufacturing, enabling the manufacturing of high-performance components with customized properties and extensive applications in various industries [14].

5. Case study

a) Making a simple part by pressing the metal powder

A process of pressing the metallic iron powder was undertaken to obtain a cylindrical piece of small dimensions. The metal powder was prepared, ensuring that it was dry and homogeneous, then poured into the mold, between the lower and upper punches. Afterwards, the actual pressing was carried out. Using a 100t mechanical press, a controlled force was applied to the powder in the mold.

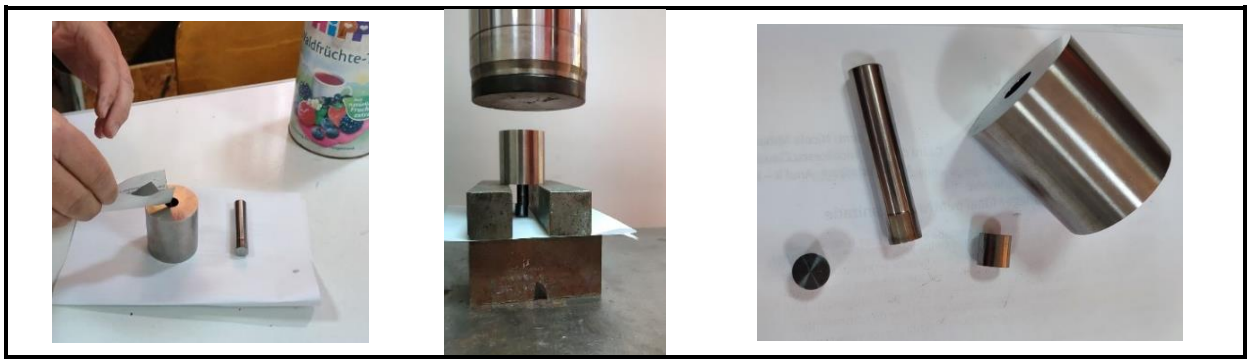

Fig. 3. Making the piece by pressing the metal powder with a 100t press

After making the piece, the following defects and potential risks were observed:

Table 1. Defects and potential risks part

Defect/risk	Cause	Avoidance by substitution with advanced powders
Low density	During pressing, the powder particles may not bond completely, resulting in a part with air voids and lower density compared to solid iron.	**HEA:**creates stronger bonding between particles during pressing, leading to a denser final part with improved mechanical properties. **Nanostructured powders:**due to their large surface area, these powders can improve the contact between particles, thus resulting in denser compaction.
Poor surface finish	The pressing process can leave a rough surface on the outer parts of the part.	**Spherical powders:**they tend to flow better during pressing, resulting in a smoother surface finish.
Fragility of the material	The iron powder itself can be brittle, especially after sintering.	HEA and other advanced alloys can improve the overall strength and ductility of the part compared to pure iron powder
Susceptibility to corrosion	Iron is prone to rust.	HEAs with elements such as chromium or aluminum can significantly improve corrosion resistance.

b) Simulated results in Ansys: deformation during laser fusion of metal powder layers

Powder coating fusion is a powerful technique for 3D printing metal parts, but as can be seen in the simulation undertaken, thermal deformation remains a significant challenge.

A simulation of a part obtained by the process of laser fusion with metal powder states of 316 stainless steel was carried out.

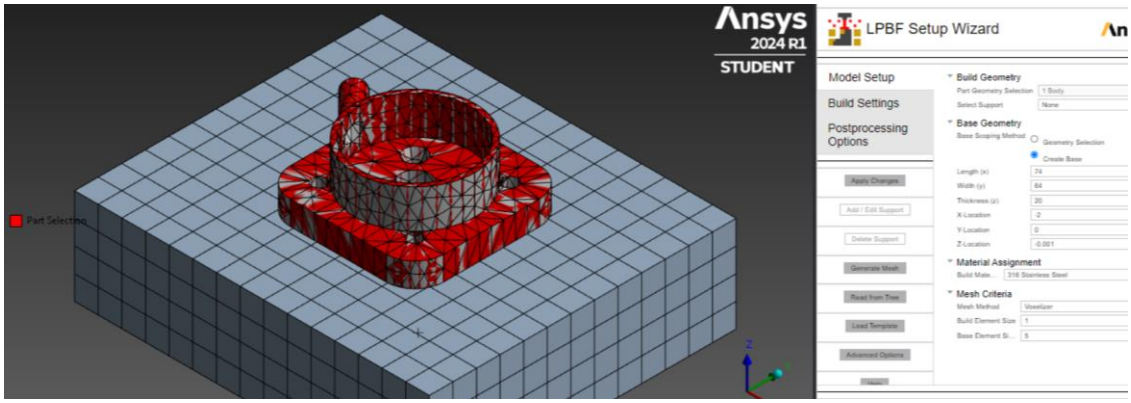

Fig. 4. Establishing initial parameters and material

The preheating force of 100°C and a single heating source was chosen.

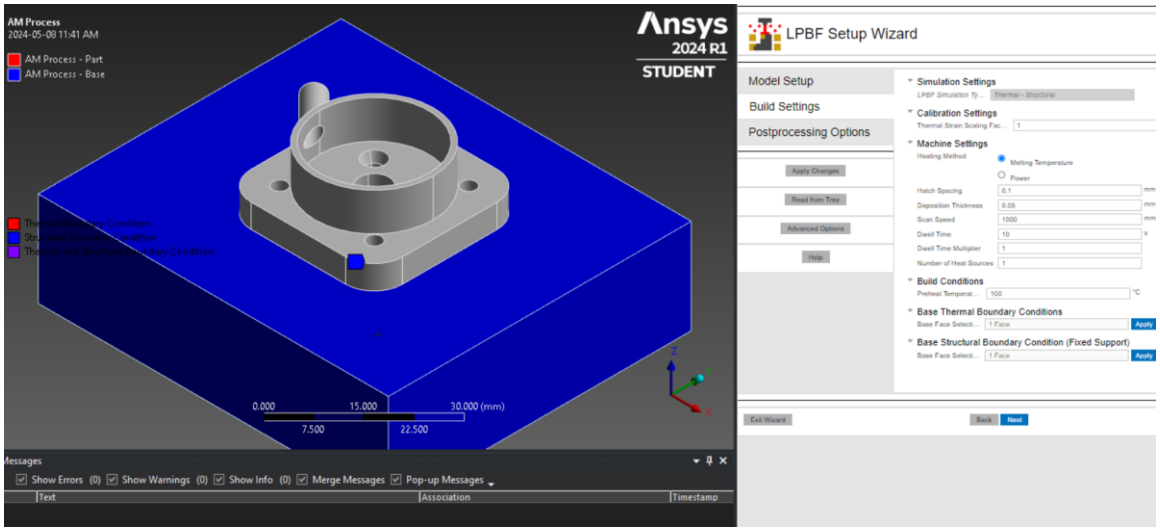

Fig. 5. Setting the heating source and preheating temperature

In an interval of 2 seconds, the variation of the maximum, minimum and average temperature was observed:

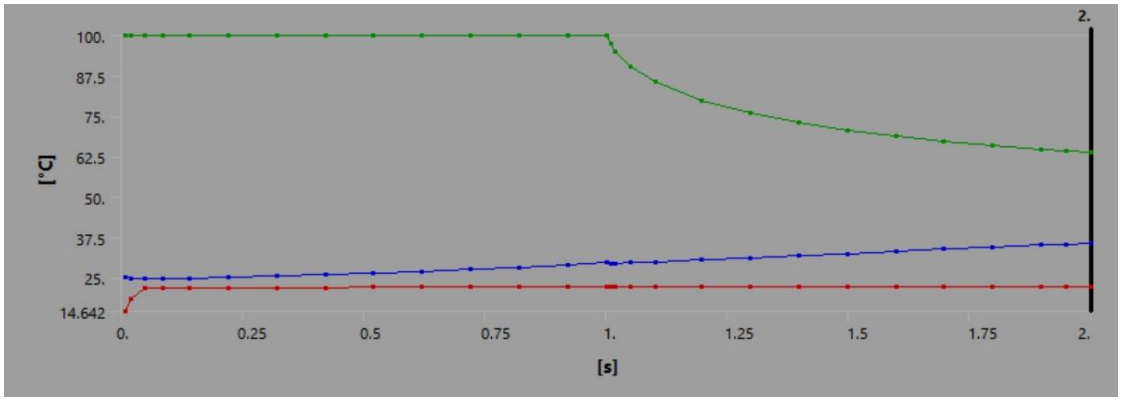

Fig. Maximum, minimum and average temperature variation

The maximum temperature remained fixed at 100°C in the first second, followed by a gradual decrease, otherwise reaching 63.66°C in the 2nd second. The minimum temperature followed a slight gradual increase reaching from 14.64°C to 22.334°C.

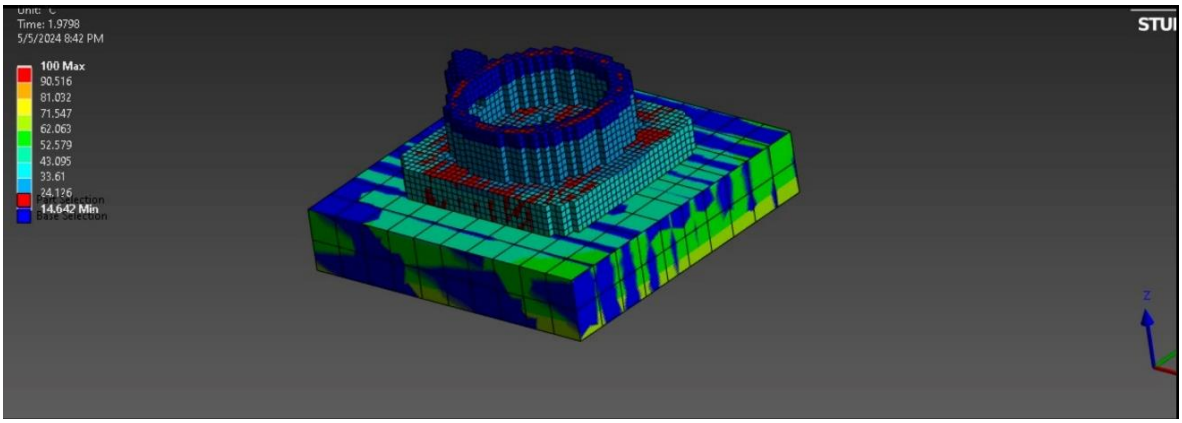

Fig. 3. Ansys simulation (water pump part)

In order to prevent the thermal deformations that can occur during such a process, current technologies can be used such as:

-Multi-beam lasers: The use of such lasers would allow for faster melting while reducing overall print time, minimizing heat exposure and reducing the risk of warping. In addition, multi-beam systems can distribute heat more evenly, thereby reducing localized overheating.

- Advanced thermal cameras monitor temperature distribution during printing, allowing adjustments to laser power, scan path and support structures.

6. Conclusions

Metal powders are widely used in various applications due to their versatility and advantages such as geometric flexibility, material economy, and customized properties. Many technologies use them, especially powder metallurgy and 3D powder printing.

To combat defects in parts (eg cracks, porosity, insufficient densification) and to prevent thermal deformation in 3D parts, recent years have brought significant innovations. Some examples include real-time thermal camera monitoring of the process, the use of advanced lasers, optimized materials and advanced support structures.

These developments contribute to the production of high-quality metal parts with increased dimensional accuracy and improved properties, further expanding the applications of metal powders in various industries.

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DETERMINING THE STRESS AND DEFORMATION STATE IN THE SEGMENTS OF A ROBOT DESIGNED FOR PALLETIZING OPERATIONS

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ABSTRACT: This paper presents the development of a four-axis educational robot, initially conceptualized as a five-axis modular system. The robot uses NEMA 17 stepper motors for cost-efficiency and precision, driven by an Arduino Mega board and controlled via a CNC Shield V3. Extensive use of 3D printing, particularly PLA and carbon fiber reinforced nylon, highlights innovative manufacturing. The robot design allows easy effector changes and incorporates robust closed kinematic chains. Detailed dynamic and static analyses using ANSYS validate the robot structural integrity for palletizing operations, confirming its readiness for industrial application. Effective power and thermal management further ensure reliable performance.

Keywords:

1. Introduction

The purpose of this analysis is to determine the necessary torque for each axis in order to achieve the robot maximum designed mass of 1 kg. For this it is necessary to determine the moments acting on the robot axes, which can be derived from a dynamic analysis of the robot. Once the moments established, it is easy to ascertain the stress and deformation states within the structure.

To achieve comprehensive results the authors decided to conduct the analysis in two phases: a static structural analysis and a dynamic system analysis. Initially, the analysis was focused on the dynamic analysis to determine the moments on all robot axes [1]. Following this, a static structural analysis was performed to identify the stress and deformation states.

The dynamic analysis provided the moments required for each axis, which were then used to perform the static analysis. This approach allowed gathering the necessary data to finalize the robotic structure and to ensure its integrity under the designed load conditions [2].

2. The development of the robot and evolution

This 4-axis robot features a closed kinematic chain system, providing enhanced load management and precision. The design includes three numerically controlled axes driven by NEMA 17 stepper motors, each offering a torque of 0.59 [Nm], and one passive axis that maintains the flange in a vertical position. The system was controlled by an Arduino Mega board, equipped with a CNC Shield V3 and three DRV8825 drivers to ensure precise motor operation.

The fourth axis was designed for quick and easy effector changes, incorporating a pinion-rack gripper mechanism controlled by a Futaba S3003 servo motor. This allows for versatile end-effector applications, making the robot adaptable to various tasks. The structure of the robot features a central shaft on the first axis, with a smaller pinion driven by the first stepper motor.

The gear ratio of 1:4 is employed for torque amplification, and a 6006ZZ bearing is used to ensure smooth movement. Positioned above the first assembly, the second axis also utilizes a smaller pinion driven by its motor, maintaining the same gear ratio for consistency. The third axis is located near the second and is integrated into the same kinematic chain, enhancing the structural integrity and coordination of movements.

Motors on the third axis are mounted end-to-end, with a half-cut pinion engaging in the kinematic chain, contributing to the robot's precise control and stability.

The fourth axis, controlled indirectly by the second axis, uses an additional kinematic chain extending from a triad on the third axis to maintain the flange's vertical position, ensuring consistent orientation during operations. The robot's components are primarily 3D printed, with most parts made from PLA to balance durability and manufacturability. Pinions, however, are printed from carbon fiber reinforced nylon, offering increased wear resistance and longevity.

To minimize friction and enhance reliability, the robot employs aluminum bearings and metal profiles on all axes. Power is supplied by a 12V 5A source, directly connected to the CNC Shield V3. This power source also drives two fans to cool the drivers, preventing overheating during prolonged use. The servo motor for the effector is powered through a step-down module that reduces the voltage from 12V to 5V, ensuring compatibility and safe operation.

The entire robot was meticulously printed using a BAMBULAB A1 printer, demonstrating the potential for integrating 3D printing technology in robotics development. This approach not only reduced production costs but also allowed for rapid prototyping and iterative design improvements. Overall, the combination of advanced motor control, robust mechanical design, and innovative use of materials makes this robot a versatile and efficient solution for handling masses up to 1 kg with high precision and reliability. Below we attached some images in the initial stage of the robot (Fig. 1), current stage (Fig. 2), and the 3D render of the robot (Fig. 3).

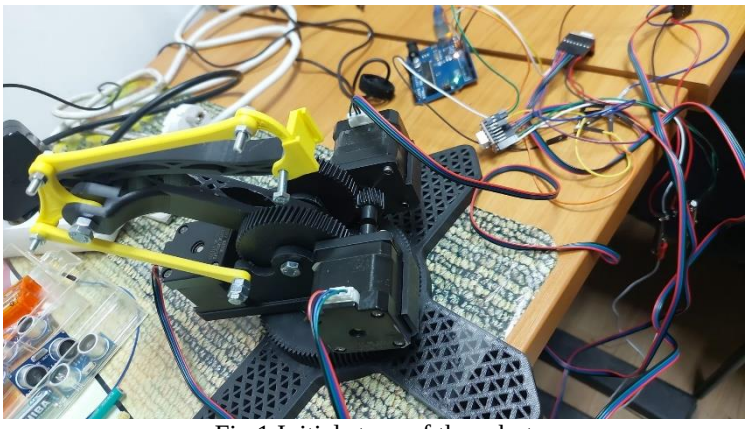

Fig.1 Initial stage of the robot

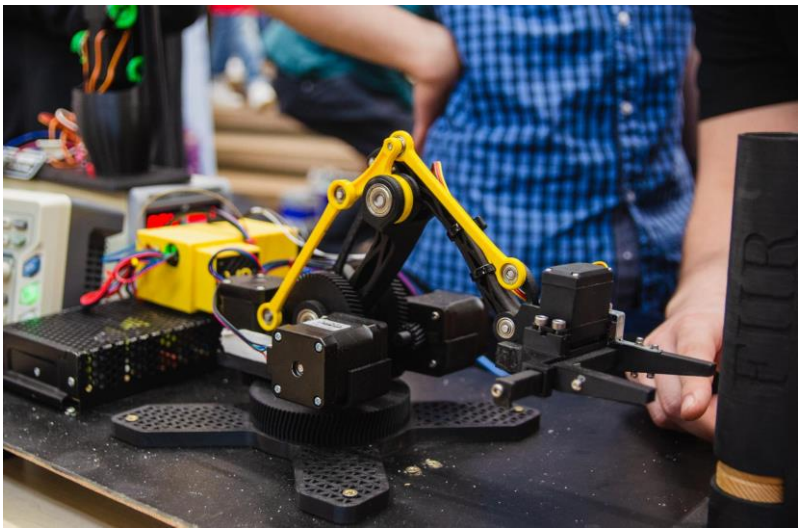

Fig. 2 The current stage of the robot

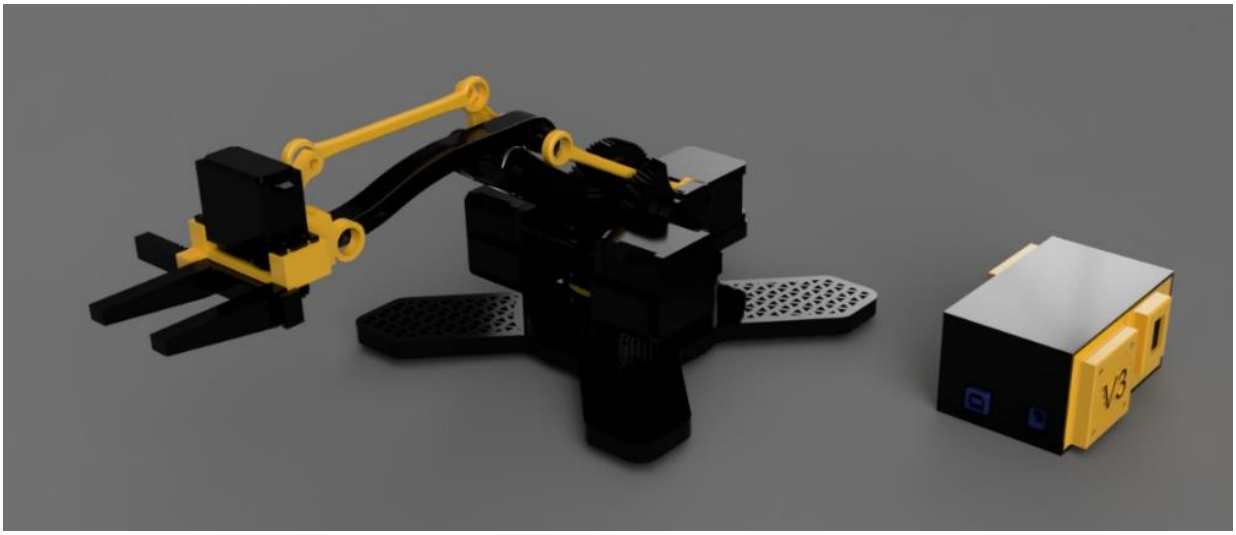

Fig. 3 Photo of the 3D model of the robot

3. Dynamic analysis of the structure

To determine the moments occurring in the kinematic pairs of the robotic structure, the Rigid Body Dynamics module is used, simulating the inertial effect on the robot's joints.

The material properties used in the simulation of the structural segments were obtained from the manufacturer's website and MatWeb [4]. 3D-printed materials are known to be challenging to simulate accurately. Therefore, the material was assumed to be isotropic, even though, in reality, the properties of structures created by the FDM process are anisotropic.

To avoid geometry conversion issues from FUSION to ANSYS, structural elements were substituted. The robot components were then correctly joined according to the interactions between its segments.

A cyclogram was developed for the simulation, with a force of 10 [N] applied at the end-effector.

As a result of the simulation, the following moments were obtained, which are relevant to the subsequent study: moments in axis 1 (fig. 4), axis 2 (fig. 5), and axis 3 (fig. 6).

Fig. 4 Moments in axis 1

Fig. 5 Moments in axis 2

Fig. 6 Moments in axis 3

The dynamic analysis of the structure is followed by a static analysis, aimed at determining the stress and deformation state in segment 1 of the articulated arm and its triad.

4. Static Analysis of Segment One and the Triad of the Robotic Structure

For the static analysis using the Finite Element Method (FEM) of segment 1, the moments from the axes of the robotic structure, determined earlier from the dynamic analysis, were used [5], [6]. Due to the complex geometry of segment 1, different settings from the usual ones in Ansys had to be applied. For the discretization of segment 1, the "uniform mesh" function was selected, and the elements used were ten-node tetrahedral elements (Tet10). The discretization of the geometry was globally controlled, with a maximum element size of 2 mm.

The imposed settings resulted in 806,219 nodes and 554,259 tetrahedral elements. Figure 5 shows the quality of the elements used in the discretization, from which it can be observed that the Ansys settings produced a favorable discretization.

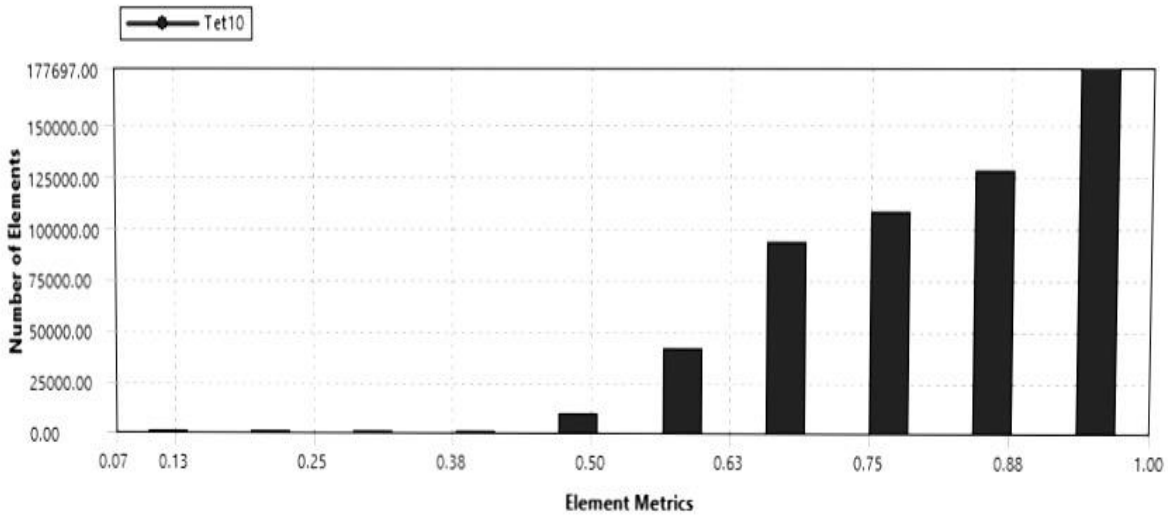

Fig. 7 Element metrics function of number of elements

Following the static analysis, the results obtained for the analyzed segments are as follows:

- **Maximum Equivalent Stress:**
  - For segment 2, the maximum equivalent stress is 7.0046 [MPa], concentrated around the corners of the cut triangles and the upper part of the bearing support of axis 3.
- **Maximum Displacement:**
  - For segment 1, the maximum displacement is 0.4358 [mm], primarily concentrated in the upper support of the bearings of axis 3.
- **Maximum Equivalent Stress:**
  - For the triad, the maximum equivalent stress is 0.319 [MPa], concentrated around the left mounting hole.
- **Maximum Displacement:**
  - For the triad, the maximum displacement is 0.0062 [mm], concentrated in the left mounting hole of the triad.

The results of these simulations indicate that the robot model is suitable for the palletizing operations for which it was designed. Additionally, the simulations provided visual representations of deformations over time and internal stresses over time.

5. Conclusion

The development and integration of this educational four-axis robot prototype demonstrate significant potential for application in industrial settings, particularly for palletizing operations. Several key aspects highlight its readiness for deployment and further optimization:

1. Scalable Design and Adaptability: The robot's design allows for easy replacement and modification of the end effector, facilitating adaptability to various tasks and applications. This modularity is critical for meeting diverse operational requirements in different industrial contexts.
2. Intuitive Control System: The implementation of a control system via a numeric keypad, emulating a Teach Pendant, provides an intuitive and efficient interface for robot operation.

This setup simplifies user interaction, enhancing usability and reducing the learning curve for operators.

3. Cost-effective and Precise Components: Utilizing NEMA 17 stepper motors over servomotors, the design achieves a balance between cost-efficiency and precision. The decision to use a closed kinematic chain system contributes to the robot's robustness, ensuring reliable performance under load conditions of up to 1 kg.
4. Robust 3D Printed Structure: The extensive use of 3D printing, specifically with PLA for most components and carbon fiber reinforced nylon for pinions, underscores the project's innovative approach to manufacturing. This choice not only reduces costs but also demonstrates the feasibility of using 3D printed materials for creating functional and durable robotic structures.
5. Dynamic and Static Analysis Validation: The detailed dynamic and static analyses, conducted using advanced simulation tools such as ANSYS, confirm the structural integrity and operational capability of the robot. The simulations indicated that the stresses and deformations within the robot's segments are within acceptable limits, ensuring that the design can withstand the operational demands of palletizing tasks.
6. Effective Cooling and Power Management: Addressing the thermal management of the stepper motor drivers with dedicated cooling fans and utilizing a step-down module to efficiently power the servo motor demonstrate attention to detail in ensuring reliable and sustained performance.

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STRUCTURAL STRENGTH STUDY OF A SOLID ROCKET MOTOR

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ABSTRACT: In this paper we planned to study the performance of several nozzle configurations, Laval and various Aerospikes, in a bipropellant solid rocket motor. To generate optimal nozzle contours, we have developed a program in FORTRAN in which we have implemented the Method of Characteristics (MOC). After generating the profiles, a series of numerical simulations will be conducted in ANSYS FLUENT to obtain the maximum thrust at different expansion ratios and to study the 2D supersonic flow in the obtained nozzle types. The physical demonstrator for the experiment will use KNSU as fuel and its instrumentation will include Schlieren imaging for the study of supersonic flow and pressure, temperature and thrust transducers. After completion of the experimental tests, the results will be compared to numerical simulations and calculations. However, our journey was marked by an unexpected setback: our first demonstrator suffered an explosion during initial tests. Despite this, we went ahead with the presentation.

KEYWORDS: KNSU, rocket motor, solid propellant, nozzle, aerospike

1. Introduction

Launch vehicles and advanced rockets require an efficient propulsion system, which must operate efficiently over a wide range of operating conditions. In addition, these nozzles must be high performance, short, lightweight and relatively easy to cool. It must also be a reusable propulsion system and must offer low-cost operations, improved reliability and short run times.

It seems difficult to fundamentally improve the performance of the bell-shaped nozzle rocket motor, as it has largely been brought to full development to date.

Because the width of bell-shaped nozzles cannot be altered to match atmospheric pressure as the rocket climbs, bell-shaped nozzles are normally designed to give optimum performance at a given altitude or pressure rating. The Aerospike eliminates this loss of performance. Because the combustion gasses are only constrained on one side by a fixed surface and on the other side by atmospheric pressure, the aerospike plume can widen with decreasing atmospheric pressure as the vehicle climbs, thus maintaining more efficient thrust throughout the vehicle's flight.

Compared to the conventional rocket engine, the aerospike nozzle engine, characterized by optimal performance at all altitudes, is a promising candidate for the propulsion device of future advanced launch vehicles.

An aerospike or plug nozzle has the unique ability to continuously compensate for ambient pressure variation as the vehicle climbs into the atmosphere. This is achieved by allowing ambient air pressure to act as the outer boundary of the diverging nozzle section and a central body to act as the inner boundary, which is usually shaped as a plug symmetrical to its axis.

Unlike conventional rocket engines, which have a bell-shaped nozzle that restricts the expanding gasses, the basic shape of the aerospike is that of an upside-down, upside-down bell. When the reconfigured bell is "unfolded" and laid flat, it is called a linear aerospike.

The linear aerospike has a series of small combustion chambers along the unfurled bell, also called a ramp, which blast hot or cold gasses along the outer surface of the ramp to produce thrust along the length of the ramp, hence the name "linear aerospike" [1-3].

In essence, the Laval nozzle comprises two distinct sections: a converging inlet followed by a diverging outlet. In the converging section, it narrows, resulting in an increase in fluid velocity while maintaining mass flow, in accordance with the principle of mass conservation. As the fluid approaches the nozzle throat, it reaches its maximum velocity, which corresponds to the speed of sound in the conditions of its environment. Subsequently, in the diverging section, the nozzle widens, allowing the fluid to transition smoothly from subsonic to supersonic flow. This expansion converts the fluid's kinetic energy into thrust, a fundamental principle underlying propulsion systems.

2. Actual state of the project and future plans

Since our project suffered an unexpected event as the first demonstrator exploded, for the next engine, we will consider oversizing the fasteners and rethinking the critical structural elements to maximize axial stresses at the expense of shear stresses. However, the new motor shown below is still based on the old one, but fitted with the central body nozzle. The new engine has to accommodate more configurations, proper instrumentation and flexibility in testing more propellants, solid and hybrid.

3. Propellant

Most solid rocket fuels produce combustion products that are a mixture of gasses and condensed phase particles (either liquid or solid), which manifest as visible smoke in the exhaust gas column. Those propellants containing metals, such as aluminum or magnesium, generate oxides of the metals as condensed-phase combustion products. Metal-particulate propellants, such as potassium nitrate (KN) or potassium perchlorate (KP), generate condensed-phase products with a particularly high molecular weight. As we have read in the literature, a higher molecular weight (M) of the products decreases the exhaust velocity and therefore the overall performance. KN-Sugar propellants produce a dense white cloud of potassium carbonate smoke and steam, about 42% of the exhaust gas mass is condensed phase matter [4].

The presence of solids or liquids in the exhaust gas leads to reduced performance for several additional reasons: this portion of the combustion mass cannot perform any expansion activity and therefore does not contribute to the acceleration of the exhaust flow, the higher effective molecular mass of these products decreases the characteristic velocity (c-star). Due to thermal inertia, the heat of the condensed phase is partially expelled out of the nozzle before transferring this heat to the surrounding gasses and is therefore not converted into kinetic energy. This is known as particle thermal retardation.

Also, because of the relatively large mass of particles (compared to gasses), they cannot accelerate as fast as the surrounding gasses, especially in that portion of the nozzle where the flow acceleration is extremely high (the throating region). Particle acceleration depends on the frictional resistance of the gas flow, which requires a differential velocity between particles and gas. The net result is that particles in the condensed phase exit the nozzle at a lower velocity than the gas. This is called the particle velocity gap.

There are a number of factors that determine how significant two-phase flow losses are on the performance of a rocket engine. One important practical factor is the nozzle contour, especially in the critical area. A more gradual acceleration of fluid flow in the vicinity of the nozzle results in a reduction of thrust losses [4].

In the following two-phase flow and how it affects the performance of various parameters related to rocket motor design, zero particle retardation will be assumed.

In other words, the particles are assumed to have the same temperature and velocity as the surrounding gasses while the reaction products flow through the nozzle. This assumption is intended to greatly simplify the two-phase problem in a practical way for rocket engine design. In reality, this is largely true for micron-sized exhaust particles [4]. This is typical for sugar propellants, which produce very fine smoke.

Fig.1. Our propellant grain

Propellant grain (see figure 1) refers to the solid material inside a rocket engine or other propulsion device that is subjected to combustion to generate thrust. It is essentially the fuel component of solid rocket motors. The design and configuration of the grain significantly influence the performance, efficiency and safety of the propulsion system. For our configuration, we opted for a hollow cylindrical grain shape.

The fuel chosen is a mixture of 95-97% agricultural purity potassium nitrate and sugar, with an oxidant/fuel ratio of 65/35.

$C_{12}H_{22}O_{11} + 6.29KNO_3 \rightarrow 3.80CO_2 + 5.21CO + 7.79H_2O + 3.07H_2 + 3.14N_2 + 3.00K_2CO_3 + 0.27KOH$

The mole fractions and mass fractions for each significant combustion product are calculated, using mathematical formulas entered into an Excel spreadsheet, keeping the assumption of stoichiometric combustion.

It should be noted that, since from the nature of the reaction products a rather dense smoke is obtained, it is necessary to consider both the mass of the gasses and of the particles condensed in that steam, according to the two-phase flow hypothesis [4].

The calculated ideal temperature value is 1743K. Then the pressure and temperature values were entered into the ProPEP3 software (see figure 2) to obtain the calculated fuel performance. The calculated thrust is 1400N maximum with a burn time of 1.4 seconds.

IMPULSE	IS EX	T°	P°	C°	ISP°	OPT-EX	D-ISP	A°M	EX-T
142.2	1.1833	1007	62.76	2704.3		13.31	244.4	0.05174	530
149.2	1.0972	1066	64.69	2842.1	106.7	15.36	256.3	0.05437	735

Fig.2. Propellant performance, results obtained from ProPEP3 software

4. Design

Since the project suddenly went into a state of rest following an unexpected incident, we have not yet been able to manufacture the metal aerospike composite nozzle, waiting to build a new version of the engine before anything else.

Designing and fabricating the structural components of the engine, and assembling it is a complex task, which is divided into several stages:

The traditional construction of an engine of this type is initially based on an initial useful thrust value chosen for other considerations, after which formulas are used to arrive at pressure and temperature values that dictate the engine structure [6]. In our case the approach was a little different, since we already had values from [4] obtained both experimentally and from mathematical formulas. We therefore started from 1000 grams, for which the table provided us with the propellant grain dimensions, imposing the dimensional constraints [7] after which the components were subsequently designed.

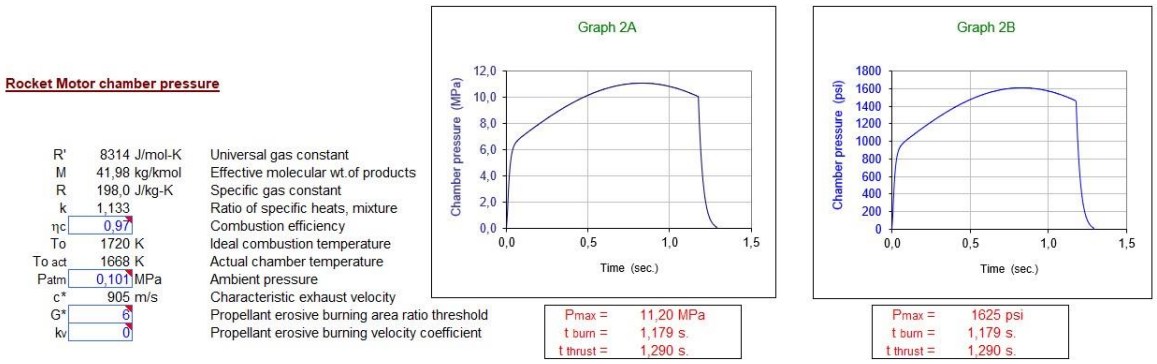


Fig.3. Ideal pressure

Design and Burst Pressures for Rocket Motor Casing

[Input data in blue text, English or (SI) units]

Casing Dimensions and Design Factors

Do =	2,165	in. (mm)	Diameter, outside
t =	0,0984	in. (mm)	wall thickness
S_D =	1,8		Design Safety factor

Material Properties

Fty =	35	ksi (MPa)	Yield Strength
Ftu =	42	ksi (MPa)	Ultimate Strength
E =	9,9	Msi (MPa)	Modulus of Elasticity
ν =	0,33		Poisson Ratio
β =	0,833		Fty/Ftu
B =	1,334		Burst factor

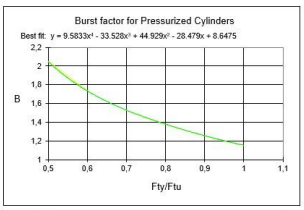
Design and Burst Pressures

P_D =	1768	psi (kPa)	**Design pressure**
P_U =	4246	psi (kPa)	**Burst pressure**
S_U =	2,40		**Burst Safety Factor**

Elastic Deformation under Pressure *

ΔD =	0,00355	in. (m.)	**Change in casing diameter, at P_D**
Δc =	0,01115	in. (m.)	**Change in casing circumference, at P_D**

Notes:
* Non-permanent deformation. For comparison purpose, a sheet of standard grade writing paper is about 0.004 in. (0.10 mm) thick.
ksi = psi (lb/in^2) x 1000
Msi = psi (lb/in^2) x 10^6
MPa = Pascal (N/m^2) x 10^6



Plotting data:

β	B
0,5	2,048
0,6	1,735
0,7	1,527
0,8	1,379
0,9	1,254
1	1,153

Fitted Polynomial coefficients

A	9,5833
B	-33,528
C	44,929
D	-28,479
E	8,6475

Fig.4. Safety factor

The engine was thus made of 3 components: body, cover and nozzle. The body was designed to withstand the specified pressure (see figure 3) after a safety factor of 1.8 according to [4] (see figure 4). The body was made from 6063-T6 aluminum, its length was 350mm, outer diameter 60 mm, with 2.5mm wall thickness, with a step of 1.25mm at the transition to the mounting regions, so that the thickness there was halved. (see figure 5 and 6).

The CAD obtained in CATiA was imported into Ansys, where a structured mesh was created and the engine was tested at boundary conditions: maximum pressure obtained from calculations applied to the internal walls of the engine. The results were satisfactory.

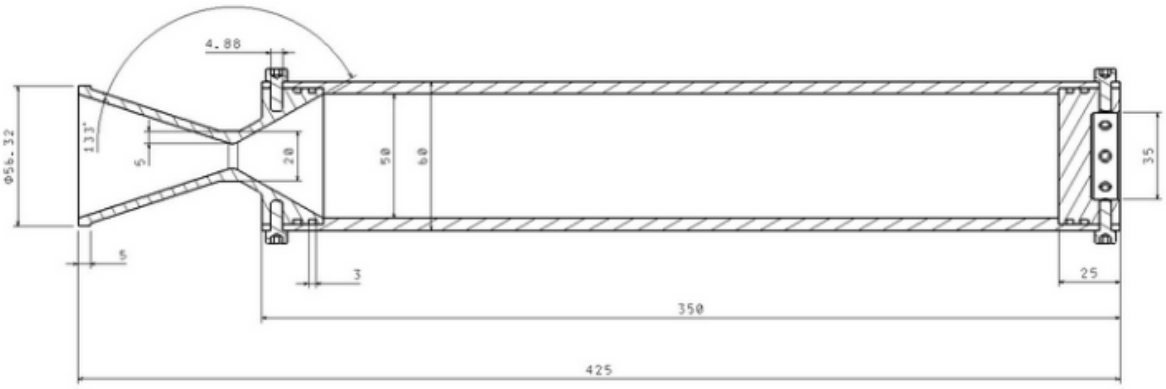


Fig.5. Technical drawing of the engine

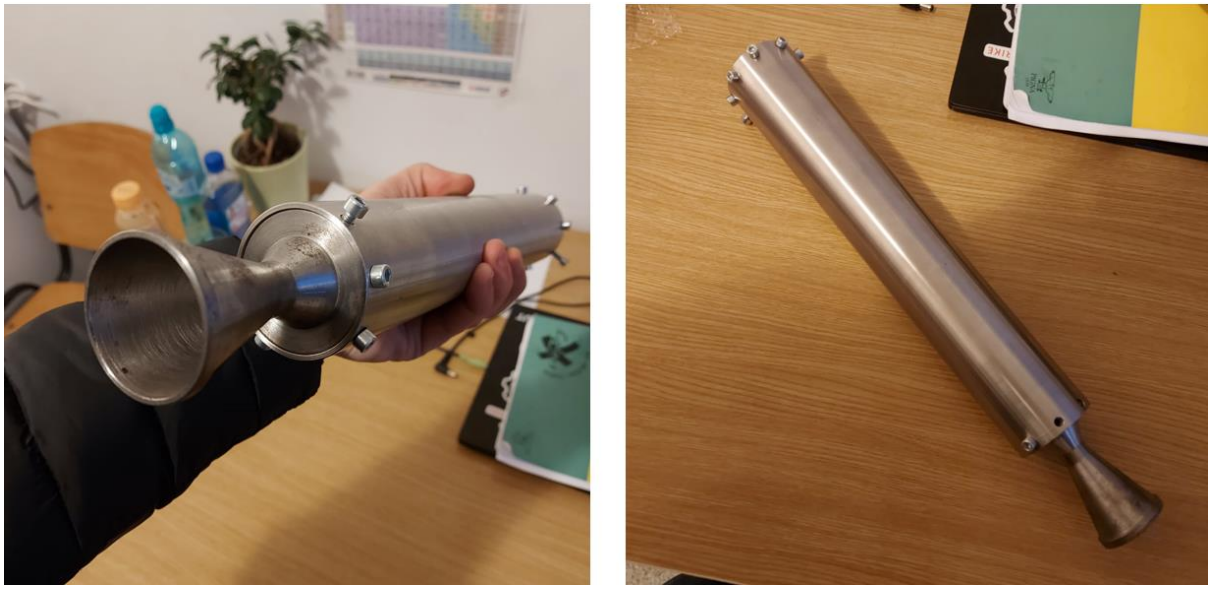


Fig. 6. The rocket engine

5. Experimental part

After the fuel was successfully poured into the engine enclosure, it solidified. Because the internal walls of the engine have a large roughness, the fuel cartridge adhered to them and could not be removed, therefore making the necessary modifications to the test bench mounting impractical. We therefore decided to carry out an 'unofficial' test to remove the fuel trapped inside the engine in order to prepare it for the appropriate instrumentation.

The engine was mounted in an upright position and ignition was done with an electric match. Figure 7 shows the evolution of combustion during firing, as well as the flow accelerated by increasing pressure in the combustion chamber.

Fig.7. Combustion evolution

6. Results and conclusion

During combustion, the fuel deposited potassium carbonate and potassium hydroxide along with other solid compounds resulting from impurities in the reactants. These led to a narrowing of the critical section of the nozzle, and thus increasing the pressure and temperature in the combustion chamber. The phenomenon is known in the speciality literature as “nozzle clogging”. The surface on the inner walls of the nozzle was “scratched”, mixing metallic particles in the exhaust flow. The mobilized particles will tend to cause the pressure drop along the length of the divergence to be less steeper than predicted by the calculations, messing up exhaust integration in surrounding airflow.

The increased pressure within the casing became greater than the one the motor was designed for, and before the casing gave out, the screws of the cap did so. Scorched by the hot gasses that started seeping over the o'rings, right over the section in which they were strained the most by shearing, the M5 screws finally failed, the motor exploded and went flying nozzle-end first for about 100 meters, before falling on the ground and receiving a visible indent

Fig. 8. The engine after the test

Nozzle scorification is the tendency of the condensed phase (especially liquid matter) to scratch the nozzle near the critical section, contributing to geometrical irregularities, which tend to produce imbalances between pressure zones. The clogging was in our case more significant than the loss of material, leading to uncontrollable pressure build-up to failure.

Fig. 9. The engine top end (left) and the nozzle (right).

7. Aerospike nozzle design

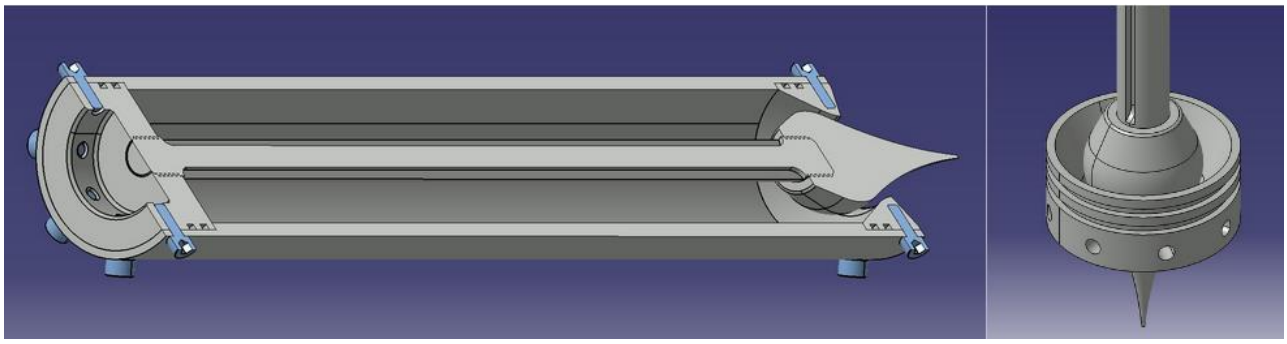


Fig. 10. Aerospike nozzle design

In figure 9 the threaded nozzle attachment can be seen, the ridge in the middle of the metal rod on the left side of the picture is to facilitate ignition.

The optimal contour of the aerospike [8] was obtained based on the creation of a program [9] in FORTRAN, using the Method of Characteristics [10, 11] and the study of fluid dynamics [12], in particular the Prandtl-Meyer expansion [13].

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NUMERICAL AND EXPERIMENTAL ANALYSIS OF STEEL PLATE MODAL STATES

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ABSTRACT: Both during the production of metal plates and the operation of different assemblies that include them, the vibrations to which they are exposed risk affecting the proper functioning of the machine. The thin plates that are used in the industry can have thicknesses of only a couple of millimeters. Their vibration in the system can lead to significant noise, high displacements and even failure through disassembly, which are prone to appear at certain frequencies, most often at resonance frequencies.

This study highlights the different modal states of a steel plate subjected to free vibrations, with the use of experimental methods and Finite Element Analysis simulations. The two techniques allowed us to observe the shapes that the plate vibrated in resonance, called Chladni Patterns and the frequencies at which they appear. Such information is critical when designing simple or complex parts which are to be subjected to vibrations.

KEYWORDS: Modal States, Vibrations, FEM, Chladni Patterns

1. Introduction

This research is part of a field of interest related to the behavior to vibrations of mechanical structures.

The information contained in vibration signals at certain frequencies can be used for the evaluation and early detection of defects in mechanical structures. A defect in a structure represents a change or deviation in the properties of the material or its geometry, which alters the normal behavior through vibration. These vibrations produce displacements and stresses that change certain mechanical and dynamic characteristics, thus leading to visible deformations.

While the experiment is critical in observing the phenomenon, numerical simulations have developed in parallel as powerful tools in creating virtual models to be subjected to the working conditions, in more economical manners. In this case, a modal analysis of a plate, which is also experimentally validated, allows an in-depth look at the phenomenon, complementary to experimental observations.

An efficient way of assessing resonance frequencies of a plate is by using Chladni's technique. Ernst Chladni was a German physicist known for his experiments on vibrations and acoustics. He demonstrated visualization of the vibration modes of rigid plates by a simple experiment in which he sprinkled sand on a thin metal plate and then excited the plate at the edge with a violin bow. This caused the plate to vibrate, and the sand collected at the points where the plate remained stationary (knots), forming distinct patterns called Chladni figures. These models allowed a better understanding of resonance phenomena and the distribution of knots and bells in vibrating structures.

2. Experiment

The equipment used in this experiment consists of a circular steel plate attached in the middle with a bolt to a shaker (Fig. 1), which produces vibrations at a set frequency set by a signal generator (Fig. 2). The plate is 400 mm in diameter and 1 mm thick. It has a central hole of 6 mm, which allowed mounting on the shaker's pole.

Fig. 2 Shaker with circular plate, resonating at 181 Hz

Fig. 2 Signal generator

In this experiment we tested different frequencies, from 1 to 250 Hz, to search for those at which of Chladni's Patterns would emerge, signaling a resonance frequency (Fig.1 & Fig. 3).

This study helps in discovering the points where certain components can undergo changes or even enter into resonance at certain frequencies, which can cause high deformations, leading to high stresses, high levels of noise and even failure. In day-to-day life structures, vibrations intervene in the working conditions of bridges, or machines with repetitive moving parts, out of which the most pronounced is the washing machine. They are, thus, required to be known and avoided in working conditions.

In this experiment we observed the deformation of the plate by pouring fine particles on it at certain frequencies that resulted in the appearance of Chladni's Models so that we can experimentally discover the frequencies at which the resonance points appear and the way the plate is deformed.

Fig. 3 Chladni pattern of a resonating plate, at 401 Hz

3. Modal Analysis using the Finite Element Method

In order to determine the modal states in which the steel plate can be in, a numerical simulation was also designed, using Ansys FEM Modal Analysis.

Firstly, by using Ansys SpaceClaim, we have created a surface with the dimensions of the plate, to which we have attributed a thickness of 1 mm (Fig. 4). We have opted for a surface instead of a solid body to reduce the complexity of the model. The simulations were carried out using linear elastic Structural Steel as the material for the plate.

As for the mesh, in order to control it, Face Meshing and Edge Sizing criteria were applied, resulting in a mesh with around 3000 Quad elements (Fig. 4). An analysis of the mesh's influence revealed that there is no loss of quality in the results of the simulation when the number of elements was reduced down to 1500, but the mesh became inaccurate when trying to simulate with an even lower number of elements (Fig. 7 & Fig. 8). It was, thus, opted to remain at 3000 elements, as the model proved simple

enough. It is worth noting, however, that this mesh is appropriate for the bandwidth chosen for the present work and, if vibration modes are to be searched for higher frequencies, a more refined mesh would be required, due to the increased complexity of the displacement field. For the Boundary Conditions, we have only used a fixed constraint applied to the edge of the center hole (Fig. 6).

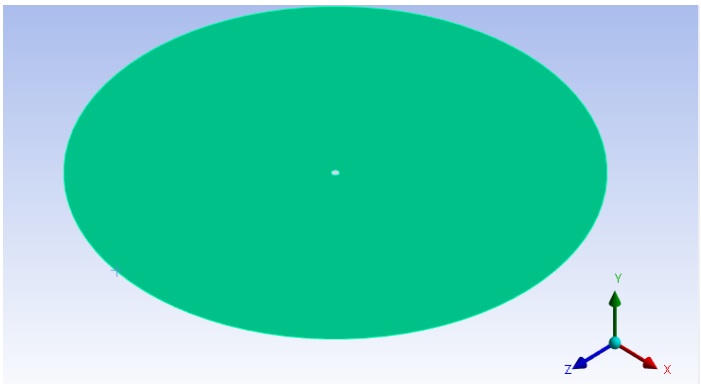

Fig. 4 Steel plate surface modeled in Ansys SpaceClaim

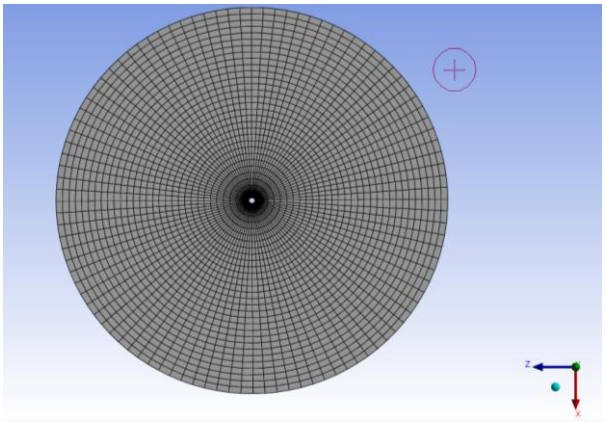

Fig. 5 Mesh of the Steel Plate with 3000 elements

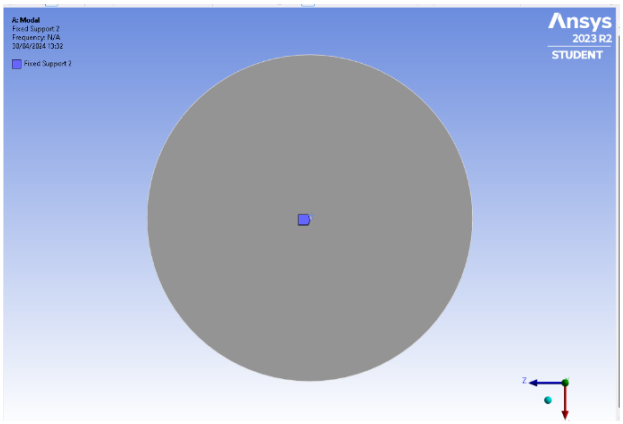

Fig. 6 Boundary conditions of the Steel Plate

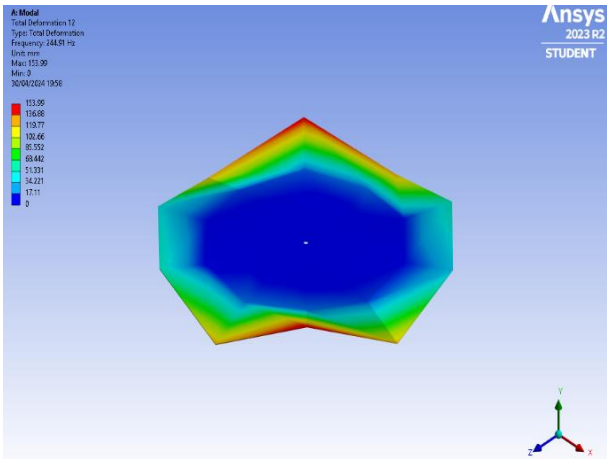

Fig. 7 Simulation with a 300 elements mesh

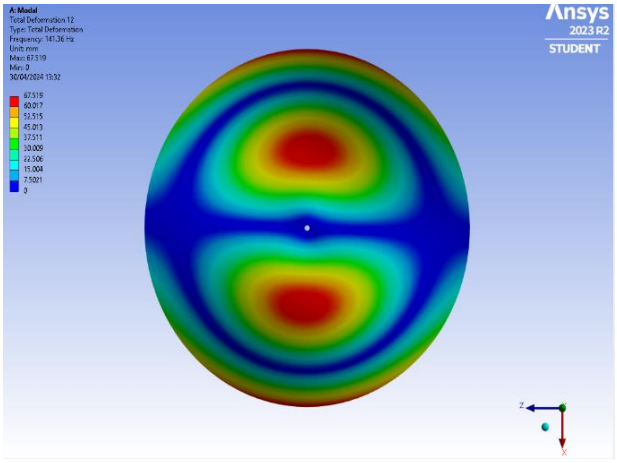

Fig. 8 Simulation Made with 3000 element mesh

4. Results and discussion

With the help of Finite Element Analysis we have determined the resonance modes up to 250 Hz, thus enabling us to compare them to the experimental results. The resonance frequencies obtained using Chladni's technique and the numerical simulation are presented in Table 1. We have discovered that the maximum error between the two methods is under 10%, the discrepancies arising from experimental imperfections. Some of the sources of errors are:

- the thickness of the steel plate has slight variation from the nominal 1mm value;
- the imperfect fluidity of the grains of semolina which, if clumped, would add a local mass to the plate, altering the boundary conditions.

It is also worth noting that the computer simulation generated modal states that we were not able to replicate in the real world, either due to values being close to other resonance frequencies or because the resonance amplitude was insufficient to produce clear Chladni forms. Thus, Table 1 contains only the modal frequencies that have been recorded by both the simulation and the experiment.

Table 1 Modal frequencies for the experimental and numerical analysis

Experiment (Hz)	Simulation (Hz)	Error (%)
13	13	0
34	32	5.88
73	75	2.73
137	133	2.91
150	141	6
208	205	1.44
234	215	8.11

From the comparison of the experiment with the simulation we concluded that they produce similar results, with the numerical simulation revealing more information in terms of displacement and stress state.

5. Conclusions

There are several factors that can influence the distribution of deformations in thin steel plates, including the orientation of the structure, the size and shape of the plate, how the vibration energy is applied, and the type of microstructure of the material. Analysis and simulation are essential methods to understanding the vibration modes of these plates, which are critical for the working conditions of machines with repetitive motion that causes vibrations. This study can be extended to include other types of thin plates and to analyze the vibration modes of structures of various materials and under different working conditions. In conclusion, the experimental and numerical analysis of plates subjected to vibration stresses is an important and complex subject, with multiple possibilities for further research and development.

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COMPRESSOR BLADE VIBRATION ANALYSIS

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ABSTRACT: The aim of this paper is the analysis of blade vibration, the object of study being a compressor blade from a MIG-21's engine, R11-F-300. To outline the context of this study, as well as its utility, a number of theoretical concepts are introduced, followed by an overview of the experiment and finite element analysis. Based on the experiment, the natural frequency of the blade has been determined, the results being compared to the ones obtained through numerical simulations. After all, a set of conclusions and observations were drawn.

KEYWORDS: vibrations, frequencies, resonance, rotor blade

1. Introduction

Vibrations are a common problem in turbomachinery that can be highly destructive and must be monitored and analyzed carefully. These are inevitable during engine operation, and several factors influence their occurrence and destructive nature, including engine type, speed, operating conditions, design solutions, and gas dynamic factors. As the rotational speed and compression ratio increase, the stresses generated by vibrations become more complex. Consequently, two main issues arise: fatigue failure due to frequent stress caused by vibrations or blade destruction during resonance, when the excitation frequency matches the natural frequency of the blade. Natural frequencies are the inherent vibration frequencies of a system, such as a solid body or structure. Understanding these frequencies is crucial for dynamic behavior analysis and structural design. (1) (2)

To avoid such critical situations, vibration studies require special attention, being a relevant and constantly topical subject in the aerospace field, with significant implications in engine design and blade calculations. Thanks to technological and mathematical advancements, simulations and models can be generated using numerical modeling and finite difference methods. This allows us to analyze the effects of vibrations on blades, how they influence fatigue failure, blade reliability, and methods to reduce the occurrence of vibrations. (2)

Given the above, the proposed objective is to analyze vibrations through a concrete experiment on a compressor blade. The obtained results will be compared with those from numerical simulations, and observations will be made regarding the differences between the two.

2. Current state

The subject being the rotor blade, some theoretical concepts related to the component it belongs to, namely the compressor, are necessary. The role of the compressor is to compress the fluid statically before combustion, providing a continuous flow to the combustion chamber. The axial compressor is characterized by the axial flow of the fluid, having two main components: rotor and stator. The construction of the compressor involves a shaft, disk, drums, and rotor blades, as well as bearings, supports, and bearings for strength and vibration reduction. (3)

The rotor blade can be considered a cantilever beam. It is subject to high rotational speeds, high pressures, and vibrations. As a result of repeated vibrations, fatigue occurs, leading over time to the appearance of cracks and subsequently the rupture of the blade. Cracks can appear at the root section, towards the tip, on the upper surface of the profile, in the middle of the blade, or at the blade foot. Moreover, in the case of resonance, the blade is destroyed. Therefore, being under such stress conditions, it creates a need to closely investigate and analyze vibrations to prevent the occurrence of fatigue and resonance.

Further on, the latter will be presented, as it is the most important and most dangerous event that can take place. (1) (2)

Resonance happens when the excitation frequency equals the natural frequency of the blade. Among the causes of excitation forces are variations (non-uniformities) in velocity fields, pressures, temperatures, the arrangement of elements such as mounts, bearings downstream or upstream of the turbine array, and separation of the flow from the blade (resulting in surging, a moment when gas flow periodically varies). Besides these aerodynamic causes, other sources of excitation arise, such as unbalanced rotors and the occurrence of deformations. (1)

In the study of vibrations, the ones that raise increased interest are bending, torsion and bending-torsion vibrations. In general, vibrations within the engine's operating speed range are considered, specifically the first two or three bending vibration modes and first two torsion vibration modes. Beyond these modes, the amplitudes and stresses decrease significantly, potentially becoming negligible. (1)

In this study, the vibrations of an axial compressor blade of the R11-F-300 engine, which equips the MIG-21 aircraft, were analyzed both through experiment and finite element method. The experimental setup involved measuring the blade's natural frequencies and modes using appropriate instrumentation and techniques. It is important to mention that the blade is made out of stainless steel, with the Young module E being 250 GPa and the density of 7850 kg/m^3.

For the experiment, the blade was fixed between two metal pieces that were welded together to be clamped in a chuck, in an attempt to create a system as rigid as possible. An accelerometer with a mass of 8.7 g was mounted at the tip of the blade to record the data resulting from striking the blade with a hammer. To minimize external deformations, the hammer was fitted with rubber at its end. Initially, a metal tip was used, but an increase in result ambiguity was observed. The recorded data was collected on a laptop, the hammer and accelerometer being connected to it with cables, and transformed from the discrete domain to the frequency domain. The PULSE software was used for data processing and frequency determination.

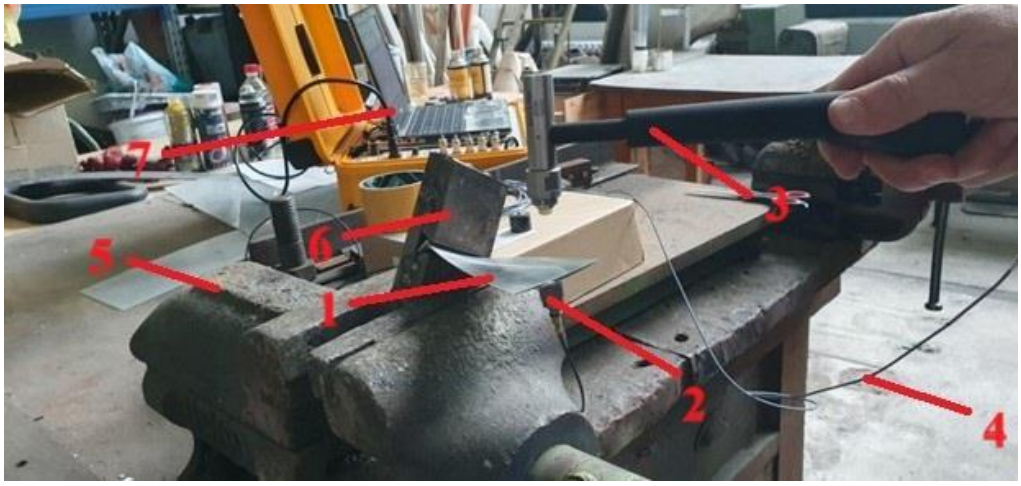

Fig. 1. The components of the experimental setup (1 – compressor blade; 2 – accelerometer; 3 – hammer; 4 – cables; 5 – chuck; 6 – clamping system; 7 – laptop)

In Fig. 1 the clamping system of the blade can be observed, along with the component elements of the experimental setup. The accelerometer is element 2 in the figure above. It was attached with double-sided tape to minimize errors, as it was noticed after several attempts that errors were amplified when mounting the accelerometer with a magnet. These errors were induced because the contact surface with the magnet was not completely flat, preventing the magnet from adhering fully to the complex surface of the blade. As a result, the accelerometer itself acquired a vibrational motion following the applied shocks, introducing uncertainties in the results. Additionally, the image also shows the hammer, initially used with a metal end and later with rubber. Since a considerable difference in the quality of the obtained graphs was noticed, the results obtained using the rubber end were retained. Also in Fig. , the system that collects data

from the hammer and accelerometer can be found. This is represented by the yellow box, where the laptop is located, with the data reaching it through the cables.

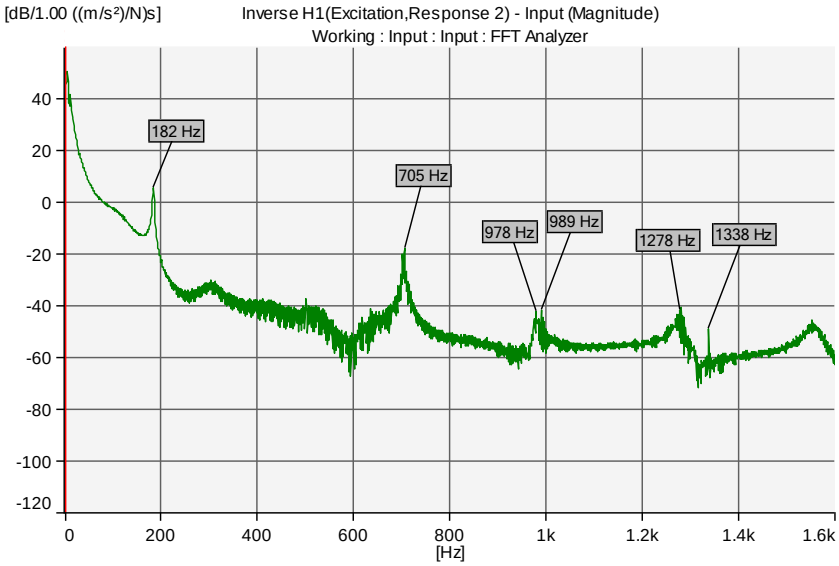

Fig. 2. Results Graph

Following the experiment, the graph in Fig. 2 was obtained. It is worth noting that in each trial, the frequency that consistently appeared first was 182 Hz, indicating that this should be the natural frequency of the blade for the first mode. Other peaks recorded, visible in the graph, are at 705 Hz, 989 Hz, and 1278 Hz, values close to the frequencies of the modes resulting from the simulation, but with considerable errors.

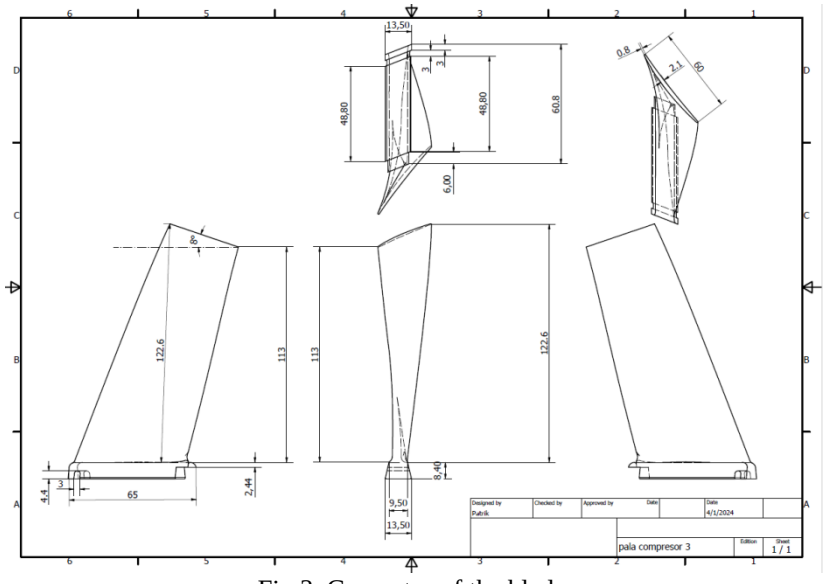

Fig.3. Geometry of the blade

The experimental results were then compared with those obtained from numerical simulations. Numerical analysis using finite element methods helped validating the experimental findings and provided insights into the distribution of vibration across the blade. This analysis is vital for identifying areas prone to fatigue and for improving blade design to minimize harmful vibrations. For this method, the program used was Ansys, in which the geometry from Fig. 3 was imported, the result of this process being shown

in Fig. 4. The material chosen for the simulation of the blade is stainless steel, with Young's module being 193 GPa and the density, 7750 kg/m^3.

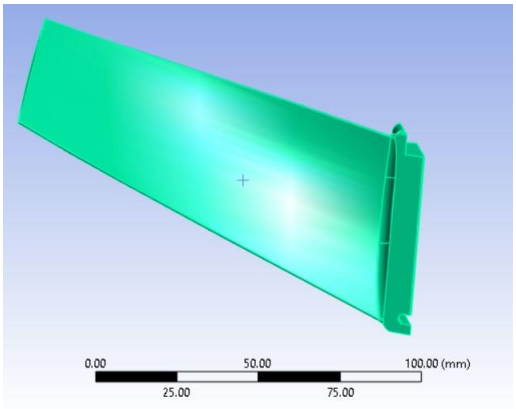

Fig. 4. Ansys Geometry

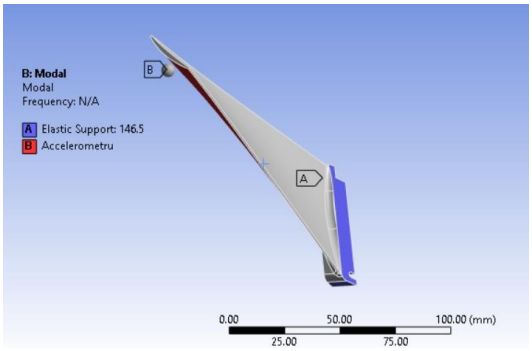

Fig. 5. Model containing the loads and constraints

Taking into account the rest of the system's components, in Fig. 5 the model containing the loads and constraints is depicted, specifically the accelerometer and the clamping system, for which it was observed that it was not perfectly rigid. The material used for the accelerometer is structural steel S275N, with a Young's modulus of 210 GPa and a density of 7850 kg/m^3. The next step of the analysis was the mesh, which involves dividing the blade into a series of finite elements connected to each other. The number of elements used is 6009, and the number of nodes is 12108.

Table 1. Frequency modes

Mod	Frecventa [Hz]
1	182.02
2	618.73
3	1060.6
4	1438.8
5	2308.5
6	2454.9
7	3328.1
8	3715.6
9	4504.5
10	5302.6

To determine the vibration modes, a limit of 10 modes was set. These correspond to the characteristic modes of motion of the system and are associated with natural frequencies. The simulation resulted in modes with the corresponding frequencies as shown in Table 1.

Comparing the results obtained through the two methods (experimental and numerical simulation), it is observed that apart from mode 1, whose value obtained through numerical simulation is almost faithful to the experimental one, the other modes experience considerable errors that increase as they move away from the first mode.

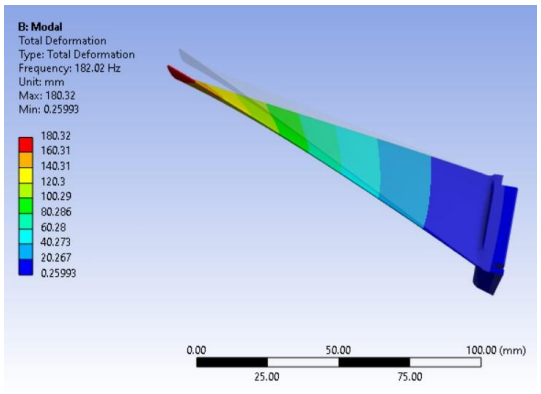

Fig. 6. Mode 1

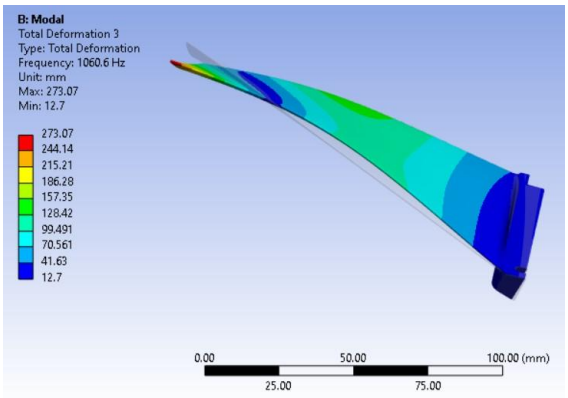

Fig. 7. Mode 3

In the figures above, some of the modes whose frequencies are noted in Table 1 are depicted. In Fig. 6 and Fig. 7, modes 1 and 3 can be observed. It is noted that the point where the recorded frequency is maximum is located at the tip of the blade.

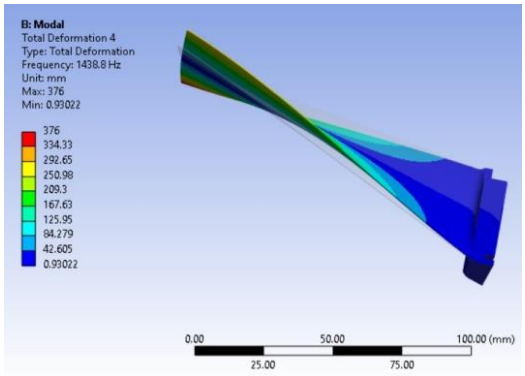

Fig. 8. Mode 4

Starting with mode 4 (Fig. 8), visible deformations start to appear, and the distribution of values on the blade also changes, with values beginning to increase at the lateral extremities. In Fig. 9 and Fig. 10, the last modes resulting from the simulation can be found, namely 9 and 10.

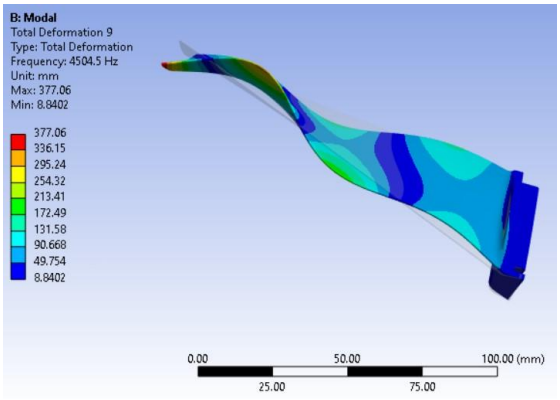

Fig. 9. Mode 9

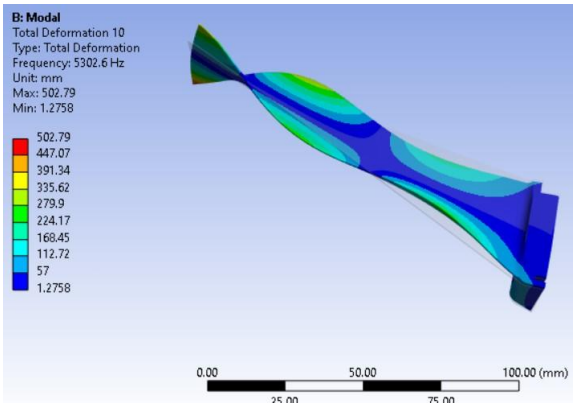

Fig. 10. Mode 10

3. Conclusions

Considering the small dimensions of the structure, obtaining frequencies is challenging. Errors occurred in the study due to the clamping system not being perfectly rigid, leading to deformations and consequently uncertainties in the results.

Drawing a parallel between the theoretical elements presented and the simulation results, it is clear that the areas most prone to cracking, where the loading is highest, are the tip, the trailing edge and leading edge, especially in the second half of the blade.

As a result of the obtained results, the study needs to be continued and improved by refining the testing system (frequency evaluation) and modifying the mathematical model to obtain values as close as possible to the experimental ones.

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FATIGUE ANALYSIS OF A TOTAL HIP REPLACEMENT

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ABSTRACT: The scientific work is based on the isolated case of a hip prosthesis that failed inside a patient. The prosthesis was analyzed, measured, modelled, and then tested using the Finite Element Method, with the aim of discovering the causes that led to the failure.

KEYWORDS: prosthesis , fatigue, MEF

1. Introduction

The total hip prosthesis is a medical device which is implanted in the femoral bone to replace a damaged or worn hip joint. There are various types of such implants, that differ from each other in terms of design, materials, or method of fixation in the bone. However, in general, a total hip prosthesis consists of the following components: femoral head, femoral component, acetabular component, and liner (Fig. 1). In terms of the materials used, the acetabular component, femoral component and femoral head are made of a cobalt-chromium alloy, and the liner can be made of ceramic or polyethylene.

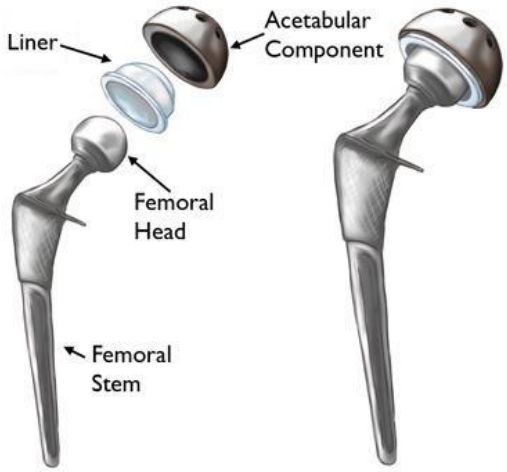

Fig. 1 Total hip prosthesis and its components

The scientific work presented within this paper is a case study focusing on a prosthesis from the Bucharest University Emergency Hospital that failed during exploitation after 5 years of use by a male patient. The macroscopic investigation of fracture surfaces led to the conclusion that the failure occurred due to fatigue. Because in the clinics there were not reported similar failures for the same type of prosthesis, it was assumed that there should be a peculiar cause that led to fatigue. In this respect, the aim of the study was to perform a finite element fatigue analysis of this hip prosthesis, to identify the cause of its fatigue failure.
To achieve the objective, several steps were taken: identification of the prosthesis type and clinical history, CAD reconstruction of the prosthesis geometry, identification of a bone size corresponding to the prosthesis geometry, realization of the bone-implant assembly, determination of the loading cases, development of the finite element model, analysis of the results and conclusions.

2. State of the art

Nowadays, the hip replacement is recognized as an essential method for restoring mobility to adults. Although not directly linked to improved survival, the more than one million hip replacements implanted worldwide each year significantly improve the lives of people with severe mobility problems [1]. Different failure modes are encountered such as aseptic loosening, joint infection, dislocation of the femoral head by slipping from the acetabular cup, wear, or implant fatigue fracture. The last failure mode is rarely encounter, as the design methods and the materials were improved. However, in some cases, due to peculiar aspects of the surgical procedure which might influence the load induced to prosthesis components, or due to microstructural defects, fatigue failure can be encountered, as it is the case of this study.
The finite element method (FEM) was successfully used for assessing the fatigue strength of total hip prosthesis [2], [3]. It is a powerful tool which can give insights regarding aspects of the mechanical behavior of bone-implant assemblies.

3. Identification of prothesis type and clinical history

After examining the prosthesis on which the study is based, it was found to be a Kent revision stem made of a cobalt-chromium alloy. In this model, fixation is by screws only, and the stem of the prosthesis is not in contact with the bone.
Also, according to clinical outcomes, the main disadvantages of this total hip replacement model are that the screws fracture and the smooth, flat surface which does not allow it to integrate with the bone. At the same time, it is straight and does not adapt to the physiological curves of the femur, sometimes requiring additional surgical procedures.
The fractured prosthesis can be seen in Fig. 2 a) b). Regarding the fracture zone, it clearly indicates that the prosthesis failed due to fatigue, as demonstrated by the visualization of the crack propagation. It leaves the initiation zone, gradually advances, and then fails abruptly, separating the femoral head from the femoral component (Fig. 2 c) d)).

a) b) c) d)

Fig. 2 The fractured prosthesis

4. CAD reconstruction of prosthesis geometry. Realization of the bone-implant assembly

The geometry of the prosthesis was created in Autodesk Software ”Fusion 360” [4]. The prosthesis was analyzed, measured with the caliper and then, using the "surface" package, the 3D model was made. The surface package was helpful in creating the curves of the model.
The next step was to identify a bone size corresponding to the geometry of the prosthesis. The femur geometry was downloaded from the ”GrabCAD” website [5]. To scale the femur to the size of the prosthesis according to the manufacturer's instructions, CT images were used corresponding to a male patient with anthropometric characteristics suitable for the size of the prosthesis. The CT measurements were performed using ”3DSlicer” [6] software. It was found that the CAD bone model had similar dimensions to the CT-scanned femur. Therefore, no scaling was necessary.
Regarding the geometry of the bone-implant assembly, this stage was carried out in the Engineering Simulation Software, ”Ansys” [7], starting from the geometry of the prosthesis and that of the bone. The bone around the implant had to be removed according to the surgical procedure. Additionally, for model reduction, the knee part is removed, adapting boundary conditions of the finite element model. At the same time, care was taken not to cut through the surface of the trochanter because it is covered by muscle inserts. According to the prosthesis supplier, the diameter of the hole in the bone must be 1mm larger in radius at the top and bottom than the diameter of the rod, to ensure the rod can easily enter the femoral canal and to prevent load transfer from the prosthesis to the bone, other than through the screws.

5. Establishing load cases

It is commonly admitted in femoral bone biomechanics, that the dynamic loads generated during a gait cycle can be reduced to three static load cases, representative enough for the dynamical reality which is difficult to be assessed [8]. Following this approach, in the current study the loads were applied equating such three load cases.
At the bone level, there are different muscle insertion regions where muscular forces are transmitted to the bone. However, in the following analysis, load cases were applied only to the femoral head This force is not a muscle generated resultant, but is generated by the contact between the pelvis and the femoral head. The approach neglects the other forces because their effect is transmitted to the bone only, not to the implant, which represents the purpose of this study.
Three static load cases taken from the gait cycle [9] (C1, C2, C3) are used in the biomechanical analyses (Fig. 3).

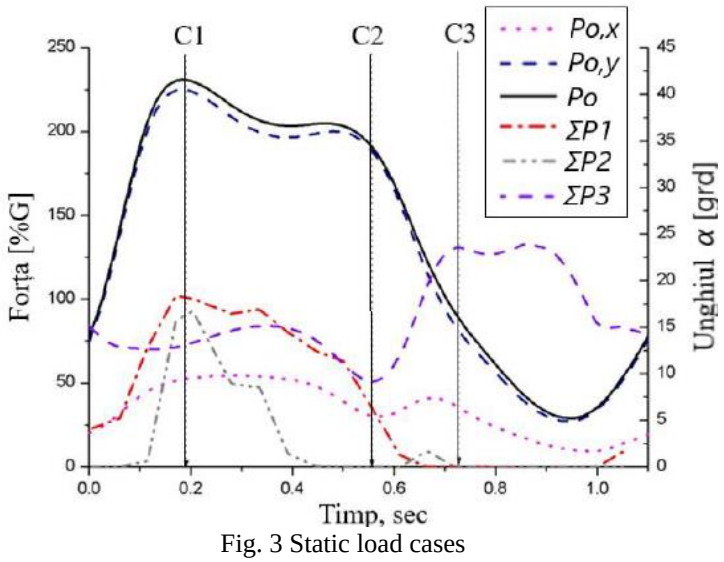

Fig. 3 Static load cases

In Table 1, coefficients from the weight force determined by measurement [10] are presented for patients with total hip prostheses. Applying theses coefficients to the weight of a patient with a mass of 80 kg, there were deduced the values of the force corresponding to the three load cases, based on the θ_R angle, which quantifies the inclination of the force with respect to the vertical direction (Fig. 4).

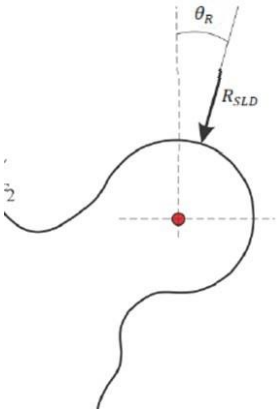

Fig. 4 The θ_R angle

Table 1. Load cases

Load case		I	II	III
R_{SLD}[xG]		2,46	2,81	3,68
θ_R[°]		13	9,2	23,5
F_{GMX}[xG] (Gluteus maximus)	x	-0,29	-0,23	-0,22
	y	-0,05	-0,11	-0,13
	z	0,42	0,31	0,26
F_{GMD}[xG] (Gluteus medius)	x	-0,23	-0,2	-0,3
	y	0,07	-0,03	-0,13
	z	0,33	0,28	0,37
F_{GMN}[xG] (Gluteus minimus)	x	-0,06	-0,11	0,12
	y	0,02	-0,02	0,15
	z	0,08	0,15	0,17
F_{PRF}[xG] (Piriformis)	x	-0,1	-0,14	-0,14
	y	-0,03	-0,08	-0,09
	z	0,05	0,05	0,03
F_{PSO}[xG] (Psoas)	x	0	0	0
	y	0	0,09	0,08
	z	-0,01	0,2	0,2

6. Finite element modeling

In the absence of material data for the prosthesis, the literature was searched, and ranges of mechanical properties were found from which the lowest values were selected. The material properties of the prosthesis ant the screws are: E = 220 GPa, $\nu = 0.3$, $\sigma_y = 720$ MPa (yield limit), $\sigma_u = 890$ MPa (ultimate limit). For the bone, which was considered isotropic, only the elastic constants were relevant, i.e. E_b=18 GPa, $\nu_b = 0.3$ (Fig. 5) [11].

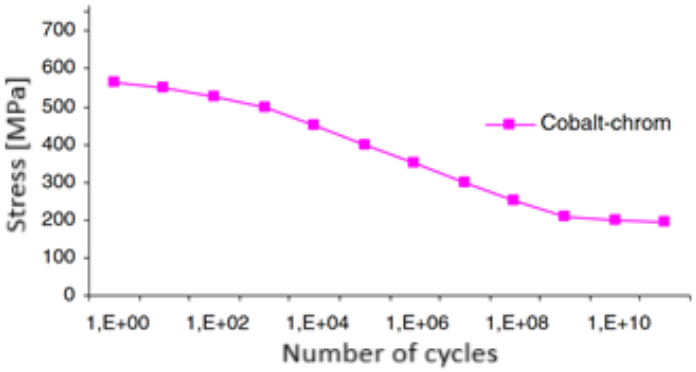

Fig. 5 Durability curve for the prosthesis

The mesh was done using higher order tetrahedral elements. Depending on the area of interest, different levels of mesh refinement were used (Fig. 6).

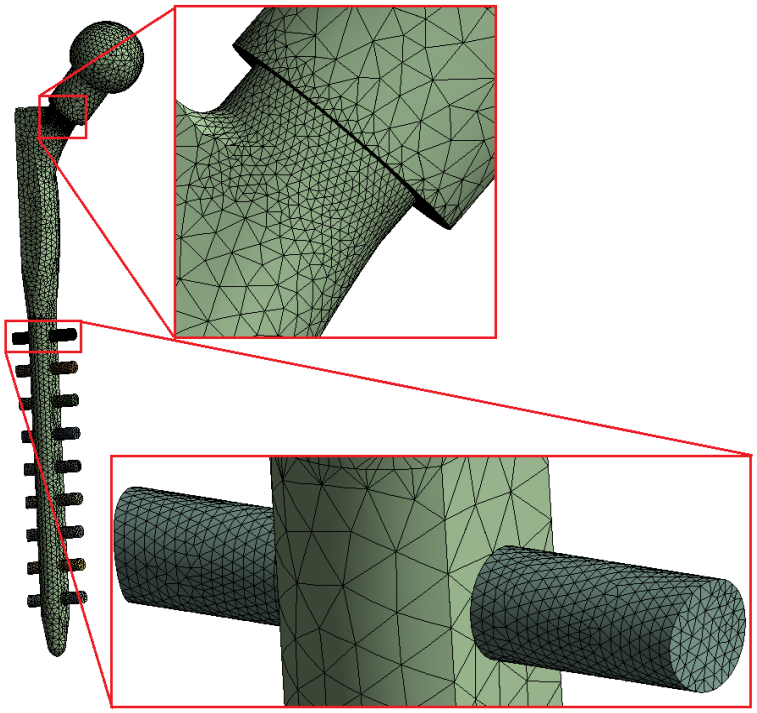

Fig. 6 The mesh

From the loading perspective, the interaction force between the femoral head and the pelvis was applied as a contact pressure, which was calculated assuming that the force was projected onto a flat surface rather than a spherical cap. The pressure applied to the femoral head was loaded in three steps, with values corresponding to the forces of each loading case in the gait cycle (Fig. 7).

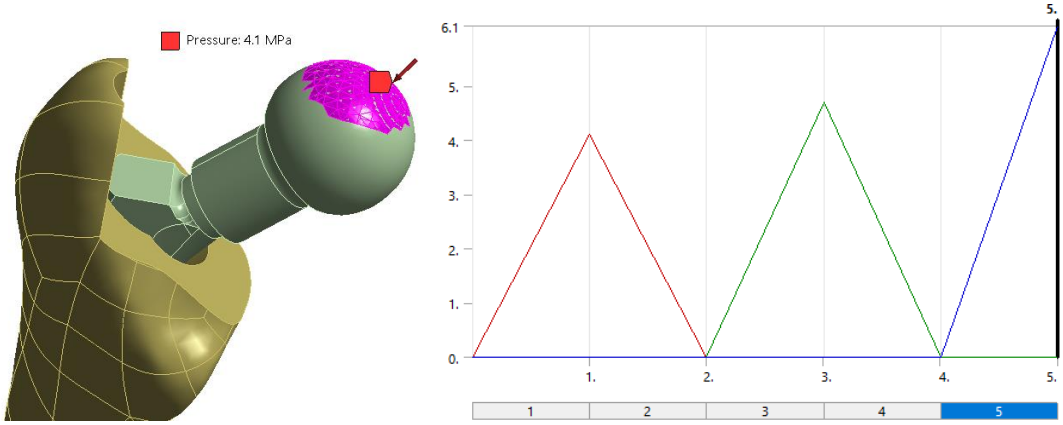

Fig. 7 The pressure applied to the femoral head

Bonded contacts were defined between the screws and the bone, and there no separation type contact between the screws and the implant stem. The absence of contact between the stem and the bone allows the load to be transmitted exclusively through the screws, as it clinically reported for the analysed implant. Furthermore, in order to simplify the analysis, the distal femur has been excluded because it is not relevant to the current study and its absence does not change the analysis results in terms of implant stresses. A fixed support was introduced in the distal section to emulate the removed part of bone.

7. Results

Figure 8. a) shows the von-Mises stress corresponding to load case 3. The detail of failure region shows low stress that could not have caused the event. At the same time, this analysis shows the maximum stress occurring at a sharp edge, in contact with the screw and in a region irrelevant to the study, so it is neglected (Fig. 8. b)). This aspect confirms the numerous cases of screw failure, problems that later led to the discontinuation of this type of prosthesis.

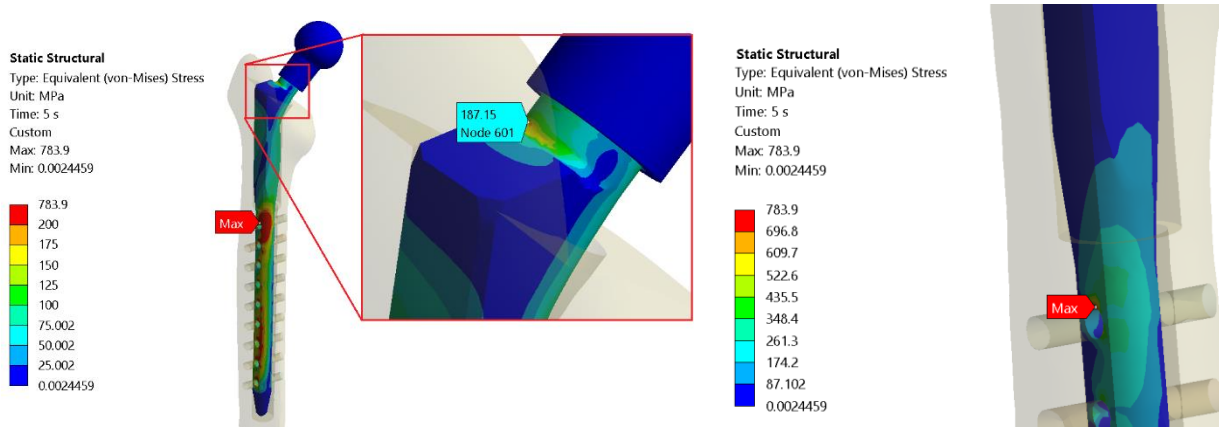

Fig. 8 The von-Mises stress corresponding to load case 3

a) b)

Figure 9. a) b) c) shows the results of the fatigue analysis in the three load cases (C1, C2, C3). In load case three, although the force is the highest, the prosthesis is the least stressed. This is justified by the value of the angle θ_R.

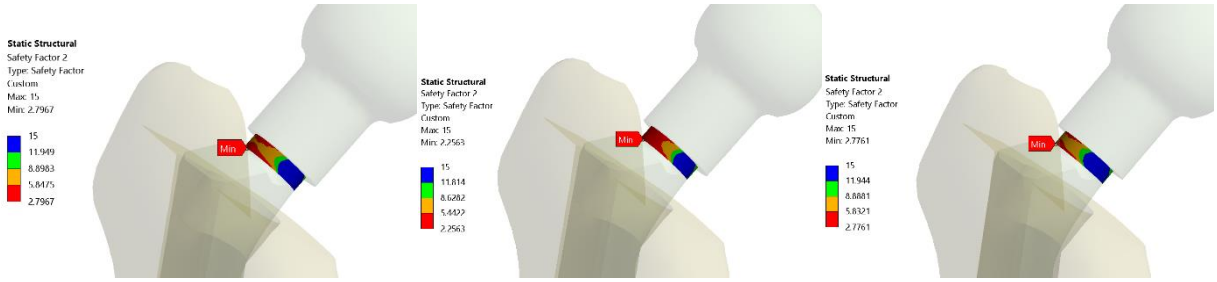

Fig. 9 The fatigue analysis of the three load cases

a) b) c)

The cumulative damage by superimposing the three load cases indicates that there is no risk of failure in the investigated region is (Fig. 10).

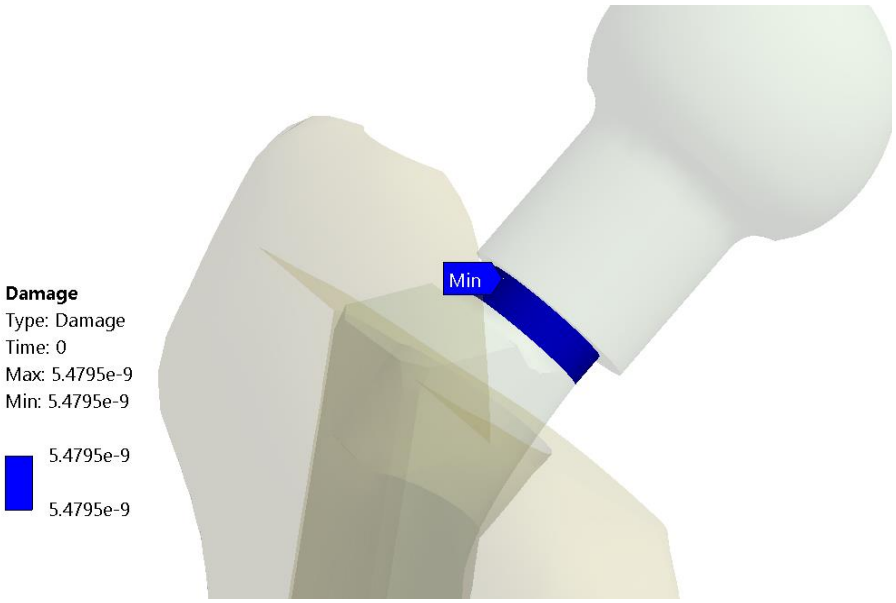

Fig. 10 The cumulative damage

The fatigue assessment was done according to the following features:
- the stress-life method was applied;
- the principal tensile stresses were taken as reference (responsible for the failure of the prosthesis);
- Number of stress cycles considered N=1,825e7 cycles (five years of use with 10000 steps per day);
- Each static load case was considered as a repeated stress cycle;
- Soderberg theory was applied to compute the fatigue safety factor;
- Damage represents the ratio between the number of cycles N and the estimated lifespan (the maximum number of cycles the prosthesis can withstand before failure).

8. Conclusions

The study presented in the paper indicated that the prosthesis design is not a fatigue failure factor. The location of the maximum stresses is not found in the section where the prosthesis failed, so it is concluded that the failure was an isolated case, determined by excessive tightening of the prosthesis head onto the neck, beyond allowable limits, which are not prescribed in the prosthesis technical sheet. The stress caused by the preload, superimposed on the operational stresses, most likely caused the failure.

Although the model presented has a higher complexity than was necessary for the fatigue study of the prosthesis, focus was placed on following the surgical procedure in cutting the bone without the trochanter as further study directions are followed, such as the inclusion of muscle forces. An analysis of interest is the determination of the maximum allowable compression force so that the life of the prosthesis not to be compromised.

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MODELING AND SIMULATION OF A 2005 TOYOTA HILUX DIFFERENTIAL

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ABSTRACT:"Modeling and simulation of a 2005 Toyota Hilux 2005 Differential" is a paper that focuses on the detailed representation of the differential of this vehicle using the Autodesk Inventor design software. By using advanced 3D modeling tools, the paper aims to faithfully reproduce the structure and the components of the differential. The main purpose is to provide an accurate and detailed representation of this crucial mechanism in the vehicle, useful for automotive engineers in the design and development process of new models.

KEYWORDS: 3D modeling, simulation, differential, mechanism

1. Introduction

A differential is an essential part of a vehicle's transmission system, allowing wheels on the same axle to rotate at different speeds during cornering. Here is a description of the main components of a differential:

Fig. 1. Differential housing

- Casing (Differential Housing Fig. 1): It is the external component that contains and protects the other parts of the differential. It is mounted in the axle of the vehicle and is often filled with oil to lubricate and cool the internal components.

- Sprockets (Satellites): These are small cylindrical gears that rotate with the input shaft. They are connected to the side wheels of the vehicle and transmit power to them via planetary gears.

- Planetary gears (Planets): They are gears that rotate around a central gear called the sun gear. These are connected to toothed wheels and allow the side wheels to rotate at different speeds during turns.

- Sun gear (Sun): It is a central gear around which the planetary gears rotate. It is connected to the input shaft and receives power from the engine through transmission.

- Side Sprockets (Coupling): These are gears that connect to the side wheels of the vehicle. They are mounted on planetary axles and transmit power to the wheels.

- Side couplings (Rear wheels): They are elements that connect the side sprockets to the actual wheels of the vehicle. They provide power transmission from the differential to the wheels and are designed to allow for differences in rotational speed between the two wheels.

Fig. 2. Drive pinion

These components work together to allow the differential to distribute power and allow the wheels to spin at different speeds during cornering, thus ensuring optimal vehicle handling and traction.

The objectives of a paper focusing on the modeling of the space group differential of a vehicle such as the Toyota Hilux 2005 are multiple and cover various technical and practical aspects. Here are some key objectives:

Fig. 3. Ring gear

Accurate representation of geometry and component details: A fundamental goal is to achieve as faithful a 3D modeling of the differential as possible, to provide an accurate representation of the shape and all its components. This involves attention to detail and the use of advanced modeling tools to capture the complex geometry of the parts.

Identification of weak points and potential improvements: Through detailed analysis of the model and simulation results, potential problems or weak points of the differential can be identified. The aim is to propose solutions or improvements to optimize the performance and reliability of the differential under varied conditions of use.

Sensitivity to low-grip terrain: Standard differentials can have difficulty distributing power effectively in low-grip conditions such as roads covered in snow, ice or mud. This can lead to loss of traction and performance.

Reliability and Durability: Differential components can be subject to wear and tear over time, especially under heavy use or aggressive driving. Identifying and improving vulnerable components can increase differential reliability and durability over time.

Compatibility with safety and traction control systems: Integrating the differential with modern safety and traction control systems can be an important concern to ensure safe and efficient vehicle operation in various driving conditions.

2. Differential housing and gears

Now let's look at how differential modeling works with a 3V motor and a gear:

3V electric motor: This is the power source of the system. The motor receives electrical current from a power source and converts this current into rotary motion. The 3V voltage determines the rotation speed of the motor.

Reducer: The reducer is a gear assembly that lowers the output speed of the motor but increases its torque. Typically, the reducer is used to adapt the speed and torque of the motor to the specific requirements of the application. It can be composed of different types of gears, such as cylindrical, helical or planetary gears.

Fig. 4. Differential pinion gear

Differential housing and gears (Fig. 2 -7): The gear motor is connected to the differential via an input shaft. The differential is composed of a series of gears that distribute power from the engine to the wheels of the vehicle. The differential gears allow the wheels to spin at different speeds during cornering, ensuring an even distribution of power and traction.

Table 1. Material estimate

Product	Quantity	Price
Bearing 6701	6	66
Socket head screw M3x20MM	6	15
3347 Socket head screws M2.5x5MM	6	15
5158 Brake nuts M2.5MM	12	15
Printer filament 3D	1	70
2554 Cylindrical head screws M3×6MM	12	30
Sandpaper	1	3
Abrasive sponge	1	3
Thermo tube	1	2
Cables	1	5

Drowned screw M3×15MM	12	3
Bearing 623	12	36
Engine + battery holder	1	30
Washers	20	1
Screws M3x10MM	19	3.5
Switch	1	8
Neodymium magnets 5x2	20	17
Ax 3×1000	1	12
Total	-	334.5

Control and monitoring: In some applications, a control system can be used to adjust the speed and direction of the motor according to the specific requirements of the vehicle or equipment. This system can monitor and adjust parameters such as speed, torque and temperature to ensure optimal system operation.

Fig. 5. Side gear

Fig. 6. Axle shaft

Fig. 7. Side and pinion gears housing

3. Conclusions

In conclusion, the modeling of the differential with a 3V motor and a reduction gear involves the integration of the electric motor with the reduction gear and the differential to ensure an efficient distribution of power and traction during the operation of the vehicle or other types of equipment. This is crucial to achieve optimal performance and stable handling in a variety of driving or use conditions.

Improvements may include optimizing the differential design, using stronger materials, and modern control and monitoring technologies to address these issues and improve differential performance and reliability.

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THE CONSTRUCTION USING THE HELP OF 3D PRINTING AND THE GEOMETRIC MODELING OF A HORIZONTAL PRESS MODEL USING SOLIDWORKS AND INVENTOR DESIGN-AID SOFTWARE

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ABSTRACT: In this scientific paper, the steps followed to represent a theoretical mechanism of a horizontal press in the three-dimensional environment by concretizing, designing and geometrically modeling it by means of the SolidWorks and Autodesk Inventor assisted design programs are presented, which then allows, by using "slicer" programs specific to 3D printers, to take the models of previously designed parts and print them using a 3D printer. To present them, the paper contains the structural analysis of the mechanism addressed, the steps followed for the design in each of the two programs accompanied by representative images and images in which the 3D printed mechanism is rendered together with the steps that were followed to reach the final form of this one.

KEYWORDS: modeling, SolidWorks, Inventor, printing, 3D.

1. Introduction

The application of the studied theoretical concepts is crucial for any engineer, and that is why this paper aims to take a given theoretical mechanism and model it using two aided design programs: SolidWorks and Inventor; this showing how the theoretical concepts of the mechanisms are applied in real cases; and also using the designed models to 3D print the mechanism, thus bringing the mechanism from the virtual environment into reality.

2. The structure of the horizontal press mechanism

The structure of the mechanism is the defining characteristic for any mechanism. That's why we start by presenting the structural analysis of the horizontal press mechanism (Fig. 1) that we will model later. Also, geometric modeling of a mechanism requires understanding of it and its structural analysis.

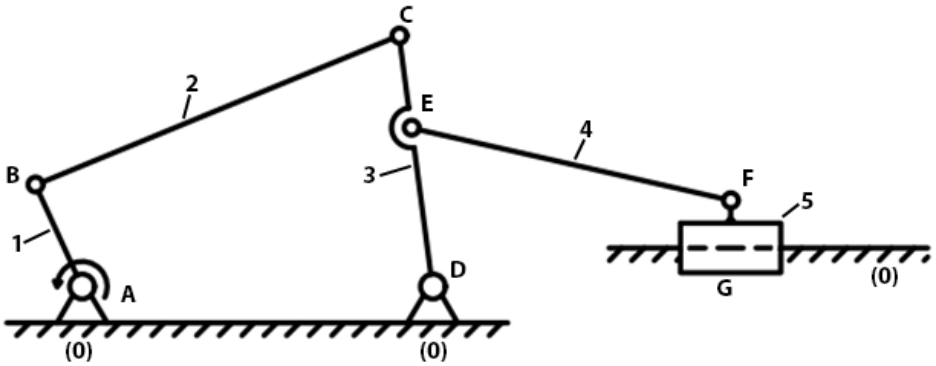

Fig. 1 Kinematic diagram of the mechanism

Table 1. Table of kinematic pairs and table of elements

Table of kinematic pairs			Table of elements		
Kinematic pair	Pair elements	Pair movements	Element	Element pair	The grade of the element
A	0, 1	R	0	A, D, G	III
B	1, 2	R	1	A, B	II
C	2, 3	R	2	B, C	II
D	0, 3	R	3	C, E, D	III
E	3, 4	R	4	E, F	II
F	4, 5	R	5	F, G	II
G	5, 0	T			

Structural characteristics:

$$n = 6\ (0, 1, 2, 3, 4, 5) \quad (1)$$

$$\boldsymbol{m = n - 1 = 5\ (1, 2, 3, 4, 5)} \quad (2)$$

$$\boldsymbol{s = C_4 = 0} \quad (3)$$

$$\boldsymbol{i = C_5 = 7\ (A, B, C, D, E, F, G)} \quad (4)$$

$$\boldsymbol{N = C - m = 7 - 5 = 2} \quad (5)$$

The degree of mobility:

$$\boldsymbol{M_3 = 3 \cdot m - 2C_5 - C_4}$$

$$\boldsymbol{M_3 = 3 * 5 - 2 * 7 - 0}$$

$$\boldsymbol{M_3 = 1} \quad (6)$$

Structural diagram:

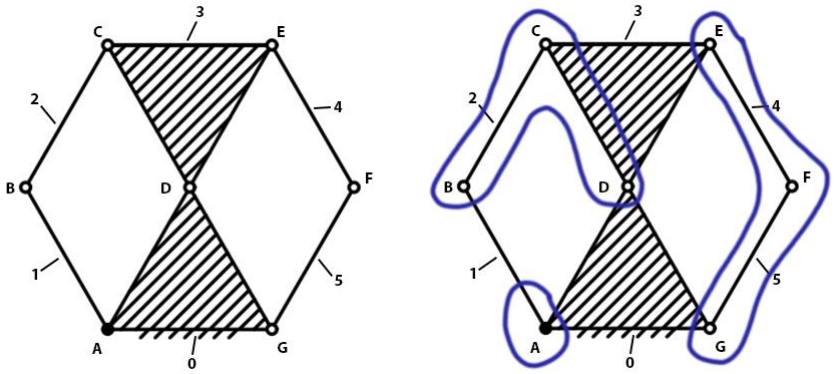

Fig. 2 The structural diagram of the mechanism and its division into structural groups

Connection (multipolar) diagram:

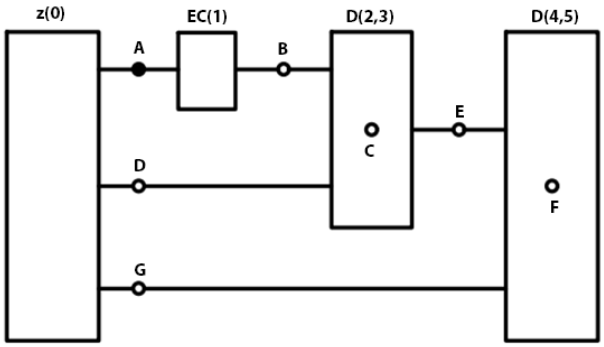

Fig. 3 Connection (multipolar) diagram of the mechanism

The structural relationship:

$$\boldsymbol{Z(0) + EC(1) + D(2,3)II/2 + D(3,4)II/2} \quad (7)$$

Class II mechanism

3. Geometric modeling in Inventor:

Geometric modeling in Inventor begins by individually modeling each component part of the assembly. The assembly will contain 7 distinct parts: Baza01, Baza02, Manivela1, Biela2, Balansierul3, Biela4, Culisor5.

It can be seen how the component parts of the assembly correspond to the kinematic elements found in the kinematic diagram of the mechanism, with the only exception being the kinematic element 0, which corresponds to two parts in the assembly in Inventor, Baza01 and Baza02 respectively.

The modeling of each part begins by drawing the sketch of each part (Fig. 4), using general 2D-aided design techniques.

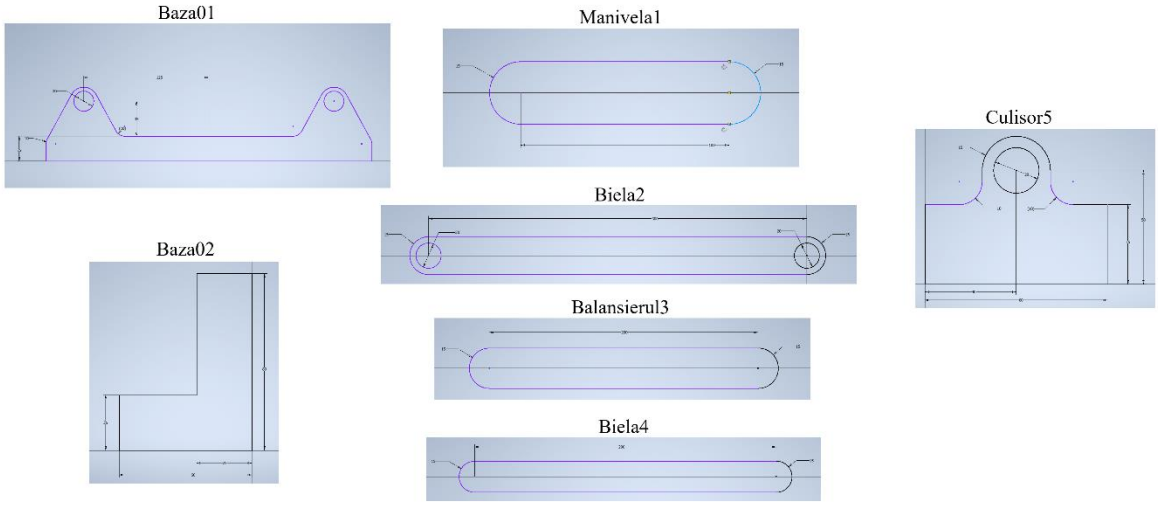

Fig. 4 Sketches of the component parts of the assembly

After sketching, the next step is to extrude the previously created sketches to create an incomplete 3D model from the 2D sketches. In order to extrude sketches, the desired surface is selected for extrusion. The sketches of the parts will be extruded to different lengths, depending on the part in question, as follows:

the parts Baza01, Manivela1, Biela2, Balansierul3 and Biela4 are extruded 12 mm, Culisor5 is extruded 10 mm, and Baza02 is extruded 280 mm.

After the extrusion stage, 4 out of 7 pieces are completed. The parts Manivela1, Balansierul3 and Biela4 still remain to be completed by sketching, extruding and cutting in them a number of circles aimed at creating the couplings between the parts of the assembly. The extrusions will have a depth of 10 mm, and the cutouts will pierce the cut piece.

Following the execution of the last modeling phase, we obtain the final shape of all the component parts of the assembly (Fig. 5). To make it look better, the Baza01 and Baza02 parts can be chamfered on the outer edges [1].

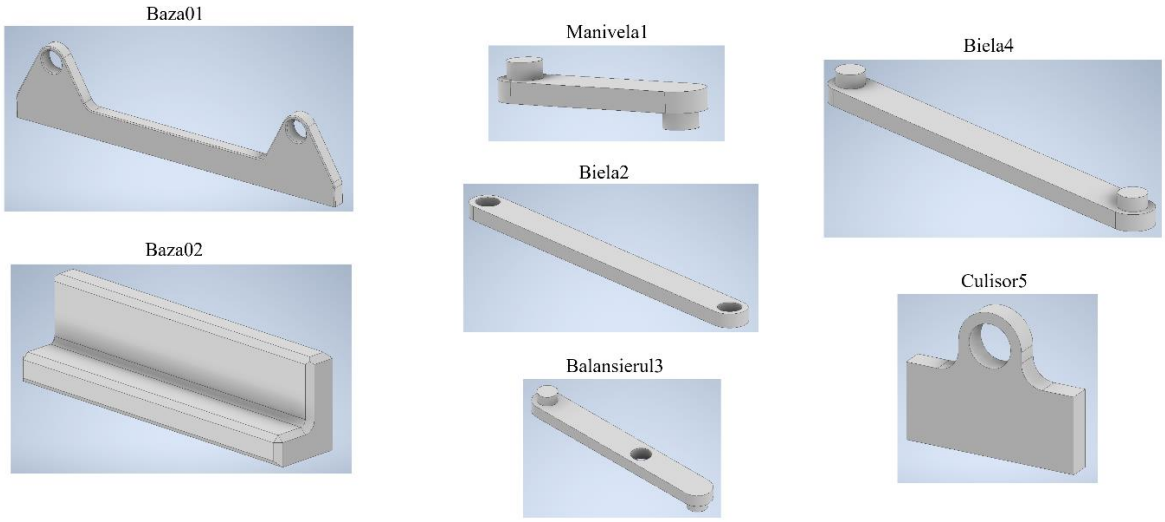

Fig. 5 The final shape of the component parts of the assembly

To assemble the mechanism, a ".iam" file will be created. Continue by bringing all the component parts of the assembly into the file. Then anchor the Baza01 part by selecting it and checking the "Grounded" option. Then successively assemble the kinematic pairs A, B, C, D, E, F by selecting the contours corresponding to the same coupling on both parts between which the coupling is created under the "Constrain" option with the "Insert" type, for each coupling separately.

The last steps are to position, align, space and then anchor the Baza02 piece, and then create the G pair between the Culisor5 and Baza02 pieces by selecting the top surface of the Baza02 piece and the bottom face of the Culisor5 piece under the "Constrain" option with the "Mate" type.

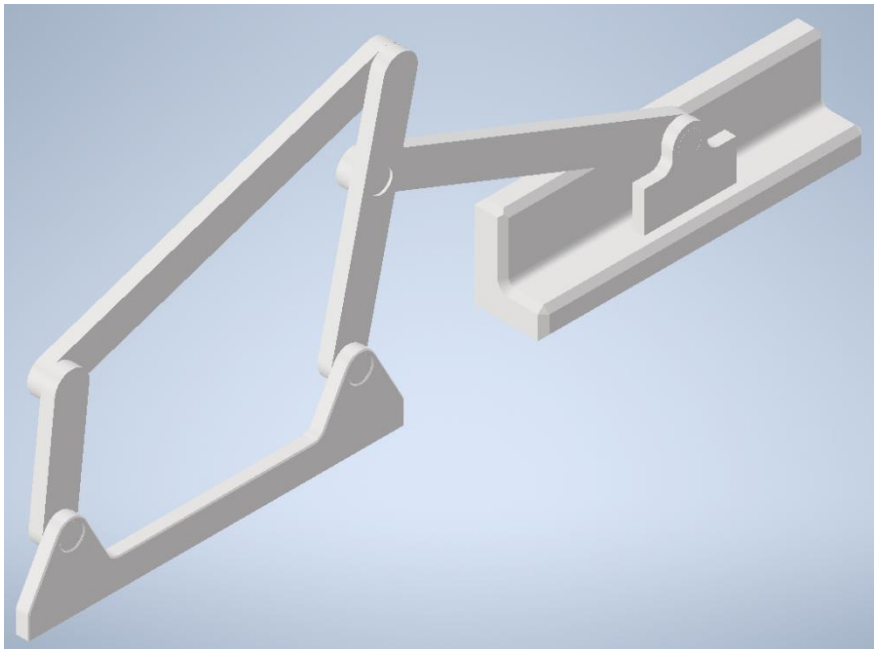

Fig. 6 The final shape of the assembly geometrically modeled in Inventor

After assembling the horizontal press mechanism (Fig. 6), the Inventor program allows us to perform the dynamic simulation of the assembly through the "Dynamic simulation" option found in the upper left part, in the "Environments" tab. The dynamic simulation option allows us to apply a force of 1N to the Manivela1 part in pair B which maintains its direction as the part rotates. After doing that, we let the program perform the dynamic simulation, which will then allow us to view graphs in which are rendered, for example, the evolutions of the slider's displacement, velocity and acceleration over time (Fig. 7).

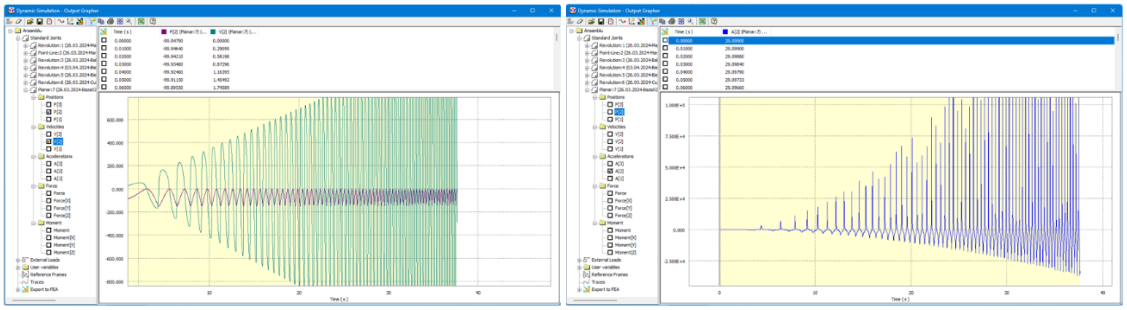

Fig. 7 Graphs of the slider's displacement (purple), velocity (green), and acceleration (blue).

4. Geometric modeling in SolidWorks:

Geometric modeling in SolidWorks begins by individually modeling each component part of the assembly, similarly to the geometric modeling done in Inventor. This step follows pretty much the same steps shown when modeling individual assembly components in Inventor, so they will not be followed once more [2].

To assemble the mechanism, an "Assembly" type file will be created. Then follows the introduction into the file of the first part of the assembly, part Baza01. This, being the first part of the assembly, will be automatically anchored. The other parts of the assembly are then inserted into the file. Then successively assemble the kinematic pairs A, B, C, D, E, F by selecting the contours corresponding to the same coupling

on both parts between which the coupling is created under the option "Mate" with the type "Coincident", for each coupling separately, as in the example in Fig. 8.

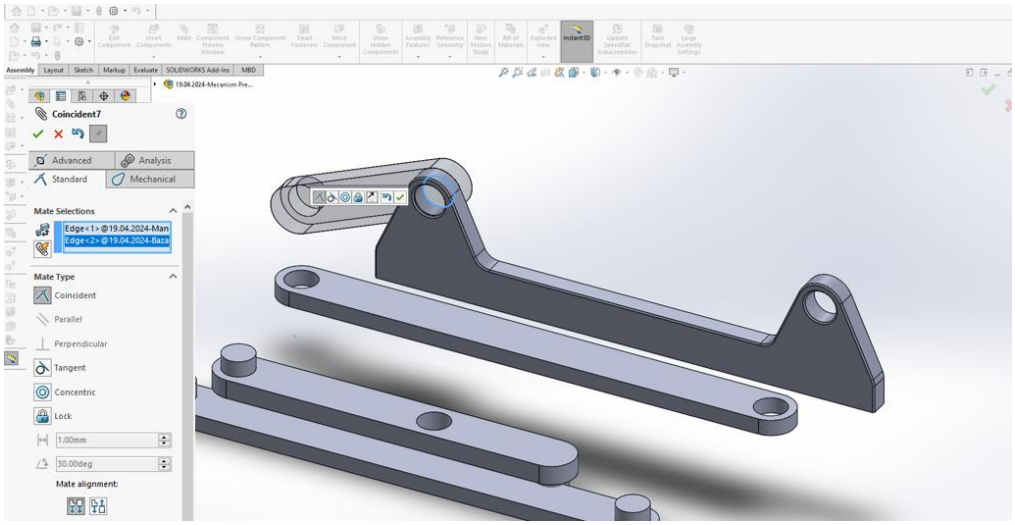

Fig. 8 Assembly of pair A of the mechanism

Finally, the Baza02 part is positioned, aligned and spaced, and then the G pair is created between the Culisor5 and Baza02 parts by selecting the top surface of the Baza02 part and the bottom face of the Culisor5 part under the "Mate" option with the "Coincident" type (Fig. 9).

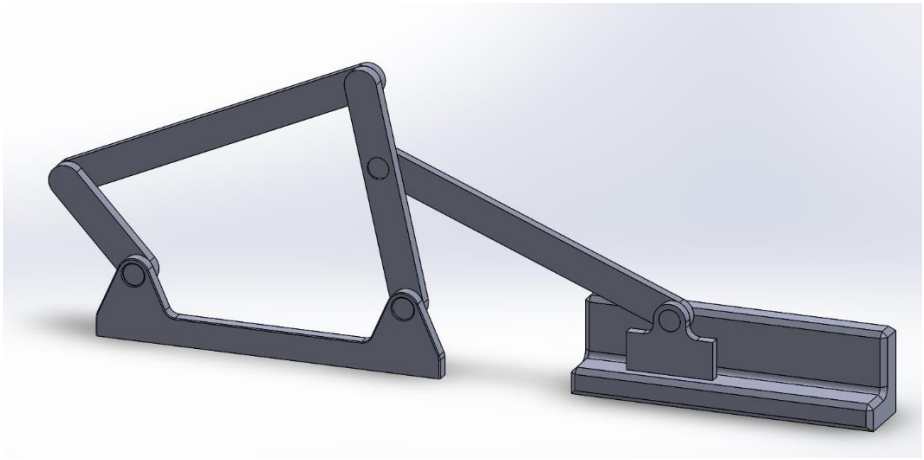

Fig. 9 The final shape of the assembly geometrically modeled in SolidWorks

After assembling the horizontal press mechanism, the SolidWorks program allows us to study the movement of the assembly through the "Motion Study" option found at the bottom of the program. This means that it allows us to do the kinematic simulation of the assembly. The motion study option allows us to apply 10RPM to the Manivela1 part in pair A [3]. After doing that, we let the program perform the motion study, which will then allow us to view graphs where, for example, the oscillations of the slider's displacement, velocity, and acceleration are rendered (Fig. 10).

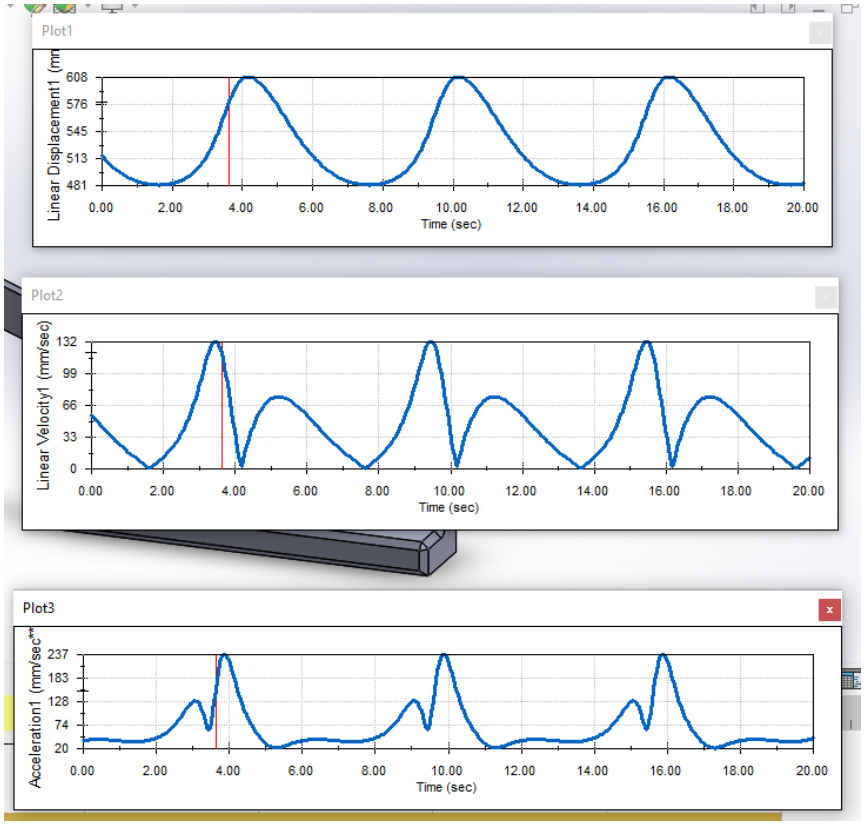

Fig. 10 Slider displacement, velocity and acceleration graphs

5. Construction with 3D printing:

After geometrically modeling the mechanism, regardless of the program used, we can export the part models in .stl format files, a format that will be used to be able to insert into the "slicer" program specific to the 3D printer used. Any 3D printer, depending on the company that manufactures it, has a characteristic "slicer" program, a program that transforms 3D models given by the user into commands for the 3D printer to print those models.

Careful! For 3D printing, at the joints of the rotation couplers it will be necessary to create a tolerance between the elements by reducing the diameters of the extruded circles by 0.5mm to allow them to be joined. This is necessary because the method used by 3D printers, method in which the parts are printed layer by layer, makes the surfaces of the joints of the pairs have a high roughness, which will not allow their assembly if the diameters with which they were designed remained unchanged.

For this paper, I used a Creality Ender-3 S1 Plus 3D printer, which has the Creality Slicer [4] program as a "slicer". I put each molded part into it, one at a time, which I then saved in their sliced form to an SD card which I then put into the 3D printer in order to print the mechanism pieces. For example, Fig. 11 shows the slicing of the piece Baza01.

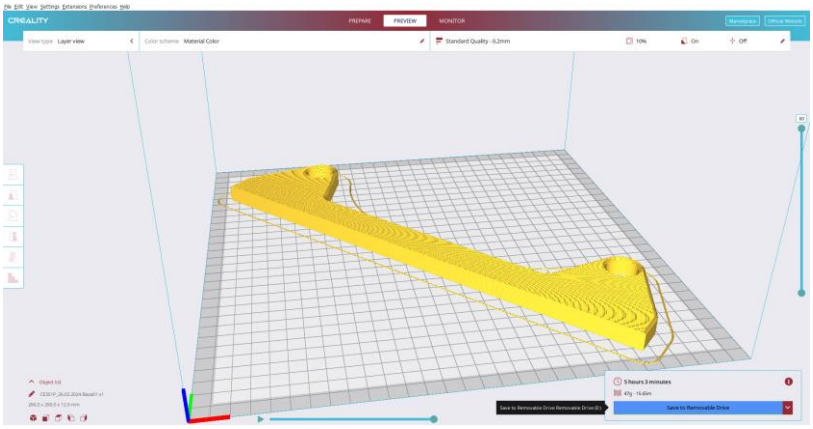

Fig. 11 Slicing the Baza01 part model

Part printing times may vary depending on the 3D printer used, the filament used by the printer, the printing options used for slicing and the volume of the printed part. In my case, when I printed the parts of the mechanism, the printing times varied between 1h30min (Culisor5) and 15h30min (Baza02).

Fig. 12 Image during 3D printing and construction of the mechanism model

Also, if desired, additional covers can be designed to keep the pairs intact, a handle can be added to the Manivela1 piece, or even a stand to support the entire assembly can be created. The horizontal press in its final form can be seen in Fig. 13, it being fully assembled and also containing the previously mentioned display accessories, these being printed using the color red to differentiate them from the rest of the assembly.

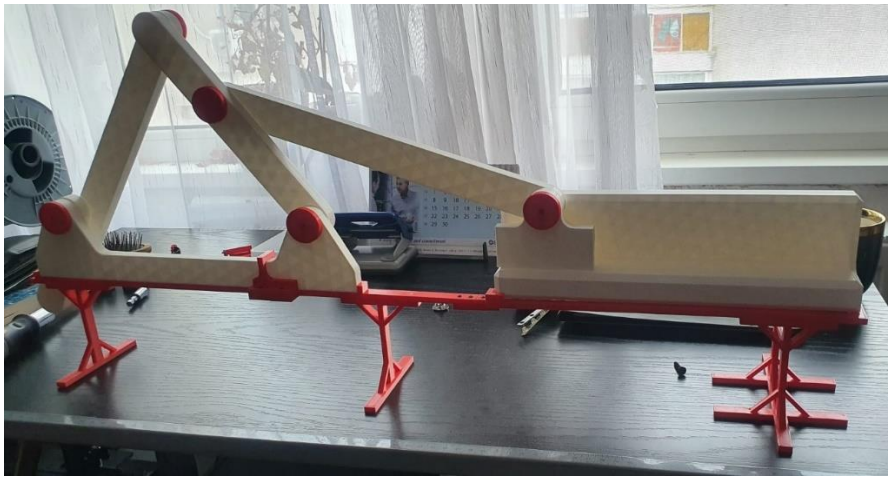

Fig. 13 Fully assembled model of the horizontal press mechanism, complete with display stands

6. Conclusions

In this scientific paper, it was presented how a theoretical mechanism must be approached in order to be modeled and built, using two different CAD programs and the 3D printing technique.

The similarities and differences in the use of the two aided design programs: Inventor and SolidWorks were highlighted, but also how to use the designed models to successfully 3D print them using a 3D printer to build the model.

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8. Markings

The following symbols are used throughout the paper:
n = total number of elements
m = number of moving elements
s = number of class IV couples
i = number of class V couples
N = number of independent non-deformable closed loops
C = total number of kinematic pairs
EC (1) = driving element
D = dyad

THE MECHANIC CANARY: THE CRANK-ROCKER MECHANISM IN THE WINGS OF BIRDS

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ABSTRACT: The problem analyzed in this paper focuses on the structural analysis and modeling of a mechanism with rods, specifically the Mechanical Canary: the crank-rocker mechanism in bird wings. The study encompasses a broad spectrum of analyses, ranging from fundamental ones like structural, kinematic, and kinetostatic analyses, to geometric-kinematic analyses and sizing of rod mechanisms. Additionally, rod mechanisms are found in the mechanisms used for moving windows in the side doors of vehicles, in mechanically operated windshield wiper mechanisms, in crane mechanisms for various lifting or lowering tasks, in industrial robot mechanisms for object manipulation, etc., thus having a wide range of applications.

KEYWORDS: mechanism, connecting rod, crank, rocker

1. Introduction

The mechanism with bars studied in this paper transforms the rotational movement (provided by the crank) into translational movement (of the slide within the frame).

This mechanism, due to its simple operation, has a wide range of applications in engineering and belongs to the category of the most diverse mechanisms in various fields of use. The objective pursued in this work is to conduct the structural analysis of the selected bar mechanism and the physical realization of the mechanism. This objective will be achieved by designing the kinematic scheme of the planar mechanism, identifying the kinematic elements and couplings within it, creating the structural scheme, and the connection scheme of the mechanism. Therefore, in this work, these goals will be pursued gradually to achieve them.

2. Current stage

In the current stage of research, it is observed that bar mechanisms are studied in a variety of contexts, ranging from basic structural and kinematic analyses to applications in vehicle mechanisms, windshield wipers, cranes, industrial robots, and other areas. They are appreciated for their simplicity and have a wide range of applications, such as vehicles, industrial equipment, and robots. The work begins by presenting the mechanism and the objectives of this study. Next, the structural analysis of the mechanism will be carried out, presenting its kinematic scheme, detailing the component elements and kinematic couplings. The number of independent contours and the degree of mobility are calculated to better understand the mechanism.

3. Structural analysis

Structural analysis means to find the elements and the kinematic pairs that connect them and the degree of mobility of the mechanism.

The selected bar mechanism in this work is part of the category of planar mechanisms and is formed by kinematic elements connected to each other through kinematic couplings. To start the structural analysis of this planar mechanism, it is necessary, first, to present its kinematic scheme.

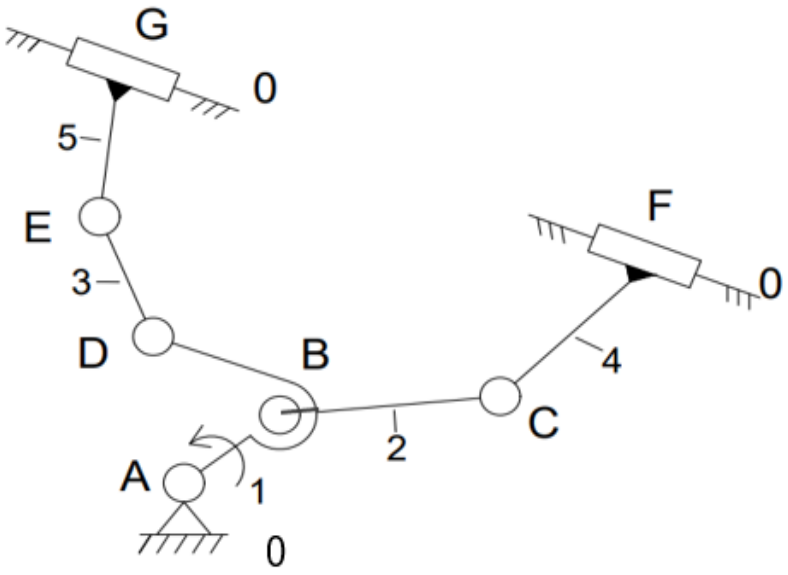


Fig. 1. The cinematic scheme of the mechanism

In Fig. 1 is represented the kinematic scheme of the mechanism, where 0 is the fixed element, 1 represents the crank, 2 and 3 are connecting rods, 4 and 5 are rockers. The number of independent closed loops is:

$$N = i + s – m \quad (1)$$

$$N = 7 + 0 - 5 = 2$$

The number of closed independent loops is two.

The mechanism is made up of:

• five mobile cinematic elements (m = 5) and one fixed cinematic element denoted by the number 0;

• seven lower kinematic pairs (rotation and translation) denoted by letters (O, A, B, C, D, E, F) - i = 7, s = 0.

The degree of mobility of the mechanism is calculated with the formula:

$$M = 3 \times m - 2 \times i\text{-}s \quad (2)$$

$$n = m + 1$$

$$M = 3 \times 5 - 2 \times 7 - 0 = 1 \quad (3)$$

$$M = 1$$

A degree of mobility of one means that the mechanism requires only one engine to be put into motion, which is in A kinematic pair. Further on the kinematic pairs table is realized, each pair being characterized by motion, a class and formed by the connection of two elements.

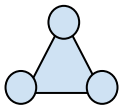
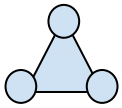
There are seven kinematic pairs, from A to G, the first five having a motion of rotation, while the last two are translating. All of them have one motion, either translations or rotation; this means five restrictions, so they all are of fifth class. Not having any kinematic pairs of fourth class means that equalization is not required.

Table 1. Kinematic pairs

KINEMATIC PAIRS	MOVEMENT MADE	NOTATION	LINK BETWEEN KINEMATIC ELEMENTS	CLASS OF KINEMATIC PAIRS
A	Rotation	A(0,1)	fixed element 0 and crank 1	V
B	Rotation	B(1,2)	crankshaft 1 and connecting rod 2	V
C	Rotation	C(2,4)	connecting rod 2 and rocker arm 4	V
D	Rotation	D(1,3)	connecting rod 2 and connecting rod 3	V
E	Rotation	E(3,5)	connecting rod 3 and crankshaft 5	V
F	Translation	F(4,0)	rocker 5 and fixed element 0	V
G	Translation	G(5,0)	rocker 4 and fixed element 0	V

In Table 1 from above are presented the kinematic pairs and in Table 2 the kinematic elements of the mechanism. There are four binary elements and two ternary.

Table 2. The elements

The number of the cinematic element	The couples that belong to the cinematic element	The name of the element	Representation
0	A,F,G	ternary	
1	A,B,D	ternary	
2	B,C	binary	
3	D,E	binary	
4	C,F	binary	
5	E,G	binary	

In Fig. 2. is presented the structural scheme of the mechanism which is realized by connecting the elements form table 2 with each other.

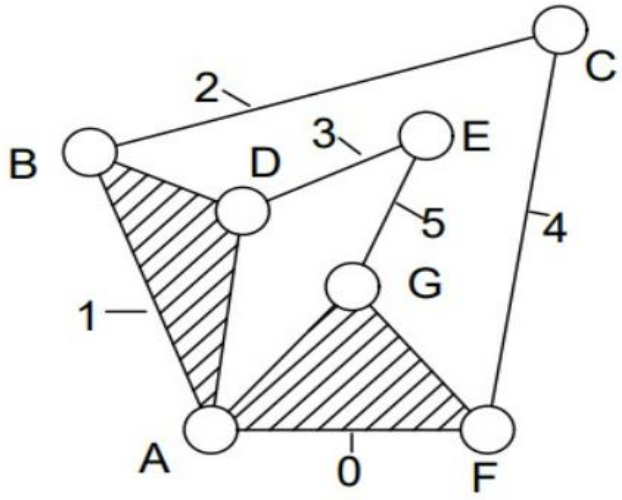


Fig. 2. The structural scheme

In Fig. 3 is represented the connection diagram.

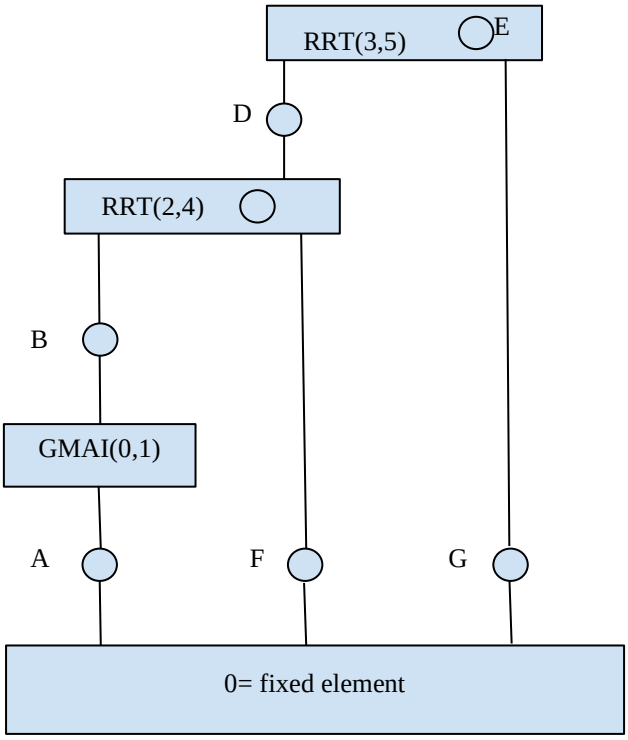


Fig. 3. The Connection diagram

4. Assembly of the mechanism

To assemble the mechanism the objects used were bonfire, tongs, clips, dowels, sandpaper, wood, popsicle sticks, glue gun, stapler, elastic, ruler.

We start by sizing the main body of the legs at 200 mm in length and a thickness between 6 and 15 mm. We build two legs, one in the front and one in the back, and add a hook for the feet of the mechanism. Its angle is approximately 165 degrees.

Fig 4. Components

We are assembling two sets of wood, one in the shape of an X for stability, and the other for the design of the wings. The wings have a radius of 195 mm and are controlled by a crank.

Fig. 5 Final mechanism

We attach the material to the wings with heated staples and finish the components with a finishing file. We use staples and a hot glue gun for assembly and fixing.

5. Conclusions

In conclusion, the paper has detailed the mechanism with bars, highlighting its importance and applicability in various technical fields. Through structural analysis and modeling of this mechanism, new perspectives have been opened in understanding its functioning and optimizing its use in different practical applications. Additionally, we have emphasized the diversity of uses of bar mechanisms, from simple applications in automobiles to advanced uses in industrial robots. Thus, the work contributes to the understanding and development of this type of mechanism, opening new directions for research and innovation in the field of mechanical engineering.

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6. Notations

GMAI = active modular group;
RRT= rotation-rotation-translation;
i = the number of lower couplings;
s = the number of upper couplings;
M = the degree of mobility of the mechanism;
m = the number of mobile cinematic elements;
n = the total number of elements.

MODELING OF A CRANK-PISTON MECHANISM

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ABSTRACT: Modeling a crank-piston mechanism involves describing and analyzing the motion of the piston inside the cylinder as a function of geometric parameters and operating conditions. This process can be achieved using principles of mechanics and thermodynamics.

KEYWORDS: mechanism modeling, kinematic joints, kinematic elements

1. Introduction

A MECHANISM is a set of bodies (elements) connected movably to each other for the purpose of transmitting and transforming motion.

MACHINE PARTS are component parts of machines and mechanisms, with a functional role, which can be calculated and designed separately. A machine part can be simple, made of a single piece (screw, wedge, gears) or compound (bearing, connecting rod, coupling) [1].

2. Study of the topic

The development of a piston, its design in the Autodesk Inventor program, and its structural analysis. The chosen mechanism is a piston that creates pressurized water and is found in a pressurized water pump. It has the role of pumping water from a reservoir or water source and compressing it under pressure into a piping system or container, to provide water with sufficient pressure for various purposes, such as garden irrigation or household water supply.

2.1 The Mechanisms

Mechanisms are a kinematic chain that has a fixed or considered fixed element and well-defined movements of all the kinematic elements in its composition [4], [5].

From a constructive point of view, there are the following categories of mechanisms:

- Mechanisms with bars.
- Mechanisms with cams.
- Mechanisms with gears.
- Diverse mechanisms. From this category, we can enumerate mechanisms with friction wheels, Maltese cross mechanisms, mechanisms with bars/cams/gears and chains/cables/belts, etc [3].

2.2 Structural analysis of the mechanism [2]

The mechanism is the totality of kinematic elements connected by kinematic pairs, and which have an element considered fixed.

A mechanism has:

- m mobile elements (m = n - 1) (n is the total number of kinematic elements - including the fixed element).
- i inferior joints, which have rotational or translational motion (pairs of class V) (C5).
- s superior joints, which have rotational and translational motion (pairs of class IV) (C4).

2.3 Stages of structural analysis [2]

a) The kinematic elements are identified by digits and the kinematic joints by capital letters. It is recommended that the fixed element be identified by zero, and the driving element be identified by 1.

b) The following are established:

• n - the total number of kinematic elements.

• m - the number of mobile kinematic elements.

• C5 = i - the number of class V joints.

• C4 = s - the number of class IV joints.

c) The degree of mobility is calculated.

d) The table of pairs and elements is drawn up.

e) The structural diagram is produced.

f) The modular groups are determined.

g) The connection diagram and the structural relationship are established.

3. Structural Analysis of the Crank-Piston Mechanism

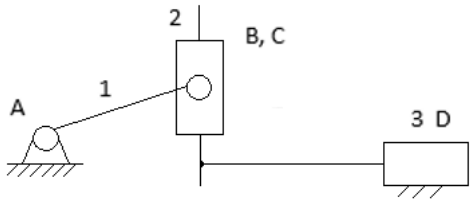

Fig. 1. Kinematic Diagram of the Mechanism

• The mechanical system consists of:

✓ three moving kinematic elements (m = 3).

✓ four lower kinematic pairs (rotation and translation) denoted by letters (A, B, C, D) (i = 4).

• The mechanism in Fig. 1. It consists of the following components:

1 – crank

2 – translating element

3 – piston

• The degree of mobility of the mechanical system (M) is calculated with the formula below. The degree of mobility shows how many driving elements are needed to put the mechanical system into motion. In the case of the crank-piston mechanism from Fig. 1 it is needed just one engine.

$$\begin{aligned} M &= 3*m - 2*i - s \\ M &= 3*3 - 2*4 - 0 \\ M &= 1 \end{aligned} \tag{1}$$

• The number of independent closed loops (N) is calculated with the following formula:

$$\begin{aligned} N &= i + s - m \\ N &= 4 + 0 - 3 \\ N &= 1 \end{aligned} \tag{2}$$

The table of kinematic pairs is described in Table 1, where each kinematic pair is named, the elements that form the pairs and the motion that it performs.

Table 1. Study of kinematic joints

Kinematic joint	The movement performed	Notation	The connection between kinematic elements	Joint class
A	rotation	0 (A, D) - R	rod 0 and crank 1	V
B	translation	1 (A, B) - T	crank 1 and the translating element 2	V
C	translation	2 (B, C) - T	the translating element 2	V
D	translation	3 (C, D) - T	the translating element 2 and piston 3	V

Table of kinematic elements, where each element is named starting from 0, the joints that the element has, the type of the element and a representation are studied below in Table 2.

Table 2. Study of kinematic elements

Kinematic element	The joints of the kinematic element	Name of the element	Representation
0	A, D	binary	A ○——○ D
1	A, B	binary	A ○——○ B
2	B, C	binary	B ○——○ C
3	C, D	binary	C ○——○ D

In Fig. 2 is represented the structural diagram of the crank-piston mechanism. The elements from Table 2 are connected, starting from the 0 element, which is connected through A kinematic pair to the first element. Element 1 is in contact to element 2 by pair B, then element 2 is connected to the third element through kinematic pair C and in the end 3 is connected to the base.

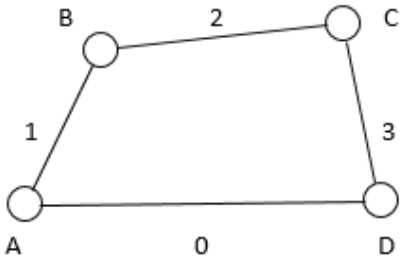

Fig. 2. Representation of the structural diagram of the crank-piston mechanism

According to the type of motion of the elements in spatial kinematic chains, where at least one element has a motion in a different plane than the others, in Fig. 2 the representation is of the quadrilateral type.

Division of the structural diagram into structural groups is presented in Fig. 3 below.

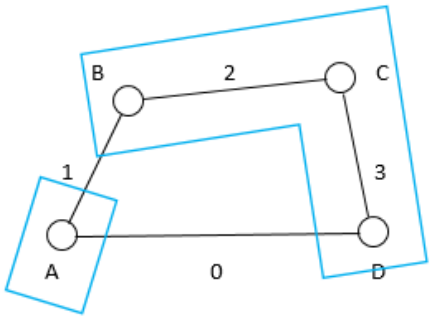

Fig. 3. Division of the structural diagram into structural groups of the crank-piston mechanism

The diagram includes the active modular group GMAI (A, O) and the passive modular group - the BCD dyad (formed by two pairs of connections, and the appearance of the passive modular group is RRT).

Connection diagram is presented in Fig. 4.

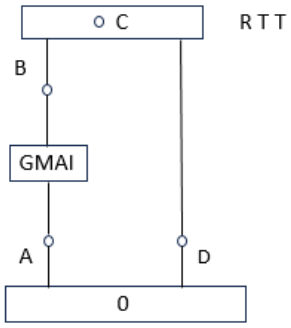

Fig. 4. Connection diagram of the crank-piston mechanism

Structural relationship is written in the following way:

GMAI (O,1) + RTT (2,3)

4. Modeling the piston-type mechanism

Modeling a crank-piston mechanism in Autodesk Inventor involves creating a digital model of this complex mechanical system. This can be achieved by utilizing a series of tools and functionalities available in the program to define the geometry and behavior of the mechanism.

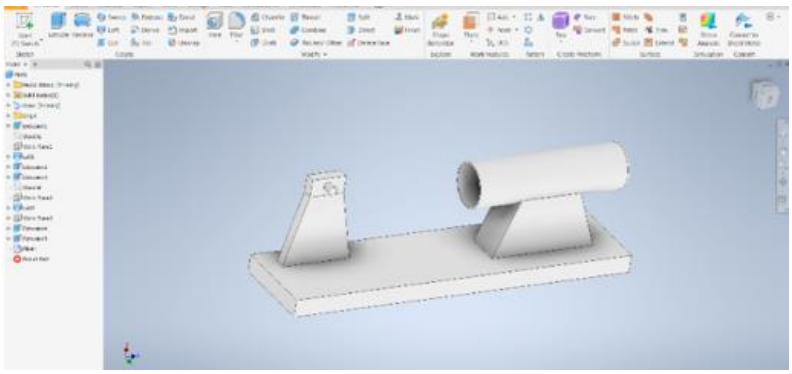

Fig. 5. Creation of the fixed element

The process begins with creating a two-dimensional sketch of the main components of the mechanism, such as the cylinder body and the piston.

These sketches can be created using the program's sketching tools, which allow for the precise definition of the shape and dimensions of each part.

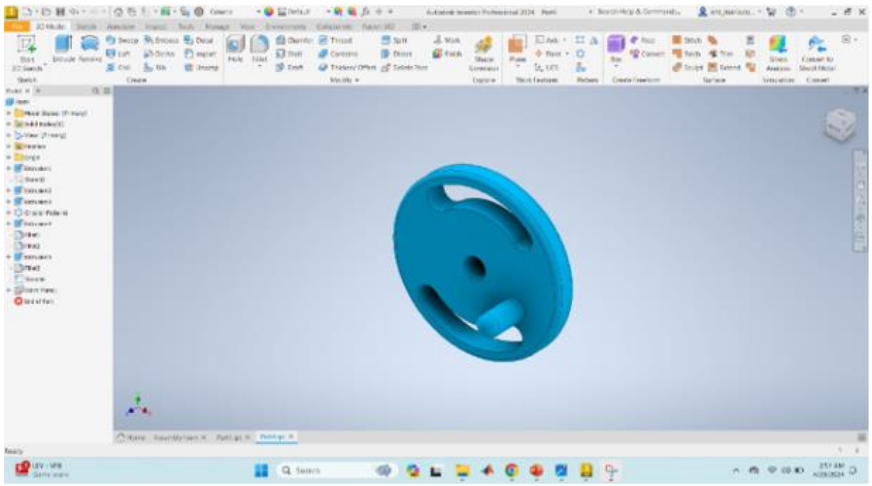

Fig. 6. Creation of the crank

After creating the sketches, the next step is extrusion or revolution, where the two-dimensional sketches are transformed into three-dimensional objects by extruding or rotating them. This process involves using specific commands in Autodesk Inventor to give shape and volume to each part.

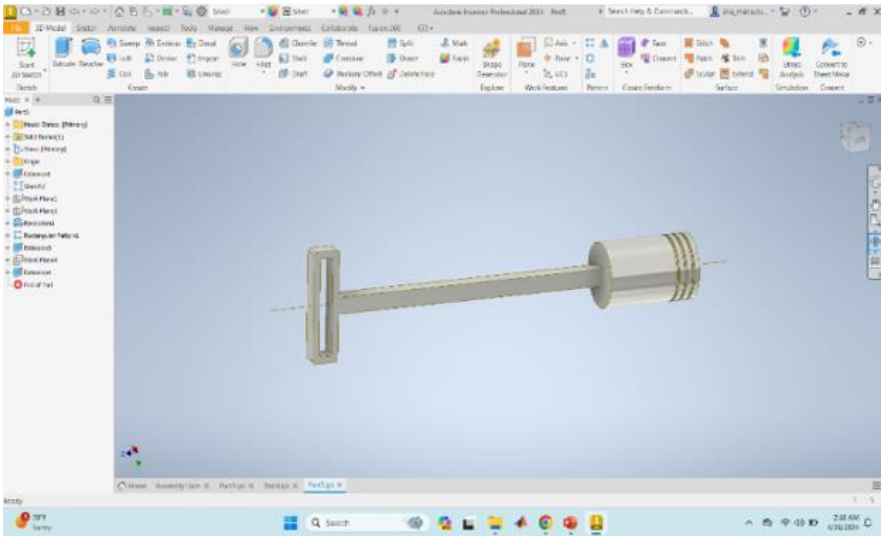

Fig.7. Creation of the piston

Once all the component parts of the mechanism have been individually modeled (Fig. 5, Fig. 6, Fig. 7), they can be assembled into an assembly. The program's assembly functionality allows for the placement and fastening of each part in the correct position within the mechanism. It also allows for the definition of relationships and constraints between parts, such as the movement of the piston inside the cylinder. Once the assembly is complete (Fig. 8), it can be subjected to simulations and analyses to evaluate the behavior and performance of the mechanism under various operating conditions.

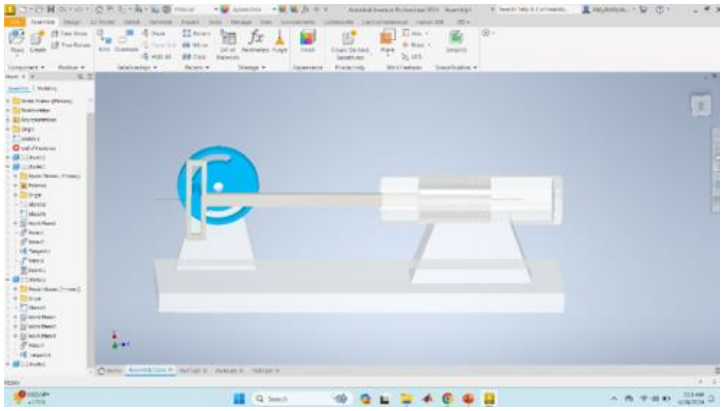

Fig.8. Assembly of the piston-type mechanism

3. Conclusions

The operation of a piston in a pressurized water pump is similar to a piston in an internal combustion engine, in the sense that it moves up and down within a cylinder. During the downward stroke of the piston, water is drawn into the cylinder through an intake valve, and during the upward stroke of the piston, the water is compressed and forced out of the cylinder through a pressure valve into the piping system or a storage tank for pressurized water. In this way, the piston in a pressurized water pump serves to create a flow of pressurized water through its oscillating motion within a cylinder, ensuring the supply of pressurized water needed for various activities and applications [6].

4. Bibliography

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5. Notations

The following symbols are used throughout the paper:
T - Translational motion (of elements/kinematic joints of the mechanism)
R - Rotational motion (of elements/kinematic joints of the mechanism)

STRUCTURAL - KINEMATIC ANALYSIS OF A MOBILE MECHANICAL SYSTEM OF" SPIDER ROBOT" TYPE

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ABSTRACT: In the paper titled "Structural-Cinematic Analysis of a Mobile Mechanical System of 'Spider-Robot'", the analysis of the leg movement mechanism of a spider robot is presented, which represents an essential aspect of its functioning. We investigated how this mechanism is designed and operates to allow the robot to move in an efficient and natural way, inspired by the real movements of spiders. Kinematic analysis methods were used to understand the geometry and connections between the elements of the mechanism, as well as to derive the kinematic equations that describe the leg movement as a function of time and position.

KEYWORDS: mechanical system, robot, structural analysis, kinematic analysis

1. Introduction

Nature is a continuous source of inspiration for robotics, leading to an increasing number of robots replicating natural elements. An example of this is the spider robot, which models its movements after those of spiders in nature. In this project, we focus on analyzing the leg movement mechanism of much a spider robot.

A mechanism is a technical system composed of multiple parts, some of which are mobile and some fixed, interlocked in a way that allows certain mobile elements to transmit forces or movements to other mobile elements within the mechanism [1, 5].

The leg movement mechanism is a fundamental aspect of the functioning of this spider robot and is essential for its ability to move efficiently and adaptably in diverse environments. While spiders in nature demonstrate remarkable agility in movement, reproducing these movements in a robotic context is a challenging subject of study.

Through this work, we aim to analyze in detail the leg movement mechanism of a spider robot. We will investigate the geometry and connections between the mechanism's elements, using kinematic analysis methods to understand how the robot's legs move based on specified parameters. Additionally, we will focus on deriving the kinematic equations that describe the leg movement in relation to the overall movement of the robot. Since the legs are identical, we have specifically analyzed one of them.

By exploring and understanding this mechanism, we hope to contribute to the development of a better understanding of the capabilities and limitations of nature-inspired robots and to facilitate progress in the field of robotics.

2. Mechanism assembly

The first step in this study was the assembly process of the spider robot. As implied by its name, both the appearance and functionality of this robot are inspired by a spider. The spider robot has 8 legs, arranged symmetrically on both sides of its body. The legs move in pairs so that the robot can move forward on surfaces, and its movements resemble those of a real spider as closely as possible.

Next, the components of the legs were measured (Fig. 1).

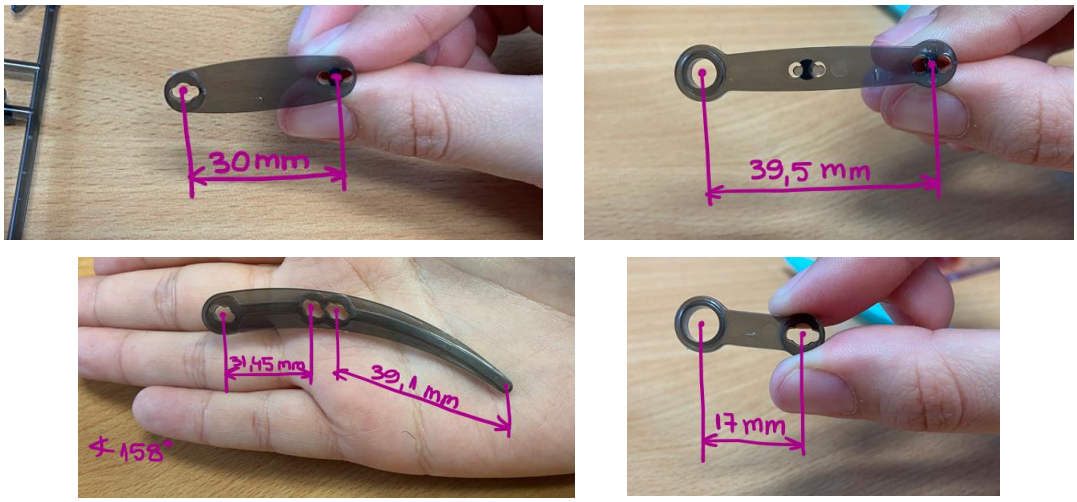


Fig. 1. Measuring the components of the legs

After the measurements were taken, the assembly process (Fig. 2) began as it follows:

Fig. 2. The assembly process

3. Structural analysis

The first step in the structural analysis [2, 3] of our mechanism was to identify the kinematic elements and couplings (Fig. 3). Our mechanical system consists of 7 lower pairs (revolute joints) denoted by letters (A, B, C, D, E, F, G). The system also includes 5 moving elements (Table 1) and one fixed element, called the frame, and denoted by the digit 0.

We establish the following:

n - the total number of kinematic elements - 6

m - the number of moving kinematic elements - 5

i - the number of lower pairs (fifth-class joints) - 7

s - the number of higher pairs (fourth-class joints) – 0

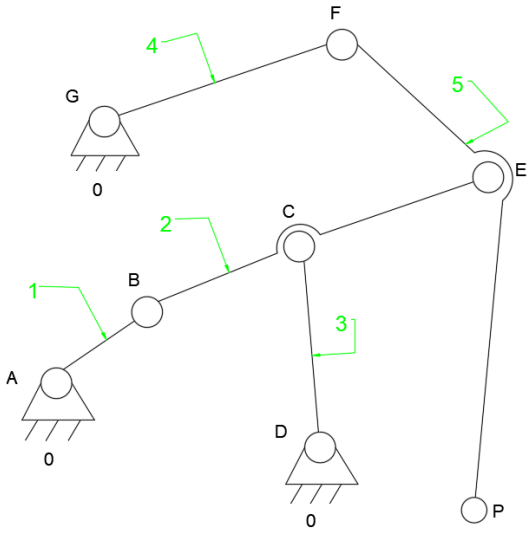


Fig. 3. The kinematic scheme

Table 1. Components

COMPONENT NUMBER	COMPONENT NAME
1	Crank
2	Connecting rod
3	Rocker arm
4	Rocker arm
5	Connecting rod

In the next step, we calculated the degree of mobility (denoted by M), which represents the number of independent parameters that position the moving elements relative to the fixed or considered fixed element.

$$M = 3 \times m - 2 \times i - s \tag{1}$$
$$M = 3 \times 5 - 2 \times 7 - 0 = 1$$

In this stage we also calculated the number of independent loops (denoted by N), which provides the number of independent vector equations.

$$N = i + s - m \tag{2}$$
$$N = 7 + 0 - 5 = 2.$$

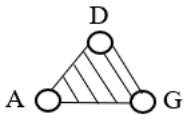
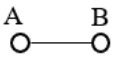
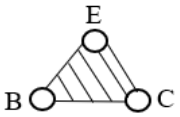
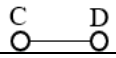
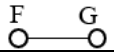
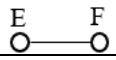
In the third stage, we created the table of kinematic pairs (Table 2):

Table 2. Kinematic pairs

KINEMATIC PAIR	PERFORMED MOTION	NOTATION	CONNECTION BETWEEN KINEMATIC ELEMENTS	PAIR'S CLASS
A	Rotation	A (0, 1) - R	Frame 0 – Crank 1	V
B	Rotation	B (1, 2) - R	Crank 1 – Connecting rod 2	V
C	Rotation	C (2,3) – R	Connecting rod 2 – Rocker arm 3	V
D	Rotation	D (0,3) – R	Rocker arm 3 – Frame 0	V
E	Rotation	E (5,2) – R	Connecting rod 2 – Connecting rod 5	V
F	Rotation	F (5,4) – R	Rocker arm 4 – Connecting rod 5	V
G	Rotation	G (0,4) – R	Frame 0 – Rocker arm 4	V

Continuing the structural analysis, we created the table of kinematic elements (Table 3):

Table 3. The elements

KINEMATIC ELEMENT NUMBER	PAIRS BELONGING TO THE KINEMATIC ELEMENT	KINEMATIC ELEMENT NAME	REPRESENTATION
0	A, D, G	Ternary	
1	A, B	Binary	
2	B, C, E	Ternary	
3	C, D	Binary	
4	F, G	Binary	
5	E, F	Binary	

Eventually, we created the structural diagram presented in Fig. 4.

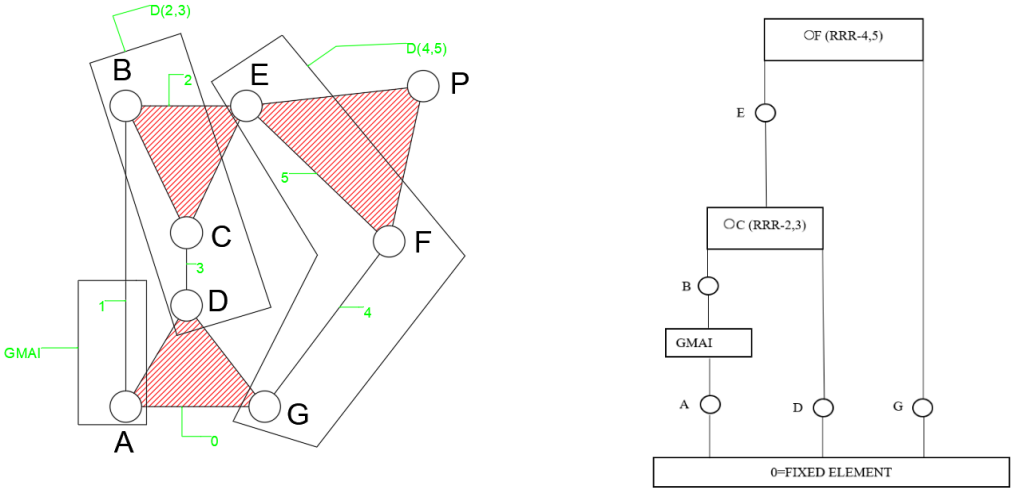


Fig. 4. The structural scheme (left) and the connection diagram (right)

At the end of this stage, we created the connection diagram (Fig. 4).

Structural relationship: GMAI (0,1)-RRR (2,3)-RRR (4,5)

4. Kinematic analysis

Initial data:

$XA = 18.25;\quad YA = 0;\quad AB = 5.72;\quad BC = 18.2;\quad CD = 18;\quad XD = 33.7;$
$YD = -10.5;\quad CE = 21.5;\quad GF = 29.3;\quad FE = 26.5;\quad XG = 16;\quad YG = 18;$
$k = 0 \ldots 360;\quad EP = 56;\quad \alpha deg = 27;\quad \omega 11 = 2.5;\quad w12 = w11$

$\phi 11_k = k \cdot \frac{\pi}{180}$ $\alpha = \alpha deg \cdot \frac{\pi}{180}$

Kinematic analysis [4] of the mechanism is presented in Table 4 and 5.

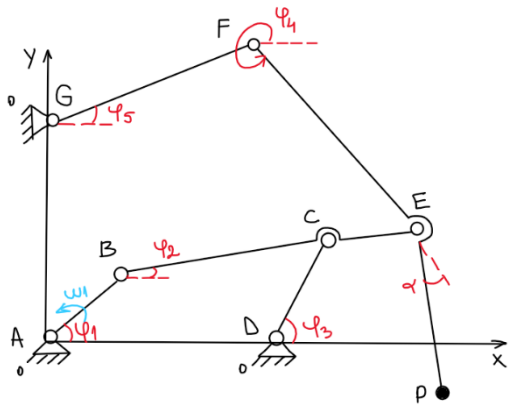


Fig 5. Kinematic analysis of the mechanism

Table 4. The equations of positions

Equations of positions for the first pair of legs	$XB1_k = XA + AB \cdot \cos(\phi 11_k)$ $YB1_k = YA + AB \cdot \sin(\phi 11_k)$ $XD = XB1_k + BC \cdot \cos(\phi 21) + CD \cdot \cos(\phi 31)$ $YD = YB1_k + BC \cdot \sin(\phi 21) + CD \cdot \sin(\phi 31)$ $\phi 21deg_k = \phi 21_k \cdot \frac{180}{\pi}$ $\phi 31deg_k = \phi 31_k \cdot \frac{180}{\pi}$ $XE1_k = XB1_k + (BC + CE) \cdot \cos(\phi 21_k)$ $YE1_k = YB1_k + (BC + CE) \cdot \sin(\phi 21_k)$ $\phi 41 = 0.3$ $\phi 51 = 4$ $XE1_k = XG + GF \cdot \cos(\phi 41) + FE \cdot \cos(\phi 51)$ $YE1_k = YG + GF \cdot \sin(\phi 41) + FE \cdot \sin(\phi 51)$ $\phi 41deg_k = \phi 41_k \cdot \frac{180}{\pi}$ $\phi 51deg_k = \phi 51_k \cdot \frac{180}{\pi}$ $XP1_k = XE1_k + EP \cdot \cos(\phi 51_k - \alpha)$ $YP1_k = YE1_k + EP \cdot \sin(\phi 51_k - \alpha)$
Equations of positions for the second pair of legs	$XB2_k = XA + AB \cdot \cos(\phi 12_k)$ $YB2_k = YA + AB \cdot \sin(\phi 12_k)$ $\phi 12_k = \pi + \phi 11_k$ $\phi 22 = 0.0$ $\phi 32 = 4.7$ $XD = XB2_k + BC \cdot \cos(\phi 22) + CD \cdot \cos(\phi 32)$ $YD = YB2_k + BC \cdot \sin(\phi 22) + CD \cdot \sin(\phi 32)$ $\phi 22deg_k = \phi 22_k \cdot \frac{180}{\pi}$ $\phi 32deg_k = \phi 32_k \cdot \frac{180}{\pi}$
Determination of the position of joint E2	$XE2_k = XB2_k + (BC + CE) \cdot \cos(\phi 22_k)$ $YE2_k = YB2_k + (BC + CE) \cdot \sin(\phi 22_k)$ $\phi 42 = 0.3$ $\phi 52 = 4$ $XE2_k = XG + GF \cdot \cos(\phi 42) + FE \cdot \cos(\phi 52)$ $YE2_k = YG + GF \cdot \sin(\phi 42) + FE \cdot \sin(\phi 52)$ $\phi 42deg_k = \phi 42_k \cdot \frac{180}{\pi}$ $\phi 52deg_k = \phi 52_k \cdot \frac{180}{\pi}$ $XP2_k = XE2_k + EP \cdot \cos(\phi 52_k - \alpha)$ $YP2_k = YE2_k + EP \cdot \sin(\phi 52_k - \alpha)$

The following figures show the positions of the kinematic pairs and their trajectory during the functioning of the mechanism (Fig. 6, Fig. 7).

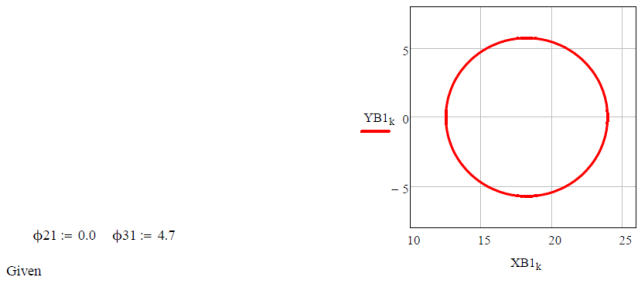


Fig. 6. Trajectory of kinematic pair B

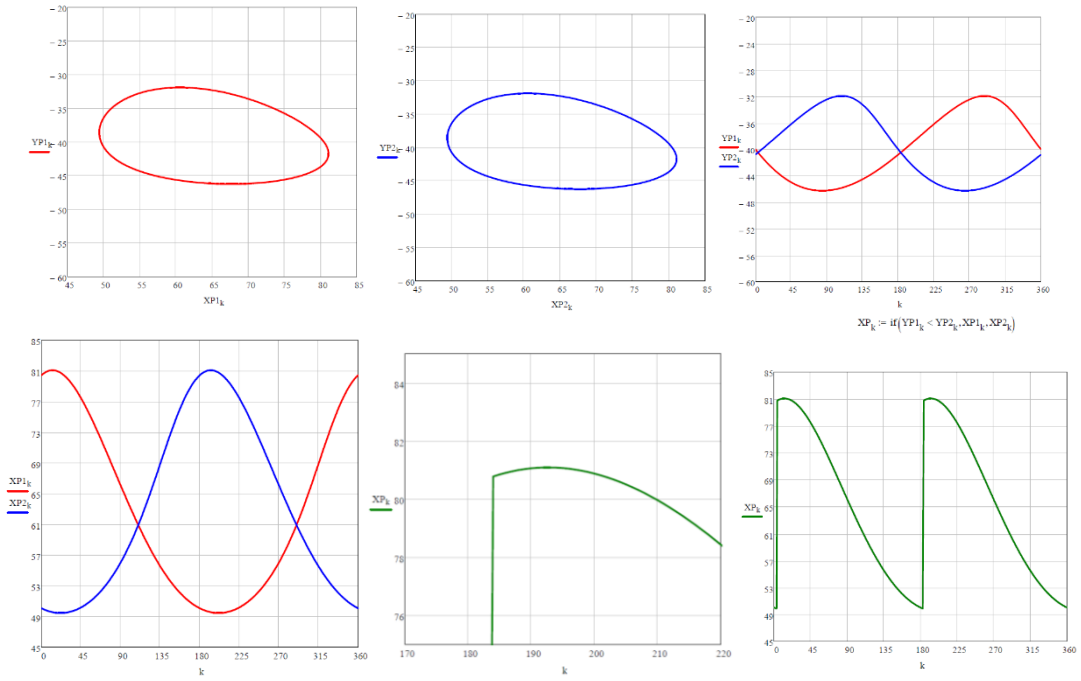


Fig. 7. Positions of kinematic pairs

Table 5. The equations of velocities

	$dYP_k = \lvert YP2_k - YP1_k \rvert$ $kTrans = match(\min(dYP), dYP)$ $XP1_3 = 80.695 \quad XP1_{183} = 49.9$ $XP2_3 = 49.9 \quad XP2_{183} = 80.695$ $kXPmax = match(\max(XP), XP)$
Equations of velocity for the first pair of legs	$VXB1_k = -AB \cdot \sin(\phi 11_k) \cdot \omega 11$ $VYB1_k = AB \cdot \cos(\phi 11_k) \cdot \omega 11$ $\omega 31_k = \frac{VXB1_k \cdot \cos(\phi 21_k) + VYB1_k \cdot \sin(\phi 21_k)}{CD \cdot \sin(\phi 31_k - \phi 21_k)}$ $\omega 21_k = \frac{VXB1_k \cdot \cos(\phi 31_k) + VYB1_k \cdot \sin(\phi 31_k)}{BC \cdot \sin(\phi 21_k - \phi 31_k)}$ $VXE1_k = VXB1_k - (BC + CE) \cdot \sin(\phi 21_k) \cdot \omega 21_k$ $VYE1_k = VYB1_k + (BC + CE) \cdot \cos(\phi 21_k) \cdot \omega 21_k$

	$\omega 41_k = \frac{VXE1_k \cdot \cos(\phi 51_k) + VYE1_k \cdot \sin(\phi 51_k)}{GF \cdot \sin(\phi 51_k - \phi 41_k)}$ $\omega 51_k = \frac{VXE1_k \cdot \cos(\phi 41_k) + VYE1_k \cdot \sin(\phi 41_k)}{FE \cdot \sin(\phi 41_k - \phi 51_k)}$
	$VXP1_k = VXE1_k - EP \cdot \sin(\phi 51_k - \alpha) \cdot \omega 51_k$ $VYP1_k = VYE1_k + EP \cdot \cos(\phi 51_k - \alpha) \cdot \omega 51_k$
Velocity results	$VXP1_{13} = -0.353$ $YP1_{13} = -41.771$ $YP2_{13} = -39.495$ $VXP1_{202} = 0.075$ $YP1_{202} = -38.566$ $P2_{202} = 42.861$
Equations of speed for the second pair of legs	$VXB2_k = -AB \cdot \sin(\phi 12_k) \cdot \omega 12$ $VYB2_k = AB \cdot \cos(\phi 12_k) \cdot \omega 12$ $\omega 32_k = \frac{VXB2_k \cdot \cos(\phi 22_k) + VYB1_k \cdot \sin(\phi 22_k)}{CD \cdot \sin(\phi 32_k - \phi 22_k)}$ $\omega 22_k = \frac{VXB2_k \cdot \cos(\phi 32_k) + VYB2_k \cdot \sin(\phi 32_k)}{BC \cdot \sin(\phi 22_k - \phi 32_k)}$ $VXE2_k = VXB2_k - (BC + CE) \cdot \sin(\phi 22_k) \cdot \omega 22_k$ $VYE2_k = VYB2_k + (BC + CE) \cdot \cos(\phi 22_k) \cdot \omega 22_k$ $\omega 42_k = \frac{VXE2_k \cdot \cos(\phi 52_k) + VYE2_k \cdot \sin(\phi 52_k)}{GF \cdot \sin(\phi 52_k - \phi 42_k)}$ $\omega 52_k = \frac{VXE2_k \cdot \cos(\phi 42_k) + VYE2_k \cdot \sin(\phi 42_k)}{FE \cdot \sin(\phi 42_k - \phi 52_k)}$ $VXP2_k = VXE2_k - EP \cdot \sin(\phi 52_k - \alpha) \cdot \omega 52_k$ $VYP1_k = VYE2_k + EP \cdot \cos(\phi 52_k - \alpha) \cdot \omega 52_k$
Results	$VXP2_{193} = -0.353$ $YP1_{193} = -39.495$ $YP2_{193} = -41.771$ $VXP2_{22} = 0.075$ $YP1_{22} = -42.861$ $P2_{202} = -38.566$

The diagrams for velocities are presented in the figures below.

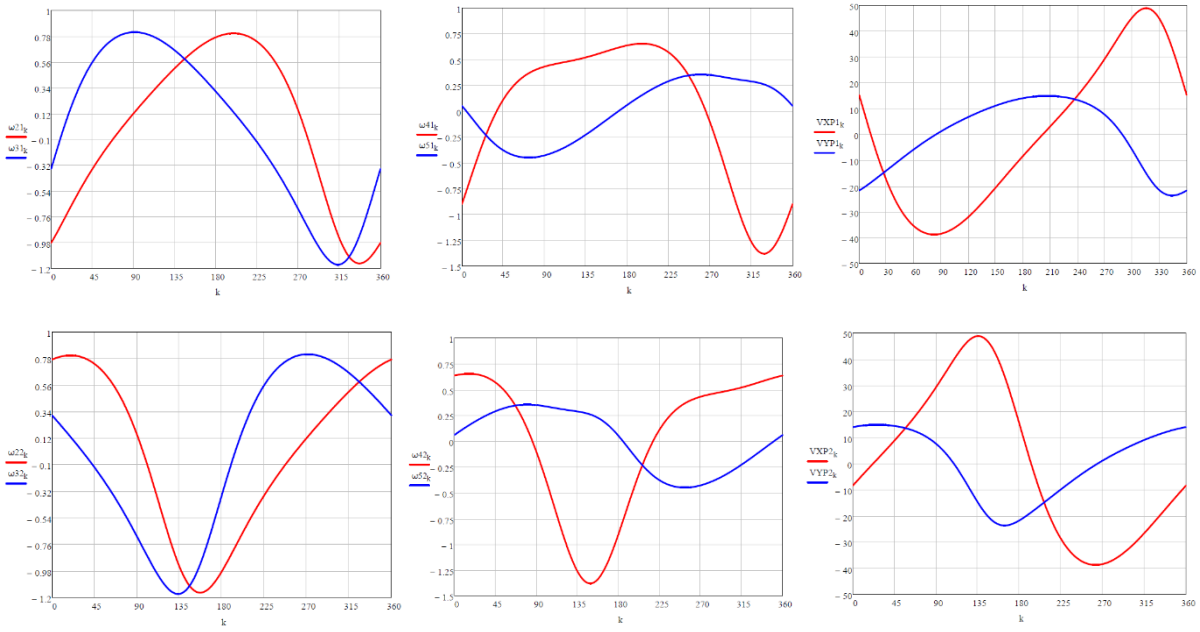


Fig. 8. The velocities diagrams

The distance covered during one full rotation of the crank is [mm/rot]:

$S = (XP1_3 - XP1_{183}) + (XP2_{183} - XP2_3)$

$S = 61.59$

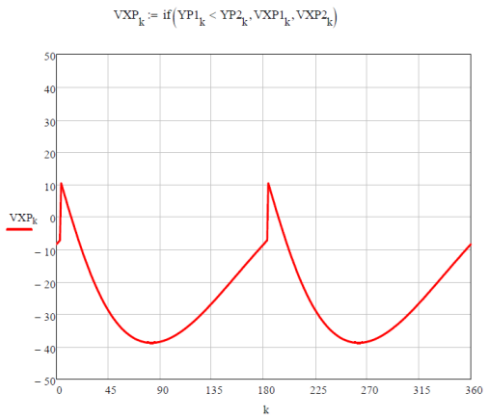


Fig. 9. The velocity diagram

If the mechanism is optimized (no backward movement), the distance increases up to:

$Sopt = \max(XP1) - \min(XP1) + \max(XP2) - \min(XP2)$

$Sopt = 63.305$

5. Conclusions

Conclusions about the spider mechanism:

1. Improved maneuverability: the spider mechanism can provide a wide range of movements, allowing a robot or machine to navigate easily in complex environments or perform detailed tasks.
2. Various applications: a spider mechanism can be used in various fields, including robotics, medicine, space exploration, as well as industries such as manufacturing and assembly.
3. Flexibility and adaptability: the ability to simulate the movements of a spider offers significant flexibility and adaptability in various scenarios and work environments.
4. Energy efficiency: by mimicking natural movements, a spider mechanism can be designed to be energy-efficient, which is important in mobile or autonomous applications.

Regarding the use of a spider mechanism as a component for another mechanism, it can be integrated into various systems to improve their functionality and maneuverability. For example, a spider mechanism could be used as part of an object manipulation system in an assembly line. Its ability to provide precise and agile movements makes it suitable for integration into a variety of technological applications.

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