

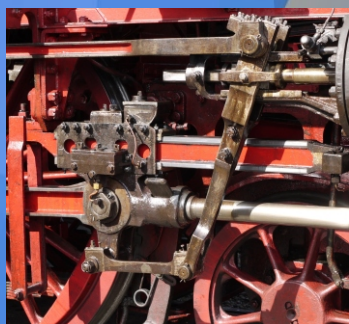
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Highway monitoring using an unmanned aerial vehicle with machine vision.

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Abstract: An increasing number of drones with a specific purpose are being developed globally. They are used in agriculture for crop monitoring and spraying, as well as in national defence, border control, etc. Time-consuming and expensive monitoring and tracking activities can be performed more efficiently in terms of time, cost and safety. The aim of this research is to develop an unmanned aerial vehicle (UAV) platform equipped with onboard artificial intelligence capability for automated monitoring of roads and roadsides. Roadside monitoring is intended for road sections where the presence of a human supervisor is unreasonable or limited by safety standards. The UAV will be set to fly along a predetermined route without pilot intervention. By using machine vision, road sections where defects have appeared are identified and recorded for later human inspection. The solution developed as a result of this study can be adapted for industrial use, for example, maintenance monitoring of conveyors or large storage areas on the premises of factories.

Keywords: DRONE, UNMANNED AERIAL VEHICLE, MACHINE VISION.

1. Introduction

An unmanned aircraft, or a drone, is by definition an aircraft that does not have a pilot on board and is controlled autonomously by means of technical aids or set on a pre-programmed flight path without the control of a pilot [1]. Drones have been used in warfare for a long time, with the first tests dating back to the First World War. In recent years, civilian use has also skyrocketed. Drones have been particularly effective in tasks that are either difficult for people to access, dangerous, or where the activity is not reasonable for people in terms of time or efficiency. Such activities include aerial photography, landscape mapping, scanning of large objects with various sensors, rapid dispatch of parcels, border surveillance and monitoring, assessment of environmental conditions, and agricultural monitoring. There are certainly additional fields of use, and with the further development of drones, the number of activities continues to grow. It is estimated that between 2015 and 2023, the civilian drone industry will grow at a steady rate of 19% annually. Despite the industry being in its early stages, leading R&D companies in Europe, Asia and North America have already emerged.

Technologically, the development of drones can be divided into seven generations [2]:

- Generation I - Radio-controlled unmanned aerial vehicle;
- Generation II - Fixed camera for recording video and still images;
- Generation III - Camera being added to a two-axis gimbal, with rudimentary safety systems and piloting assistance;
- Generation IV - Well-established platform solution, with a camera on a three-axis gimbal, high-resolution video recording 1080p, improved safety systems and autopilot;
- Generation V - 360-degree gimbal camera, video recording in 4K or higher quality, intelligent pilot assistance;
- Generation VI - A solution suitable for various business activities while considering safety and other relevant standards and norms, load carrying capacity, automated safety systems. Intelligent autopilot with fully autonomous capability;
- Generation VII - Autonomous mission capability.

A study conducted in the USA researched drone usage by fields of business, see **Figure 1**. Aerial photography, real estate, and research continue to be the most common fields of use. From this, one could assume that a similar picture emerges in Europe as well.

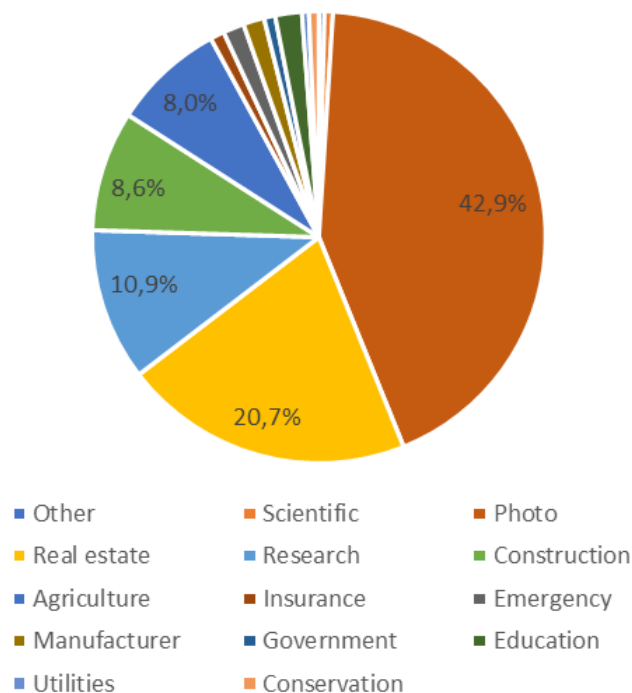


Figure 1. Drone usage by sectors [3].

Drones can be classified according to the purpose of use, field, design, aerodynamic features, payload, and other more specific characteristics. The broadest classification of drones by purpose is civil and military use. Since military drones are generally developed as offensive weapons, for reconnaissance, fire-control, surveillance or some other similar tasks, their application for civilian purposes is either too expensive or difficult for various reasons. The current study does not cover military drone technologies.

Civilian drones can be divided into three major groups according to their purpose of use: toys, recreational drones, and professional drones. From now on, only drones for professional use for a specific task will be considered.

Due to their aerodynamic characteristics, professional drones can be divided into four main groups, each of which is suitable for carrying out a mission with a specific profile:

- a) A drone with several rotors (Multirotor), see **Figure 2** (a). These are particularly suitable for monitoring purposes in limited airspace and mainly on the basis of visual contact with the operator. The advantage of this type of drone is their compactness and user-friendliness. They are usually small in overall dimensions and do not require much space or a runway to operate. For the pilot, controlling the drone is simplified by various intelligent software and hardware solutions. As a rule, an aircraft of this type will have electric motors and is powered by a battery.

However, the disadvantage of such electric drones is shorter flight endurance, which results from the limited capacity of the batteries.

- b) Rigid-wing drone - The advantage of this drone is its long range, which is achieved by using an aerodynamic wing. The majority of the power source's energy is spent on moving the machine forward, see **Figure 2** (b). As a result, fixed-wing drones are used for monitoring open spaces and large-scale objects such as fields, roads, etc. The downside is the size of the machines. As a rule, the wingspan is over one meter, which means a suitable runway for takeoff and landing is required. Internal combustion engines are often used in this design. Depending on the type of internal combustion engine, there may be stronger vibrations compared to electric drives. Fixed-wing drones must have an aerodynamic shape and land on a downward slope. Therefore, any load or observation modules are generally integrated into the body. Often only experienced pilots can operate such drones. They are able to take off and land safely so that the equipment remains intact.
- c) Single main rotor helicopter drone, **Figure 2** (c) - similar in design to a helicopter. This type of drone can, in principle, be flown longer than a multi-rotor drone.
- d) Hybrid drones - In drone taxonomy, the term VTOL is used to describe a fixed-wing aircraft that takes off and lands in a vertical position, see **Figure 2** (d). However, when reaching flight speed, the aircraft switches to horizontal flight like fixed-wing aircraft, and when the speed decreases, it changes the direction of movement to vertical again. Such a design has several advantages - the aerodynamic design gives it an advantage over a conventional helicopter drone in terms of flight range, and the VTOL landing is as comfortable as a helicopter drone without requiring a long landing strip. These types of drones are good for monitoring large objects. Other hybrid drones have also been developed, the design of which incorporates combinations of all of the above types. One such hybrid is called a transition-type drone. These are helicopter drones that also have fixed wings. At least one propeller is placed horizontally, which is used for the vertical direction. The wings provide additional lift. One drone can use several power sources - electric drives and internal combustion engines. With this type of drone it is possible to perform observation flights in very different conditions.

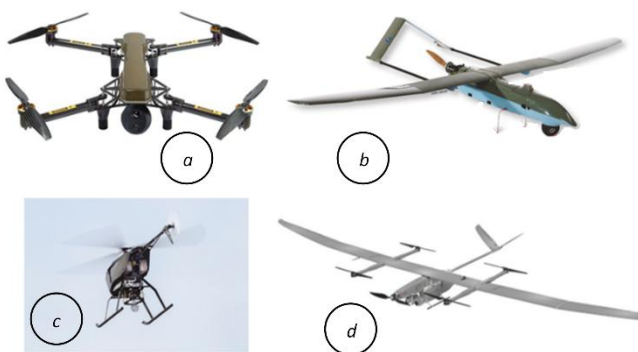


Figure 2. Drones grouped by their aerodynamic characteristics [4], [5], [6].

2. Development

The mission profile envisages flying the drone over a route where the drone is located above a roadway safety strip, separation strip or slope zone on the left side of the roadway in relation to the

direction of flight. The vertical position of the drone is 3 to 5 m above the ground, except in cases where it is necessary to overcome an obstacle. The choice of flight height is based on the camera's optimal field of vision, the average size of detected objects, and safety. Flying over the carriageway has been reduced to a minimum to ensure safety and is only used if the track moves perpendicularly across the lanes. The test route is approximately 1 km long. The drone takes off and lands at the same point. During the (over)flight, the UAV will be recording video footage of the detected objects and marking their location using a GPS.

Based on the specifics of the mission, a maximum possible speed is determined, which allows the detection of deficiencies in road maintenance from the video footage. Based on the established parameters the maximum length of the route to be monitored within one month would be up to 300 km. The average range of one flight is estimated to be 3 to 10 km. The take-off and landing of the should preferably take place from a limited safety area along the road without the need for additional launch equipment. It must be possible to decelerate the drone to low speeds of 3 to 5 km/h during takeoff and landing to ensure personnel safety. Transport to the starting and landing area should be carried out with the same vehicles that are currently in use for monitoring. Therefore, the overall dimensions of the drone should not be larger than 1 x 1 x 0.5 m to ensure easy transportation by car.

Table 1. Drone type ranking by general characteristics.

Characteristics	Multirotor	Rigid wing	Helicopter	Hybrid
Vertical takeoff and landing	Yes	No	Yes	Yes
Flying at speeds 3 ... 6 km/h	Yes	No	Yes	Yes
Flying at speeds 55 ... 90 km/h	Yes	Yes	Yes	Yes
Range 10 km	No	Yes	Yes	Yes
Dimensions 1 x 1 x 0,5 m	Yes	No	No	Yes
Transportability	Yes	No	No	Yes
Optimal shape	Yes	Yes	No	No
Rank:	2	4	3	1

The requirements listed above, see **Table 1**, are best met by a hybrid class drone capable of vertical takeoff and landing, that is able to transition to airplane mode to cover longer distances. Flying in airplane mode ensures a longer mission range, minimizing the number of flights and decreasing flight preparation time. Drones of this type are generally developed to perform a specific task, and their acquisition cost is not practical within the scope of this study.



Figure 3. Drone flight testing.

As this study mainly focuses on analysing the feasibility of monitoring, it is reasonable to compromise at the expense of the flight range and the time required for flight preparation. As a result, a multi-rotor drone that operates on battery power was found to be the most optimal. A drone of this type is capable of taking off and landing on the spot, with no additional equipment needed. It is able to fly at low speeds and can adjust the speed to record the best possible video. Having smaller dimensions, drones of this class can also fit in the trunk of a car. On the other hand, the flight duration and range of this class are limited. The drone developed as a result of this study is shown in Figure 3.

The drone has been designed in a way that ensures that the prototype can be configured to perform various tasks at the same time at optimal cost. The overall construction is shown in **Figure 4**. The drone consists of a base frame, Figure pos 1, to which all components are attached. The TBS Source X carbon composite frame assembly is used as the base frame. The selection was made primarily on the basis of mass, configurability and cost efficiency. Mad Polar XC5000 380kV brushless permanent magnet motors, Figure pos 2, are used. The flight computer and the necessary auxiliary systems are placed between the lower and upper plates of the frame, providing them with the best protection in the event of a collision. The battery packs are placed under the drone and are attached to the bottom plate with velcro straps, Figure pos 3. A cargo attachment slot is attached to the bottom plate, Figure pos 4. It is possible to connect additional devices to the attachment slot using a 10 mm diameter rod. The rod is fixed with an M3 set screw. The camera is mounted by using a 1/4-20 UNC thread. The attachment rod is designed with a weak part that breaks in the event of a collision, pos. 5 in the figure, thereby ensuring minimal damage to the camera.

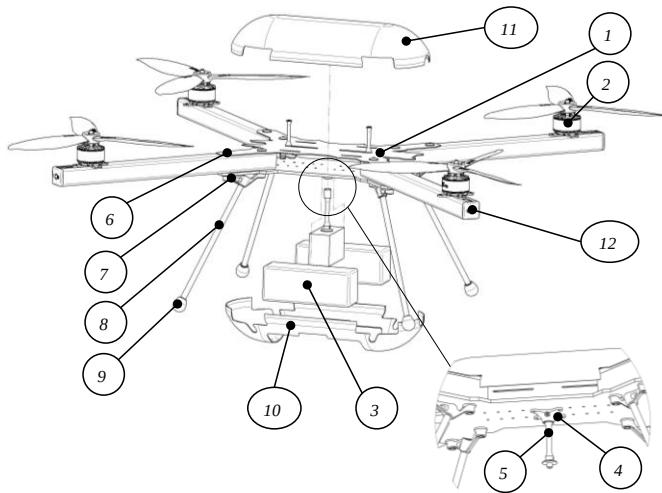


Figure 4. Prototype construction.

Lightweight bolts are used to connect the frame and motor beams, Figure pos 6, which also fasten the landing gear supports, Figure pos 7. The landing gear consists of a leg tube, Figure pos 8 and an end plug, Figure pos 9. The landing gear is designed to withstand five times the weight of the drone and absorb energy after exceeding it, ensuring minimal damage to other components. A cost-effective aluminum tube is used for the leg tube, which can be quickly replaced, as it does not require special tools and can also be performed on-site. A lower and upper cover, Figure pos 10 and pos 11, is installed around the center of the frame, which protects the electronics to some extent from environmental conditions.

The drone is controlled by three integrated systems. **Figure 5** shows the names of the components, the connections between them and the approximate placement on the drone: 1 - Motor MAD Polar XC5000 380kV, 2 - Motor controller APD 120F3, 3 - Distribution block APD PDB500, 4 - Onboard computer BrainFPV RADIX Flight Controller, 5 - Transmitter/receiver (radio) TBS Crossfire

Diversity Nano RX, 6 - Receiver antenna (video) 2.4Ghz Yagi, 7 - Transmitter (video) Unify 2G4 800mW, 8 - FPV camera Caddx Ratel, 9 - Antenna (video) VAS 2.4GHz Victory Antenna, 10 - GPS antenna, 11,12 - Battery Tattu R-Line 22.2 V 4000mah 6S 95C.

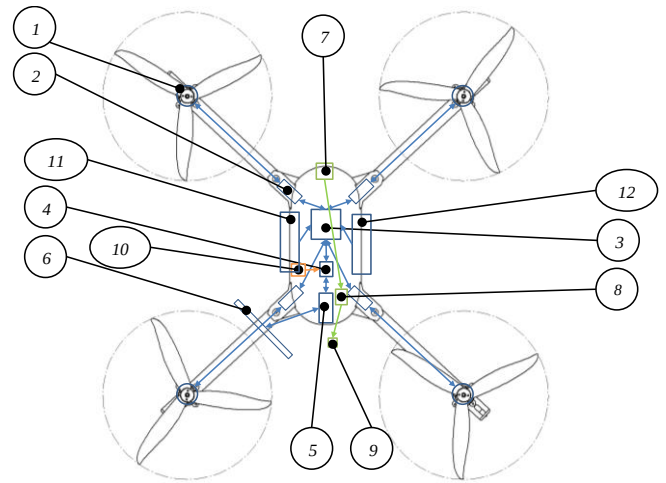


Figure 5. Integrated systems of the prototype.

3. Machine Vision

Digital image processing using algorithms was developed in the 1960s at the Massachusetts Institute of Technology and the University of Maryland [7]. The technology was extremely expensive and time-consuming at the time and did not find widespread use. It wasn't until the 2000s, when mainstream computers had achieved the required computational power to produce real-time images at reasonable costs, that the technology was widely adopted. [8].

The following provides an overview of a possible partially automated solution that helps to reduce human workload when detecting highway defects. Using the software OpenCV (Open Source Computer Vision Library), an object recognition system based on video and utilizing machine learning algorithms was created. OpenCV (Open Source Computer Vision Library) is an open-source machine vision and machine learning software library [9] which is suitable for creating a decision-making system based on empirical data using different algorithms and models.



Figure 6. Video footage from the drone's primary camera.

A similar solution where objects are automatically detected is widely used in security cameras, modern passenger cars, and in manufacturing for the purpose of tracking parts on a conveyor belt. Object recognition works by comparing either the colour or shape model of the detecting body with pre-recorded standards. The process of detecting traffic signs is described in the Laguna study [10]. The four stages of object detection are given below:

- Pre-processing of the frame - during this stage, the size of the frame is optimised to ensure fast processing. The

contrast of the frame is corrected to separate objects and reduce noise. The colour of the frame is changed to grayscale. The frame is shown in Figure 6.

- Edge detection of objects in the frame and separation of the objects is performed.
- The shape of the objects is compared with the signature of the objects in the database, also the shape and location of possible road signs in the frame are determined.
- Traffic sign recognition using shape and colour signatures from the database is performed, and the most likely result is displayed.

These four stages are performed for all frames during video recording, as can be seen in **Figure 7**. During post-processing, the probability of detecting road signs is 88...94%, based on the previously mentioned article, which means the technology can be considered as having high potential.



Figure 7. Video frame before and after processing.

The main complicating factors in the identification of objects (traffic signs) are the following [11]:

- The effect of lighting, dependent on the time, day or weather conditions;
- Colour changes due to the age of the object and the effect of radiation;
- Geometry changes due to environmental conditions (corrosion etc.);
- Scale changes as you move closer to the object when recording;
- Similar shapes in the frame;
- Identifiable objects being covered by trees, houses, people, etc;
- Particularities of the photo recording system;
- Vibration and the resulting blurring of the frame.

In addition, the following factors become problematic:

- If there is no sign at all or its shape has changed significantly,
- If the road sign viewing direction is changed.

The purpose of automatic object recognition is to select video segments where objects (traffic signs) are successfully recognised or where the objects should be identified based on their original GPS location but have not been recognised. For example, a spot where a traffic sign should be installed, but is missing, is a risk. After post-processing, only objects that need further detailed evaluation and classification are shown to the inspector.

4. Results and Discussion

During the case-study, a drone prototype was developed that is capable of carrying the necessary equipment for roadway

monitoring and performing detection flights on a given route. In the first stage of the study, the main focus was on the automatic execution of the flight route. As a final result, the drone was able to fly on a pre-entered route at 90 km/h for 30 minutes, covering a maximum distance of 45 km. However, the obstacle avoidance system needs further development, as the drone has to fly relatively close to the observed objects in order to obtain a video with the necessary detail. Also, as trees and bushes grow bigger and taller over time, they can invade the flight corridor area, creating potentially dangerous situations.

The failure probability for various components of the drone must be considered. Due to weight restrictions, the developed drone does not have duplicated systems that would ensure trouble-free operation with a higher probability. A drone with a mass of 5 kg and a flight speed of up to 90 km/h has high kinetic energy, and in the event of a malfunction and/or loss of control, the impact force is considerable. When dealing with such a problem, a potential solution might be to move the drone's flight path higher so that it is possible to use secondary emergency systems, such as ballistic parachutes or the like. An equally important hazard is wild animals who are scared of the noise generated while flying fast and low. The behaviour of startled animals is unpredictable, and in the worst case, an animal may run onto the road causing a potentially dangerous situation.

Although the original research task was set to be the installation of a complete object recognition system on the drone, it was abandoned during the tests. The main reason was the required weight reduction of the drone based on the reasons above, as the weight of the entire system proved to be too high. Object recognition as a technology has developed to a level that allows it to be used to completely fulfill the purpose of the study. However, only a small variety of defects were able to be detected due to the limitations previously described. In order to implement a complete system, a larger number of defects (from roadside garbage to cracks in the roadway) should be automatically detected. The technology has potential but needs further research and development to create a usable system.

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Industry 4.0 assembly line using mixed reality and data lake systems.

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Abstract: This article presents an Industry 4.0 assembly line that employs mixed reality (MR) and data lake systems to optimize the assembly process. MR devices such as HoloLens are used to provide operators with real-time assistance. The data generated by the MR devices is stored in a data lake system, which allows for real-time monitoring of the assembly process. This case study demonstrates the potential for MR and data lake systems to revolutionize traditional manufacturing processes and improve productivity and quality in Industry 4.0.

Keywords: ASSEMBLY PROCESS, MIXED-REALITY, DATA LAKE, BEARING, INDUSTRY 4.0,

1. Introduction

The assembly line discussed in this study comprises eight stations, which include both assembly stations and quality control stations. The goal is to leverage the power of cutting-edge technologies to streamline and optimize the production process, ensuring precise assembly and thorough quality control measures. By incorporating data lake systems and mixed reality goggles, manufacturers can unlock new possibilities for increased efficiency, reduced errors, and improved overall productivity.

Data lake systems, characterized by their ability to store vast volumes of structured and unstructured data, offer significant advantages in managing the diverse data generated by assembly line processes. With the integration of sensors, Internet of Things (IoT) devices, and other data collection mechanisms, real-time data can be collected, stored, and processed in the data lake. This facilitates data-driven decision-making, predictive maintenance, and proactive troubleshooting, enabling manufacturers to address potential issues before they escalate into major disruptions. [1-3]

This paper aims to explore the benefits and challenges associated with implementing data lake systems and mixed reality goggles in an Industry 4.0 assembly line. It investigates how these technologies can enhance the bearing assembly process by improving efficiency, accuracy, and quality control. Additionally, the study examines the potential barriers and considerations for successful adoption, including data privacy and security, infrastructure requirements, and training needs.

2. Assembly process

The assembly process of the bearing with housing and bearing cap consists of eight stations, where the product is systematically moved along the assembly line. The initial four stations utilize a conveyor system to transport the product, while the subsequent stations incorporate Cartesian manipulators, vision quality control, and operator intervention to ensure a seamless and high-quality assembly.

Station One: In this station, an operator places the housing of the bearing onto the conveyor. To identify the specific product for the assembly line, an RFID system is employed, allowing for accurate tracking and traceability.



Fig. 1 Assembly line.

Station Two: A Cartesian manipulator operates in this station, precisely inserting the bearing into the housing. The manipulator's controlled movements ensure proper alignment and fit between the bearing and the housing.

Station Three: Another Cartesian manipulator (**Fig. 1**) takes charge in this station, positioning the bearing cap onto the housing. The manipulator's precise movements guarantee a secure and accurate placement of the bearing cap.



Fig. 2 Third station. Bearing cap is positioned on housing.

Station Four: In this station, the bearing cap is securely screwed onto the housing. The assembly line incorporates a screwing mechanism to ensure consistent and reliable attachment, enhancing the overall integrity of the assembly.

Station Five: The assembly line reaches the station where vision quality control is implemented. Advanced vision systems perform a comprehensive visual inspection of the assembled product. Any flaws or defects detected are promptly recorded and sent to a database for further analysis and corrective actions.

Station Six: The product is transported from the fifth station to the sixth station using a Cartesian robot. This robot ensures a smooth and precise transfer of the product, maintaining the workflow along the assembly line.

Station Seven: If any flaws or defects are identified during the quality control inspection, the assembly line stops at this station. Skilled operators stationed here correct the detected issues or, if necessary, disassemble the bearing assembly for proper corrective measures.

Station Eight: In the final station, an industrial robot takes over to move the completed product to the repository field. This robot handles the transfer of the assembled product efficiently, ensuring smooth logistics and storage operations.

3. Management system

In the context of managing data generated in an assembly line, a data lake system proves to be an invaluable and comprehensive tool. Its utilization in this specific scenario is of utmost significance as it takes on a crucial role in effectively handling a multitude of aspects inherent to the assembly process.[4]

In the assembly line system, every product is associated with its own unique data packet, which serves as a comprehensive repository of information. This data packet contains essential details about the product, including the specific components that have been selected for assembly. The components typically include four screws, a bearing, a bearing cap, and a bearing housing, which are vital for the product's functionality and structure.

Additionally, the data packet includes an identification (ID) number assigned to each product, enabling efficient tracking and traceability throughout the assembly process. This ID number serves as a unique identifier, ensuring that each product can be easily distinguished and monitored as it progresses along the assembly line.

Moreover, the data packet captures information about the current station where the product is located within the assembly line. This station information provides real-time visibility into the product's position and allows for effective management of the production flow. It ensures that each product moves through the designated stations in a sequential manner, facilitating a streamlined and organized assembly process.

Furthermore, the data packet includes a status attribute, providing insights into the product's current state. The status can indicate whether the product is "under assembly," signifying that it is currently being worked on by operators and undergoing the assembly process. Alternatively, the status can indicate if the product has been identified as "defective," requiring further inspection or rework. Finally, the status can indicate that the product is "ready," indicating that it has successfully completed the assembly process and is prepared for the next phase, such as quality control or packaging.

By encapsulating this vital information within each product's unique data packet, the assembly line system ensures efficient and accurate tracking, monitoring, and management of each individual product. This data-driven approach allows for improved quality control, enhanced productivity, and effective decision-making throughout the assembly line workflow.

One notable component integrated within the system is a mobile application that empowers users to effortlessly place orders and customize them according to their specific requirements. This feature offers a high degree of flexibility, allowing orderers to select from a range of options, such as choosing the desired elements from a selection that includes four screws, a bearing, a bearing cap, and a bearing housing. This level of customization enhances customer satisfaction and ensures the precise fulfillment of individual needs. Another

the mobile app to retrieve relevant information and submit orders, ensuring a smooth and efficient flow of data.

Within the data lake system, a robust and organized database serves as a centralized repository for all the data generated throughout the assembly line process. It efficiently stores and retrieves information related to orders, customization preferences, and assembly data. This comprehensive database ensures that all relevant data is readily available and accessible when needed, enabling swift retrieval and analysis to support decision-making processes and optimize overall operations.

Integral to the assembly line system are Programmable Logic Controllers (PLCs) that seamlessly interface with the data lake system. These controllers have direct access to the data stored in the database, enabling them to retrieve pertinent information about each order. As the product progresses through different stations along the assembly line, the PLC controllers can modify the status of an order, ensuring accurate tracking and monitoring of the product's journey.

In summary, the data lake system orchestrates seamless coordination between the mobile application, web API, database, and PLC controllers. This integration allows for real-time access to order information, customization options, and assembly data. The system enables efficient management and tracking of the assembly line process, empowering decision-makers with timely and accurate insights, optimizing resource allocation, and facilitating streamlined operations from order placement to final product delivery.

4. Mixed-reality

Mixed reality is leveraged in the assembly line to introduce innovative and transformative capabilities that enhance various aspects of the manufacturing process. In this context, mixed reality technology plays a crucial role by enabling the creation of a digital twin of industrial robots and providing virtual Human Machine Interfaces (HMIs) for operators. Additionally, mixed reality offers the potential to conduct training sessions for workers, utilizing immersive and interactive experiences.

One notable application of mixed reality in the assembly line is the creation of a digital twin of industrial robot. A digital twin is a virtual representation of a physical robot that closely mimics its behavior, characteristics, and movements. By developing a digital twin using mixed reality, manufacturers gain the ability to simulate and test robot movements, sequences, and tasks in a virtual environment before executing them in the physical realm. This virtual prototyping helps optimize robot performance, reduce errors, and minimize downtime, ultimately improving overall productivity and efficiency.[5]

Mixed reality also enables the deployment of virtual Human Machine Interfaces (HMIs) in the assembly line. HMIs are graphical interfaces that allow operators to interact with machines and control systems. By utilizing mixed reality, HMIs can be visualized and accessed in an immersive and intuitive manner. Operators can view and interact with virtual control panels, indicators, and buttons overlaid onto the real-world environment. This augmented visualization enhances operator efficiency, reduces errors, and provides real-time access to critical information and controls, leading to improved overall operational performance.[6]

Moreover, mixed reality offers the opportunity to conduct training sessions for assembly line workers. Through immersive and interactive experiences, workers can receive virtual training in a simulated environment that replicates real-world assembly line scenarios. Mixed reality technology allows trainees to interact with virtual components, tools, and machinery, providing a safe and controlled learning environment. This immersive training approach helps to develop skills, improve efficiency, and ensure consistent quality standards across the workforce.

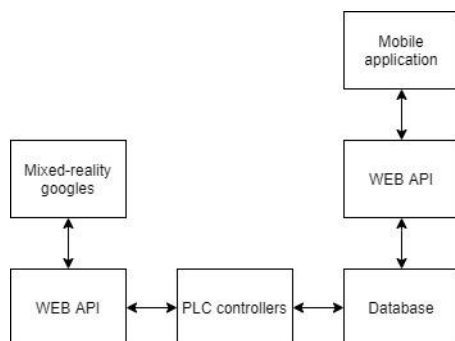


Fig. 3 Schematic diagram of the system

To enable seamless communication between the mobile application and the underlying data management system, the mobile app is connected to a web API. This connection serves as a vital conduit, facilitating the exchange of data between the application and the central database. The web API acts as a gateway, enabling

5. Summary

In summary, the integration of data lake systems and mixed reality goggles in an Industry 4.0 assembly line offers numerous benefits, including increased efficiency, reduced errors, improved quality control, and enhanced productivity. However, there are challenges to overcome, such as data privacy and security concerns, infrastructure requirements, and the need for proper training. By addressing these challenges, manufacturers can unlock the full potential of these technologies and optimize their assembly line operations.

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Simulation Modeling for Mass Customization Furniture Production: Investigating Production Volume and Machine Load in scope of Industry 4.0 standard

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Abstract: The subject of the conducted research and development project was the simulation modeling of solutions for a mass production system of customized furniture. Within the project, a digital twin of the custom furniture production and flexible manufacturing in the FlexSim 3D Simulation Software environment were utilized. The research and development work aimed to investigate the impact of production volume on machine load and the overall system efficiency. The scientific paper presents the methodology of project implementation, as well as the characteristics of input data and the process of producing customized furniture. The functioning logic of the simulation model is also described, along with the outcomes of the solutions for various scenarios. The paper includes the results of computer simulations for individual variants and provides potential recommendations. The project was carried out at Handcraft Sp. z o.o. company.

Keywords: FLEXSIM, INDUSTRY 4.0, SIMULATION MODEL, PROCESS FLOW, OPTIMIZATION, LOGISTICS

1. Introduction

The research and development project aimed to simulate the impact of new solutions on the mass production system of customized furniture. Simulation modeling techniques and the FlexSim 3D Simulation Software environment were utilized to accomplish the aim.

The publication consists of eight main sections. The first section presents the objective of the research and development project. The second section describes the methodology of conducting the research and development work, including process simulation in the FlexSim environment, which was used to evaluate the effects of the new solutions. The third section provides a characterization of the input data, with a detailed compilation of data for the advanced shelf that served as the basis for constructing the simulation model. The fourth section describes the first stage of the production process of customized furniture, which is related to the use of a panel saw. The fifth section presents the logic of the simulation model and the aspects considered when evaluating the results using the example of the panel saw's operation. The sixth section provides a detailed description of the effects of the new solutions for two production volume scenarios for the panel saw: the current production level and a level five times higher. The seventh section presents recommendations for further actions to increase the efficiency of the panel saw. In the final eighth section, other recommended actions are described as a summary of the results of the research project.

2. The aim of the research and development project

The research conducted at Handcraft Sp. z o.o. aimed to develop a simulation model to evaluate the effects of new solutions. The work involved creating a simulation model for the concept of a mass production system for customized furniture. Additionally, a scenario analysis was performed to examine the impact of production volume on machine load and the overall system efficiency. Experimental simulations were also conducted as part of the research to optimize material flow and achieve maximum system efficiency.

This study aims to assess the effects of the solutions by evaluating the ability of the designed system to fulfill orders. Simulation modeling was performed for various production levels, including:

- current production volume,
- two times the production volume,
- three times the production volume,
- four times the production volume,

- five times the production volume.

For each of these variants, simulation modeling was conducted to assess the effects and provide recommendations.

3. Methodology of the procedure

3.1. Process simulation

Simulation involves imitating a real system or process [4, 5, 10]. This is achieved by constructing a model that represents the analyzed problem, enabling experimentation and testing of ideas [8, 13-19]. The model should accurately reflect both the physical and logical aspects of the system, as well as the relationships between them [12, 20-21]. Simulation consists of the following stages:

- defining the analysis objective,
- collecting and analyzing data,
- designing and constructing the model,
- determining experiments to be conducted,
- validating and verifying the model, which involves checking the consistency of the model with the real system or design assumptions,
- analyzing and interpreting the results of the conducted experiments [26, 28, 33].

The classical process of simulation modeling can be presented using a diagram, as shown in Fig. 1.

Research and development work on innovative pallet production technology utilizing full traceability infrastructure has been divided into the following stages [6, 9]:

- data collection,
- analysis of current logistic processes,
- creation of a simulation model for current logistic processes,
- research aimed at locating the new pallet production line and determining the positioning of the purchased DU pallet line and dryer in a way that minimizes transportation distances and improves material flow,
- research aimed at determining the number of required forklift trucks to handle the logistic processes, considering the increased efficiency resulting from the construction of the new pallet production line,
- simulation analysis of logistic processes for different variants of the location of the new pallet production line, DU pallet line, and dryer. Evaluation of resource utilization and transportation distances [3, 7, 24].

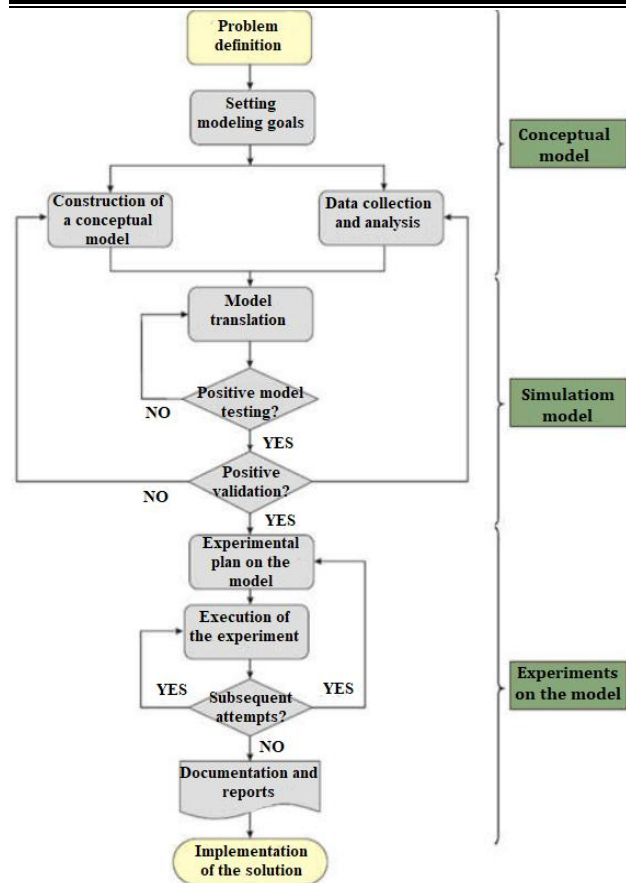


Fig. 1. Stages of simulation modeling [Karkula M.: Modelowanie i symulacja procesów logistycznych. AGH, Kraków (2013), p. 108].

3.2 FlexSim 3D Simulation Software

FlexSim 3D Simulation Software is an advanced simulation package that enables modeling, simulation, and optimization of complex processes [1-2, 11]. It is particularly useful in the areas of manufacturing, logistics, and services. By utilizing OpenGL technology, commonly known among computer game developers, the software allows for the construction of three-dimensional models and realistic visualization of processes [23, 29].

FlexSim offers significant computational capabilities, making it an ideal tool for advanced research and development work. Its advanced numerical layer enables obtaining surprising results through the analysis of selected scenarios and comprehensive exploration of the space of possible solutions [30-32]. The built-in OptQuest® module allows for quick identification of optimal or near-optimal solutions. The Experimenter module enables the repetition of simulation experiments multiple times, depending on the complexity of the problem and variability of individual parameters. Additionally, the ExpertFit® module allows for representing the natural variability of modeled processes by fitting appropriate theoretical distributions to empirical data.

The analysis of results from conducted simulation experiments is facilitated by the available real-time graphs and statistics within the software.

4. Input data

4.1 Order Structure

An analysis of orders was conducted for the period from October 2017 to May 2018 to determine the average product structure for customized furniture and the distribution of furniture types sold. The collected data was used to generate datasets used in the simulation model. The most frequently ordered furniture items are shelves, both basic and advanced, while tables and cubes

represent a small percentage of sales [25, 27]. The order structure of the company during the analyzed period is shown in Chart 1.

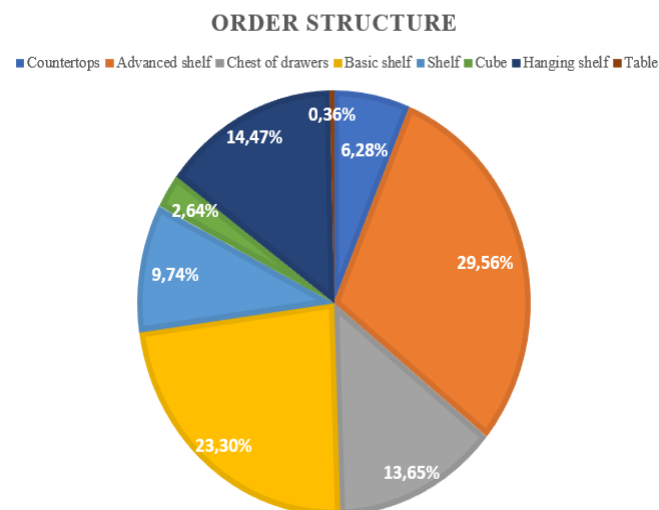


Chart 1. Order structure of the company (own elaboration).

Additionally, a detailed analysis was conducted for each furniture type to determine the type of panels used in the construction of each furniture item (small, medium, or large panels) and the material from which they are made. The analysis considered small panels to have a length of up to 690 mm, medium panels up to 1610 mm, and long panels exceeding 1610 mm.

4.2 Advanced shelf

The majority of orders for advanced shelves consist mainly of one or two types of material panels. The term "material panel" refers to the type of material, such as wood, MDF, HDF, laminate, etc., from which a particular panel is made. The maximum number of different types of material panels in a single order is six. Chart 2 presents the percentage distribution of orders based on the number of types of material panels.

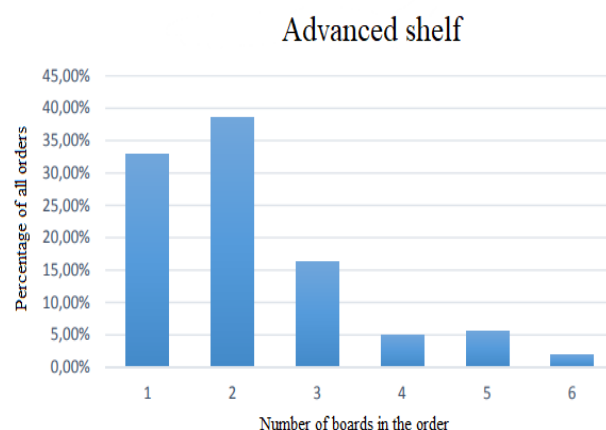


Chart 2. Percentage distribution of orders based on the type of material boards - advanced shelf (own elaboration).

An analysis of panel sizes in various orders was conducted, taking into account the number of panel types in each order. The minimum, average, and maximum number of panels of a specific size were determined. Detailed results for the advanced shelf are presented in Table 1.

Table 1. Analysis of board sizes - advanced shelf (own elaboration).

Number of board types	Number of individual board sizes in the order								
	Small boards			Medium-sized boards			Large boards		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
1	1	12	52	1	3	21	1	2	19
2	2	12	44	2	5	25	1	3	17
3	5	14	48	2	4	13	1	4	19
4	6	35	92	1	6	22	2	4	17
5	11	30	94	2	5	15	1	4	18
6	18	31	50	4	15	40	2	6	15

The main materials used for the production of advanced shelves are MDF and beech wood. Other materials have a small share. Table 2 presents a detailed breakdown of the proportion of each material in the order structure.

Table 1. Proportion of individual materials in the order structure - advanced shelf (own elaboration).

Type of material	Percentage share
Beech – 20 mm	18,11%
Beech – 30 mm	7,59%
Solid beech – 20 mm	2,08%
Solid beech – 30 mm	0,28%
Oak – 20 mm	1,38%
Oak – 30 mm	0,66%
Solid oak – 20 mm	4,66%
Solid oak – 30 mm	1,19%
White HDF	2,13%
Bavarian beech HDF	0,90%
HDF Calvados	0,21%
Black HDF	0,67%
Maple HDF	0,37%
Alder HDF	0,22%
Walnut HDF	0,27%
Gray HDF	0,59%
Ash – 20 mm	0,05%
Ash – 40 mm	0,05%
White MDF – 16 mm	5,06%
White MDF – 18 mm	16,59%
White MDF – 30 mm	0,88%
Lacquered MDF – 18 mm	12,10%
Lacquered MDF – 30 mm	5,20%
Ashen MDF – 18 mm	2,17%
Plywood – 15 mm	2,43%
Pine – 20 mm	8,44%
Pine – 30 mm	2,74%
Pine – 40 mm	0,15%
Solid pine – 20 mm	0,93%
Light oak HDF	1,87%

A similar methodology was applied to analyze:

- basic shelves,
- hanging shelves,
- chests of drawers,
- shelves,
- countertops,
- cubes,
- tables.

4.3 Summary

Based on the analysis of historical orders, it can be concluded that the company currently fulfills orders using both wood and MDF/HDF boards in similar proportions. Approximately 88 panels are cut daily, with a total area of 20 m², out of which 79 m²

undergoes the additional edgbanding process. The edgbanding machine primarily handles MDF boards. Detailed data regarding the number and structure of cut panels are presented in Table 3.

Table 2. Structure of cutouts on a panel board (own elaboration).

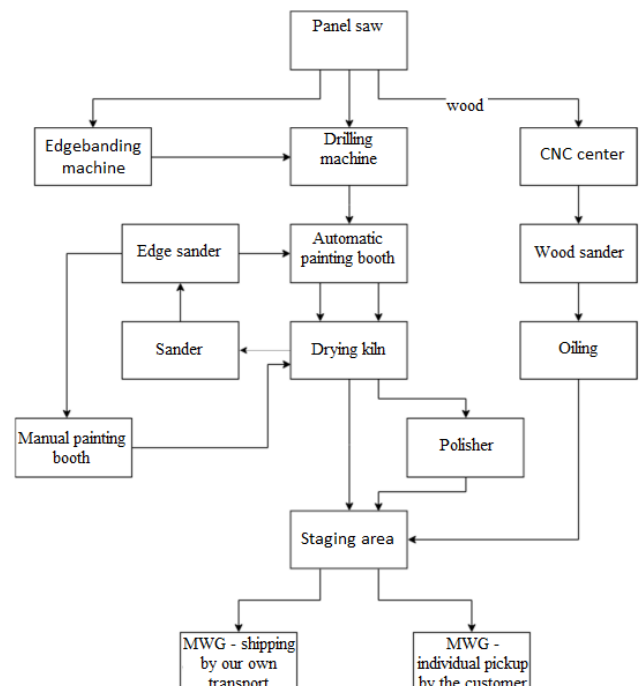
	Wood	Boards	Total	Per day
Total number of panels	9939	9597	19536	88
Total surface area of panels [m ²]	2030	2316	4346	20
Total surface area of panels to be veneered [m]		17353		79

To create a simulation model, the following data sets have been developed:

- data regarding the current production level carried out by the company,
- doubling production - increased the assortment variety by 50 types of decorative boards, while maintaining the proportion of wood in the overall number of orders,
- tripling production - while maintaining the proportion of wood in the overall number of orders,
- quadrupling production - while maintaining the proportion of wood in the overall number of orders,
- quintupling production - while maintaining the proportion of wood in the overall number of orders.

5. Production process

Fig. 2 presents a general diagram of the material flow in the production process. In the following section, a detailed description will be provided for the production stage related to the panel saw.

**Fig. 2. General flowchart of production (own elaboration).**

The first stage of production is the cutting of the panel on the panel saw. Fig. 3 presents a visualization of this tool and the panel storage in the discussed simulation model.

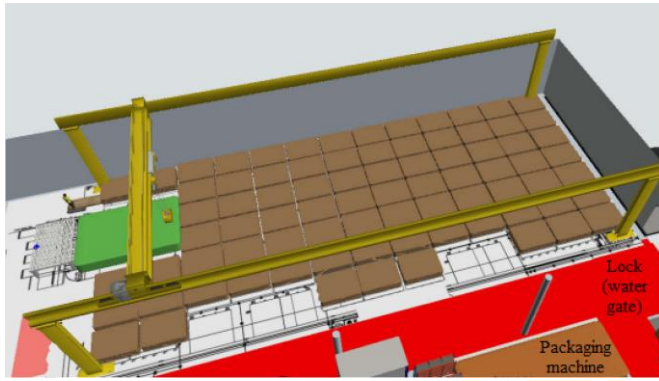


Fig. 1. Visualization of a panel saw with a board storage in a simulation model (own elaboration).

The panel saw, using an automatic feeder, retrieves the appropriate panel from the stack and places it on the saw, which then performs the cutting. The operating principles of the saw are as follows:

- during panel cutting, the saw takes into account orders containing the same material from the next 7 days,
- the material for cutting is taken in the order of order fulfillment, considering the predicted completion time,
- the saw's efficiency, initially set at 50 panels per shift, has been reduced due to the specific nature of orders fulfilled by the company. There is a large number of panels with small sizes and diverse dimensions, as the company produces customized furniture to meet individual customer needs,
- the cut pieces are stacked on a pallet. After the cutting process is completed, the pallet is moved along the roller conveyor towards the transportation path, from where it is transported to subsequent stages of production, depending on the type of furniture.

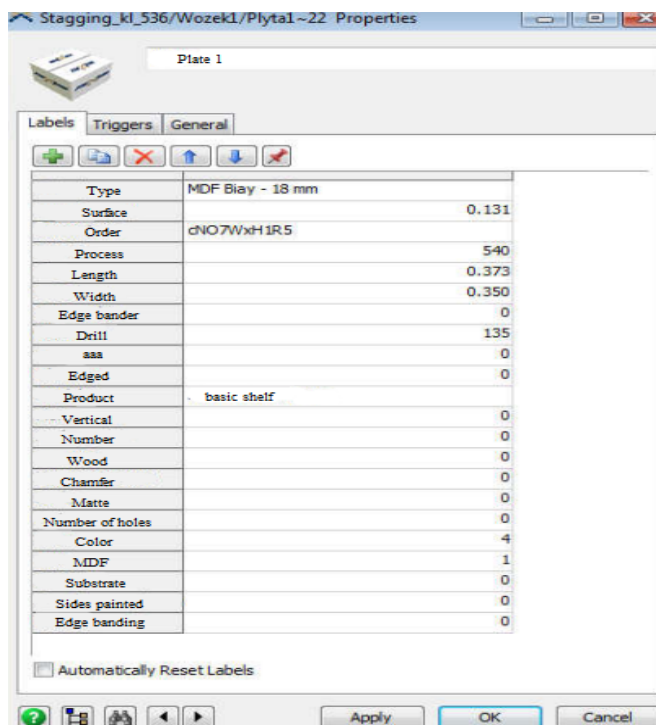


Fig. 2. View of panel properties after being cut by the panel saw (own elaboration).

The cut panels, when processed using the panel saw, exhibit various physical properties that are described in the simulation program, as shown in Fig. 4. After the cutting process is completed, the panel goes through a series of subsequent locations and operations, which include:

- edgebanding machine,
- transport pallet,
- drilling machine,
- CNC center,
- paint shop,
- staging area.

6. Simulation model

The study utilized ProcessFlow technology for constructing the simulation model. ProcessFlow enables centralized logic of element flow using block diagrams [22]. Each diagram element contains controlling code. This flexibility allows for adapting the 3D model to changing conditions. Fig. 5 illustrates the logic of the discussed area of the simulation model, which is the panel saw.

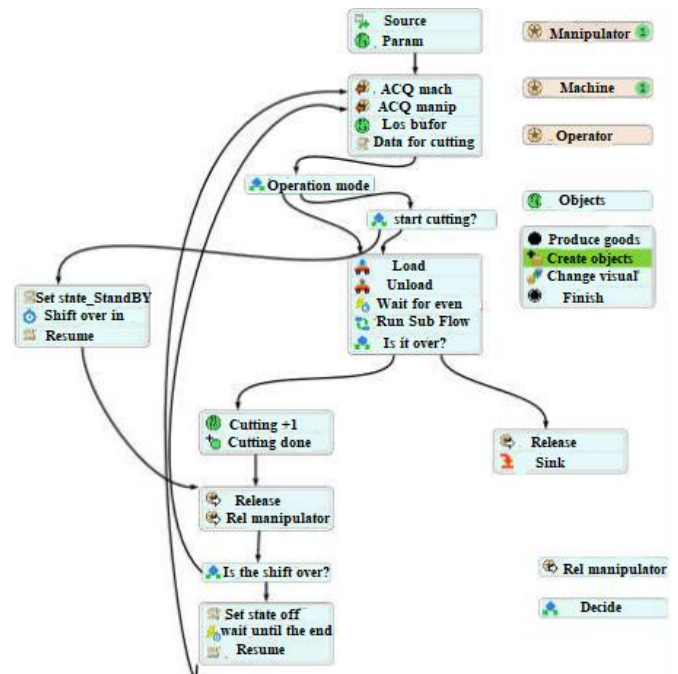


Fig. 3. Logic of operation for the panel saw in ProcessFlow (own elaboration).

Identical drawings depicting the logic of operation were prepared for other areas and actions of the simulation model, namely:

- edgebanding machine,
- transport pallet,
- drilling machine,
- CNC center,
- paint shop,
- staging area.

7. Analyzed variants

7.1 Current production volume

In the current production implementation, the workload of the panel saw remains at a low level, reaching around 10%. Charts 3 to 5 graphically represent the number of working hours, the surface

area of cut panels, and the number of panels cut, respectively, based on individual working days.

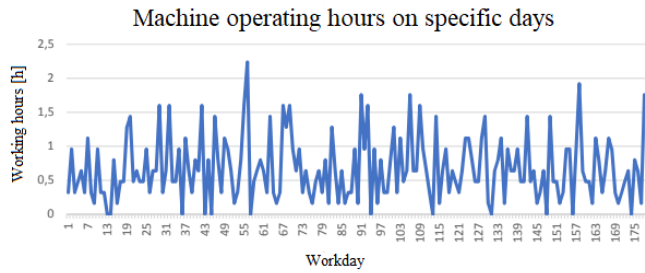


Chart 3. Chart of the number of operating hours of the panel saw on each day of the simulation (own elaboration).

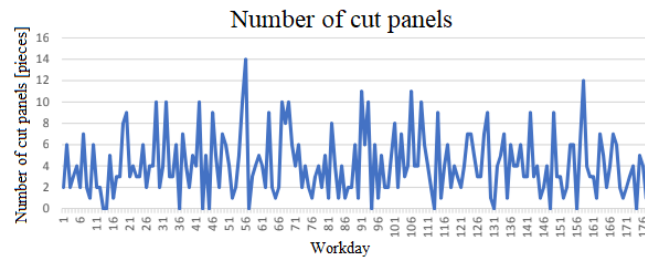


Chart 1. Chart of the number of cut panels by the panel saw on each day of the simulation (own elaboration).

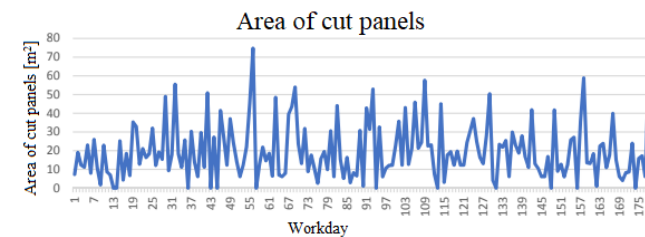


Chart 2. Chart of the area of cut panels by the panel saw on each day of the simulation (own elaboration).

Based on the analysis of Charts 3 to 5, significant variability in the workload of the panel saw can be observed, resulting from large fluctuations in demand over different periods of time. However, even during periods with the highest number of orders, the saw does not reach an overloaded state.

7.2. Five times production volume

In the case of implementing a five-fold increase in production level, the workload remains at a moderate level, reaching approximately 50%. Charts 6 to 8 illustrate the number of working hours, the surface area of cut panels, and the number of processed sheets per day for this production scale variant.

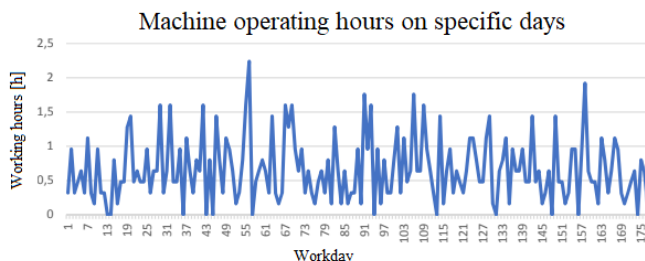


Chart 3. Chart of the number of operating hours of the panel saw on each day of the simulation (own elaboration).

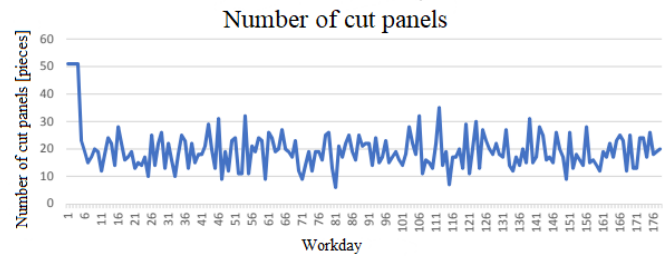


Chart 4. Chart of the number of cut panels by the panel saw on each day of the simulation (own elaboration).

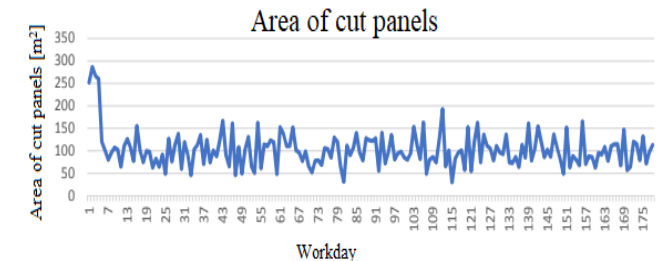


Chart 5. Chart of the area of cut panels by the panel saw on each day of the simulation (own elaboration).

The charts 6-8 show the variation in workload of the panel saw associated with demand fluctuations over time. However, there is no occurrence of overload even during the period of highest order volume.

Similar charts have been developed for the other areas of the simulation model mentioned in the previous section. Additionally, an analysis has been conducted for all these areas in three different production scale variants: twice as large, three times as large, and four times as large.

8. Recommendations

8.1. Workload comparison

Table 4 provides a synthetic presentation of the percentage values of workload for individual machines in specific production scale variants.

Table 3. Machine load in different production scenarios (own elaboration).

Machine	Current production	Double production	Triple production	Quadruple production	Quintuple production
Panel saw	10%	19%	29%	38%	50%
Edgebanding machine	19%	37%	52%	74%	93% Recommended purchase of another machine
Drilling machine	20%	46%	64%	86% Recommended purchase of another machine	104% Recommended purchase of another machine
CNC Center	23%	47%	69%	93% Recommended purchase of another machine	114% Recommended purchase of another machine
Automatic paint booth	3%	7%	10%	13%	17%
Manual paint booth	6%	14%	21%	28%	34%

8.2 Further production growth

By implementing the recommended actions, such as purchasing additional drilling machines and edge banders, further production growth of up to ten times the current volume can be achieved. This progress corresponds to reaching the maximum efficiency of the panel saw. Depending on the proportion of different material types

in the orders, there may also be a need to invest in additional CNC centers for wood processing to ensure timely order fulfillment.

9. Summary

To optimize the mass production system of customized furniture, the following changes are recommended in the initial system concept:

- the use of two edge banders instead of one in the production system is recommended,
- introducing two drilling machines instead of one in the production system,
- changes in the material flow should be made so that some wood processing can be done on the drilling machines in case of high load on the CNC center, or consider purchasing an additional CNC center,
- in the painting area, it is recommended to replace the conveyor roller-based transport system with the use of transport carts.

Ensuring the purchase of additional equipment will allow for a more balanced distribution of workloads in the production system. With the current proportion of individual products in orders, the production capacities of different machine groups will be similar. The model of the production area, incorporating all the mentioned recommendations, is presented in Fig. 6.



Fig. 6. View of the model after incorporating all recommendations (own elaboration).

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Preliminary use of hydrogen for ozone concentration control

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Abstract: We achieved a CT(ozone concentration(ppm) X exposure time(min))value of 60, which can inactivate coronavirus from 1/10 to 1/100 by operating for 24 h at an appropriate ozone concentration (less than 0.1 ppm) using feedback control in the previous report. In this system, the only way to reduce the ozone concentration is the decomposition reaction of ozone in the natural world, and it was not possible to cope with the rapid increase in ozone. In this study, we investigated the reduction of ozone concentration using hydrogen. As a result, it was clarified that the concentration of ozone rapidly decreased even with about 1/100 of hydrogen's explosion limit (about 4%).

Keywords: Internet of Things, MATLAB/Simulink, Ozone, Sigfox, ThingSpeak, hydrogen, Oxygen and hydrogen gas generator

1. Introduction

With the evolution of Internet technology and different sensors and technologies, the Internet of Things (IoT) era has arrived, in which many things around the world, such as home appliances, automobiles, buildings, and factories, are connected to the Internet in addition to conventional Internet connection terminals such as personal computers and smartphones [1].

Recently, coronavirus has spread worldwide and is becoming a big challenge. Under such circumstances, coronavirus inactivation using ozone has been reported. Since ozone gas affects the human body, in 1985, the Japan Society for Occupational Health's Allowable Concentration Committee set 0.1 ppm as the allowable concentration in the working environment [2].

Furthermore, we have installed a Sigfox antenna at the Hiroshima Institute of Technology and have been developing IoT devices via the Internet using the Sigfox network.

after operating for 24 h at an acceptable ozone concentration (less than 0.1 ppm) and employing feedback control, we achieved a CT value of 60, which can inactivate coronavirus from 1/10 to 1/100.[3]

However, in order to reduce the concentration of ozone in the room, it was necessary to use a method that is difficult to control concentration, such as diffusion of ozone or reaction with moisture in the gas phase. As a result, it has been difficult to control the ozone concentration with high accuracy. In this study, as a new technology to reduce the ozone concentration, we tried to release the hydrogen filled in the cylinder or oxygen and hydrogen gas generator into the room and react it with the ozone to reduce the ozone concentration.



Fig. 1 Experimental Device for Inactivating a New Coronavirus Using Ozone.[4]

2 Experimental

The ozone generator consists of ozone generation module (Fig. 2 (a)), breadboard for wiring (Fig. 2 (b)), and Arduino UNO for controlling ozone generation module (Fig. 2 (c)).

The Sigfox Shield for Arduino V2S was plugged into the Arduino UNO Rev3 to turn it into an IoT device, and the ozone sensor was also plugged into the Sigfox Shield to complete it. (see Fig. 2 (d)) [5]

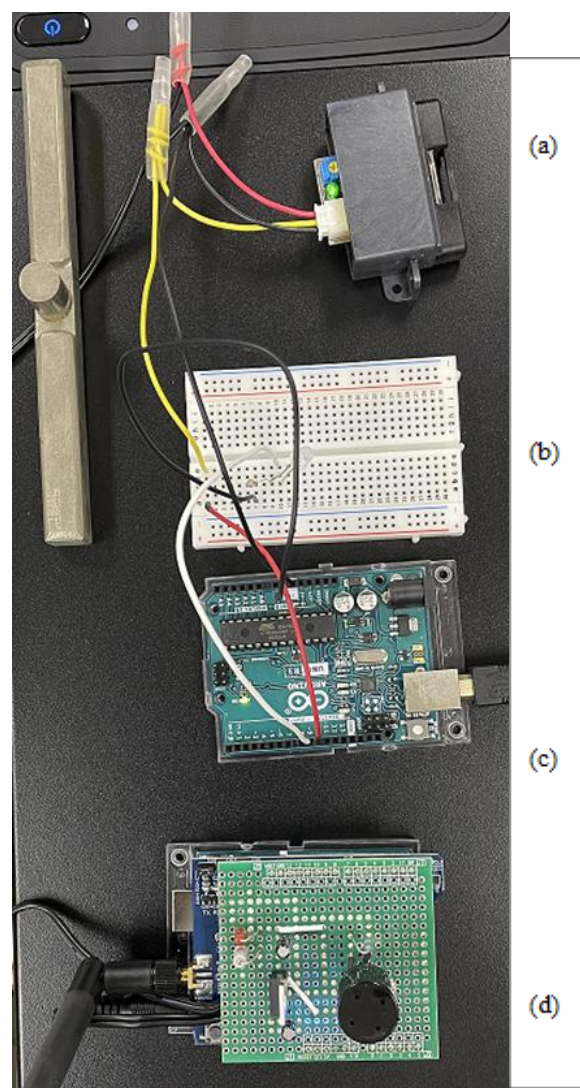


Fig.2 Arrangement Photograph of the Ozone Generator and Measuring Device when Measuring the Ozone Concentration. (a) Ozone Generation Module, (b) Breadboard for Wiring, (c) Arduino UNO for Controlling Ozone Generation Module, and (d) Ozone Concentration Measuring Instrument.

In the IoT device, a temperature/humidity/ barometric pressure sensor (BOSCH BME-280) was used as the sensor. The sensor specifications [6] are

- Operating temperature range: -40°C to $+85^{\circ}\text{C}$ (rated)
- Humidity: 0%–100% (relative humidity)
- Atmospheric pressure: 300–1100 hPa
- Temperature accuracy: $\pm 1^{\circ}\text{C}$ (0°C to 65°C)
- Humidity accuracy: $\pm 3\%$ RH (25°C , absolute accuracy tolerance)
- Barometric pressure accuracy: ± 1.0 hPa (0°C to 65°C , absolute accuracy)

As a new technology to reduce the ozone concentration, we tried to release the hydrogen filled in the cylinder (see Fig.3) or oxygen and hydrogen gas generator (see Fig. 4) into the room and react it with the ozone to reduce the ozone concentration.



Fig. 3. From the right, a hydrogen cylinder, a pressure regulator, and a flow meter (H_2 2000cc/min)



Fig. 4 Oxygen and hydrogen gas generator (TED-CUBE, WAC Inc.) (O_2 1000 cc/min, H_2 2000 cc/min)

3. Results and Discussion

When hydrogen gas was added to reduce the ozone concentration, the ozone concentration and hydrogen concentration were shown in Fig. 5 and 6, respectively. It was observed that the introduction of hydrogen initially reduced the ozone concentration and then increased the hydrogen concentration.

Next, when oxygen and hydrogen gas are added instead of hydrogen gas, the ozone concentration and hydrogen concentration were shown in Fig. 7 and 8, respectively. Similar to hydrogen gas, it was observed that with the oxygen and hydrogen gas generators, the ozone concentration first decreased and then the hydrogen concentration increased. Hydrogen gas from a oxygen and a hydrogen gas generator were found to reduce ozone concentration similar to hydrogen gas.

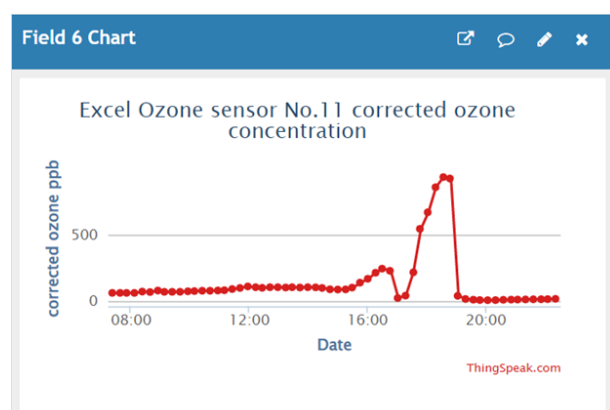


Fig. 5. Ozone concentration (ppm)(Use of hydrogen cylinders).

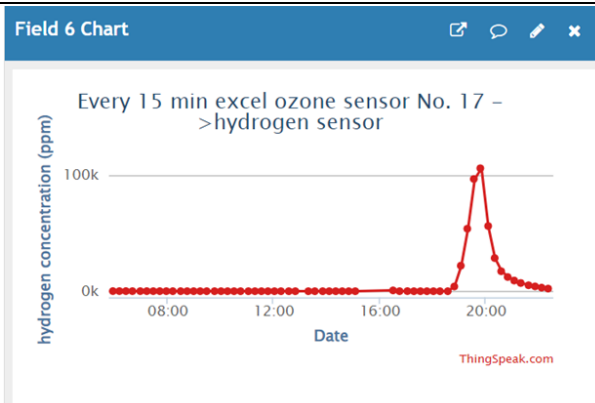


Fig. 6. Hydrogen concentration (ppm))(Use of hydrogen cylinders).

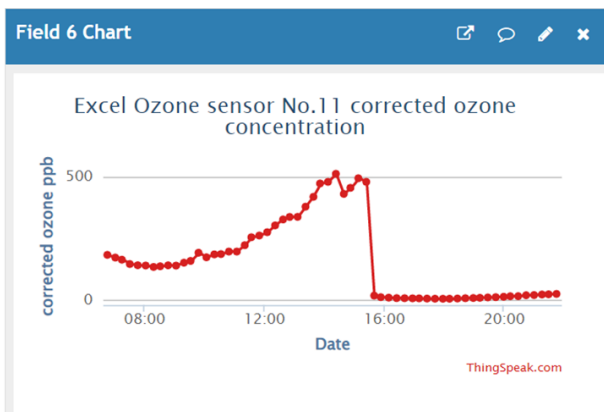


Fig. 7. Ozone concentration (ppm)(Use of Oxygen and hydrogen gas generator).

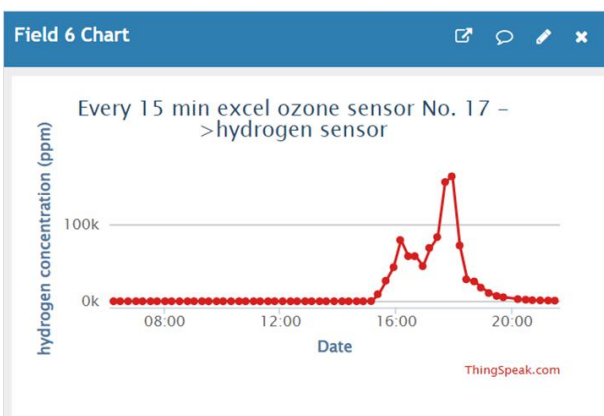


Fig. 8. Hydrogen concentration (ppm))(Use of Oxygen and hydrogen gas generator).

4. Conclusion

In the previous report, a CT(ozone concentration(ppm) X exposure time(min))value of 60, which can inactivate coronavirus from 1/10 to 1/100 by operating for 24 h at an appropriate ozone concentration (less than 0.1 ppm) using feedback control was reported. In this system, the only way to reduce the ozone concentration is the decomposition reaction of ozone in the natural world, and it was not possible to cope with the rapid increase in ozone. In this study, the reduction of ozone concentration using hydrogen gas from gas cylinder or oxygen and hydrogen gas generator was achieved. As a result, it was clarified that the concentration of ozone rapidly decreased even with about 1/100 of hydrogen's explosion limit (about 4%).

5. Acknowledgment

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Analysis of interference fit joints formed by thermal drilling technology with CNC process control

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Abstract: The paper focuses on the evaluation of the quality of joints of thin-walled dissimilar overlapped materials, formed by thermal drilling without a screw. The shaped interference fit joint is formed by simultaneously forming both overlapped materials, preheated by the friction of a flowdrill tool, and forming a pair of embedded concentric bushings. The joints were made on a CNC milling centre, at constant speed, with tool feed being the only variable. Three tool movement strategies - three movement schemes - were tested. By evaluating the quality of the joints using metallographic sections, the optimum tool movement strategy was selected.

Keywords: MECHANICAL JOINING, THERMAL DRILLING, DISSIMILAR MATERIALS, LOAD-BEARING CAPACITY OF JOINTS

1. Introduction

In many industrial applications, components made of thin plate or thin-walled profiles are widely used. The problem with such structures is the joining, especially when different materials have to be joined (uncoated and galvanized steel, steel with aluminum or composite, etc.) [1].

The Flowdrill process is characterized by the formation of an elongated bushing, which is formed by rotation and pressure of the tool without chip removal [2]. The bushing has a specific shape according to the tool used. This process is also called friction drilling, flow drilling, thermomechanical drilling, etc. The purpose of this method of hole formation is to form a bushing in thin sheets without any addition of material where a sufficient number of threads can be placed [3-6]. Subsequently, a thread can be formed in the formed bushing, thus forming a detachable joint with a connecting element. However, it is also possible to form a mechanical form fit joint of two sheets without a bolt, just by two concentric nested bushings wedged together [7]. In this process, it is necessary to ensure that the resulting bushings of the two materials to be interpenetrated adhere tightly to each other, follow each other's shape, and do not push away from each other due to the spring back effect, which could lead to "opening" of the joint. As this is an atypical application of thermal drilling for joining two overlapped dissimilar materials, there is a lack of information on suitable process parameters in the relevant literature. These vary according to the type of material to be drilled. For example, tool speeds for drilling corrosion-resistant steels are recommended to be reduced compared to those for low carbon steels by 15%, while for Al and non-ferrous alloys it is recommended to increase the speed by 50% compared to drilling carbon steels [8]. The question is what are the appropriate parameters for joining the steel-Al alloy pair, which material should be adapted to. In order to achieve repeatability of process parameters during joint formation, thermal drilling should be done on CNC machines where drilling parameters can be precisely defined and controlled during the toolpath. The heat generated affects the drilling process and depends mainly on the speed and tool feed. Regarding CNC centers, it is more efficient to vary the tool feed than the tool speed, so we decided to take this route in the experiment [8].

The aim of the paper work is to experimentally verify the possibility of using the side effect of the thermal drilling technology (flowdrill) for joining two overlapped thin plates without the use of a bolt, just by forming a pair of nested concentric bushings, while three modes of tool feed will be tested.

2. Materials and Methods

The choice of materials for the experimental program was based on materials currently used in the construction of automotive bodies so that both Fe alloys (galvanized and ungalvanized) and non-ferrous alloys were represented.

Materials selected for experimental works:

- DC04 - extra deep-drawn, uncoated, low-carbon, cold-rolled steel for bodywork. Referenced like DC.
- TL 1550-220+Z - hot-dip galvanized fine grained HSLA steel with excellent cold formability, grade VW (equivalent to CR210LA or HR210LA). Referenced like TL.
- EN AW-6082 T6 (AlSi1MgMn) - precipitation-hardened high strength Al alloy, weldable by MIG and TIG welding technologies. Referenced like Al.

The thickness of steel sheets was 0.8mm, the thickness of Al alloy was 1mm. The chemical composition of the materials used is given in Table 1.

Table 1: Chemical composition of materials in wt.%

Mat.	C	Mn	Si	P	S	Al	Nb	Ti	Fe
DC	0.040	0.25		0.009	0.008				bal.
TL	0.1	1.0	0.5	0.08	0.03	0.015	0.1	0.15	bal.
Mat.	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Al	1.0	0.4	0.06	0.44	0.7	0.02	0.08	0.03	bal.

Table 2: Mechanical properties of materials (in transversal direction)

Mat.	Re [MPa]	Rm [MPa]	A80 [%]	Zn layer [g/m ²]	r	N
DC	197	327	39	-	1.900	0.220
TL	292	373	34	104	1.350	0.190
	Re [MPa]	Rm [MPa]	A50 [%]			
Al	295	344	14			

r - coefficient of normal anisotropy, n - strain-hardening exponent

The shape and dimensions of the test specimens as well as the geometry of the joints calculated for tool Flowdrill long $\phi 5.3$ mm are shown in Fig. 1. The hole is always made in the centre of the overlapped area.

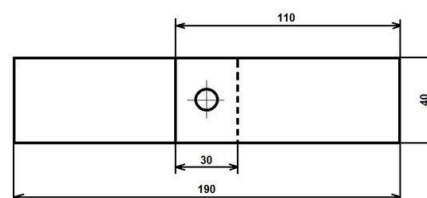
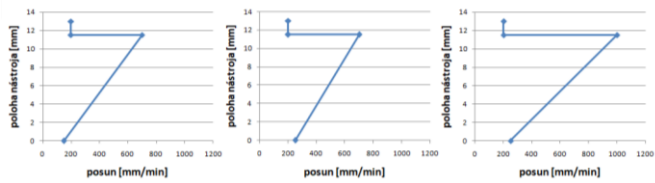


Figure 1: Shape and dimensions of test specimens and joints designed for FD long $\phi 5.3$ mm tool

The joints were created on a CNC milling centre DMG mori DMU 60evo. According to [8], it is recommended to set a small tool feed at the contact of the tool tip with the material, which should then increase linearly or stepwise, and then the tool feed should slow down again at the lowest reversal point of the tool movement. Based on these recommendations, three tool feed modes were selected and tested on the tool working path, Fig. 2.



a) 150-700-200 mm/min, b) 250-700-200 mm/min, c) 250-1000-200 mm/min
Figure 2: Selected tool feed modes

The initial tool feed was 150 or 250 mm/min, gradually increasing to 700 or 1000 mm/min on the 11.5 mm path, finally on the 1.5 mm path the tool feed dropped to 200 mm/min and the tool

stopped 0.6 mm below the flange part of the tool to prevent deformation or damage to the collar.

The geometry of the joints as a function of the tool feed mode was then examined by optical microscopy on metallographic sections along the axis of the joint.

3. Results

Table 3 shows the metallographic sections of the joints formed at the three tested tool feed modes on the CNC machining centre.

Table 3: Metallographic cross-sections of joints made at three tool feed modes, LM

Mode:	Tool speed [min ⁻¹], initial tool feed – maximal tool feed, tool feed in lowest reversal point [mm.min ⁻¹]		
Joints	3800, 150-700, 200	3800, 250-700, 200	3800, 250-1000, 200
Al-Al			
DC-DC			
TL-TL			
DC-TL			
TL-DC			
DC-Al			
TL-Al			

The Al-Al joints failed to establish, increasing the initial and maximum tool feed did not lead to an improvement in connection forming. The DC-DC and TL-TL joints are accompanied by a large spring back effect and too large a bending radius of the bottom plate, which makes it impossible to form nested concentric bushings of sufficient thickness. Instead, there is only an intense thinning of

the heated material of inner bushing between the tool and the outer bushing, which acts as a punch and die in the process of forming the inner bushing. For the material combinations DC-TL and TL-DC the situation is similar, however, when DC is in the upper position, due to its high ductility (as an indicator of formability) it thins more intensively and therefore the inner bushing formed from it is too

thin. However, if TL steel is in the upper position, it thins less intensely. The best joints were achieved in the steel-Al combination, with minimal spring back effect and tight-fitting inner bushings. As for tool feed modes, it is the DC-Al and TL-Al joints where their effect is best seen. Too little initial tool feed caused the Al sheet to bend and the joint to open. Increasing the initial tool feed from 150 to 250 mm.min⁻¹ eliminated this problem, but

increasing the maximum tool feed from 700 to 1000 mm.min⁻¹ did not produce any significant change in the shape of the bushings.

Fig. 3 summarizes the achieved average inner bushing height, inner bushing thickness at the expected failure location, and microhardness at the outermost part of the inner bushing for each material combination.

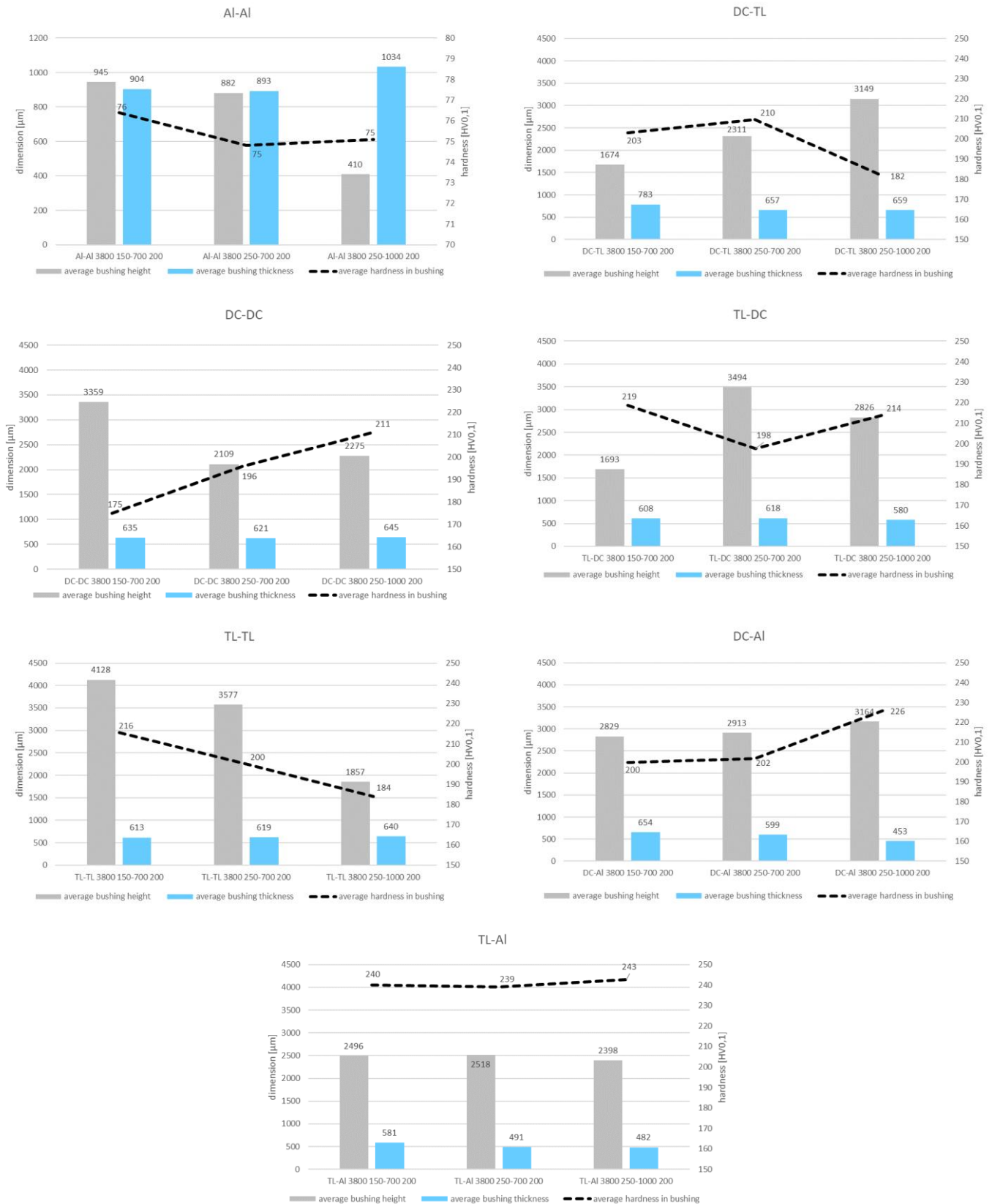


Figure 3: Average bushing height and thickness, microhardness in the bushing for individual joints

Fig. 3 shows that deformation hardening occurred in DC and TL steels, which was manifested by an increase in microhardness in the

bushing, which represents the most overstrained region of the material in the joint. The DC steel sheet had an initial hardness of

106 HV0.1, after forming to the shape of the bushing, the hardness in the outermost part of the bushing varied between 175-226 HV0.1, depending on the tool feed used. The strain hardening of the TL steel showed an increase in hardness from 131 HV0.1 in the initial condition to values between 184 and 243 HV0.1 in the bushing.

In Al sheet material softening occurred, the hardness in the bushing was around 75 HV0.1, while the initial hardness was 119 HV0.1. The Al sheet was supplied in the T6 condition, i.e. it is a solution treated and artificially aged alloy. Its structure consists of a number of Mg_2Si precipitates dispersed in an α -Al matrix. This type of alloys has limited application in terms of operating temperatures to ambient temperature. Any heating may disturb the precipitation hardening effect. At temperatures of 100-500°C, the precipitates can overage, i.e. grow, reducing their strengthening effect; bigger precipitates prevent the movement of dislocations less effectively. Heating above 500°C already leads to dissolution of the precipitates, and if followed by slow cooling, the fragile intermetallic θ phase at grain boundaries may be formed, thus weakening their cohesion. In thermal drilling, Özek et al. [9] found a maximum temperature of Al alloys 1 mm from the hole of about 245°C at comparable tool speeds but significantly smaller tool feed. It is possible to estimate the Al temperature at feed rates up to 1000 mm.min⁻¹ to be >300°C, which could have induced a softening of the Al alloy in the vicinity of the hole.

In thermal drilling, not only the mechanical properties determined at ambient temperature play an important role, but especially their change when heated. It is therefore necessary to know the creep curves of materials, the change in the modulus of elasticity of materials with temperature and the physical properties of materials, especially thermal conductivity. Fig. 4 shows the decrease of Young's modulus of steel and aluminium when heated.

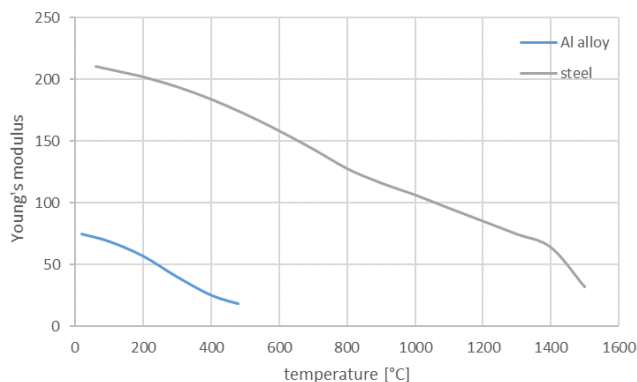


Figure 4: Temperature-dependent change in modulus of elasticity of steel and Al alloys

Fig. 4 shows that already at ambient temperature, it takes three times less stress to achieve some deformation of Al than to achieve the same deformation of the same cross-section made of steel. As the temperature increases, this difference increases even more, the Young's modulus of Al decreases more drastically with temperature than that of steel. This is the reason why Al sheet cannot be in the top position when joining with flowdrill technology - it is pushed sideways when heated instead of forming a bushing. Therefore, a material with a higher stiffness (Young's modulus) must be placed in the top position. In the lower position, the aluminium alloy can be placed, which will therefore only be heated indirectly, by conducting heat from the steel into the Al, and will be shaped by copying the resulting steel bushing. In this way, a joint with a suitable geometry, with tightly fitting concentric nested bushings, with certain load-bearing capacity, can be formed. Joints formed by this process can be combined with adhesive bonding.

3. Conclusions

The following main findings can be drawn:

- thermal drilling technology can be used to create a pair of nested concentric bushings capable of carrying a certain level of load
- the best joint geometry is achieved with a steel-aluminium alloy material combination, with the recommendation to place the steel in the upper position of the pair to be joined
- this technology is not suitable for joining steels of the same or unequal grades or for joining aluminium alloy pairs.
- For the most promising joints (DC-Al and TL-Al), no significant effect of the tool feed mode on the geometrical characteristics of the joints was observed, but the displacement modes 3800, 250-700, 200 and 3800, 250-1000, 200 resulted in the formation of tightly fitting concentric bushings with a minimum gap between the plates.
- From the point of view of time saving in joint formation, the following mode can be recommended for joining steels and Al alloys with the above properties and thickness: speed 3800 min⁻¹, tool feed 250-700 mm.min⁻¹, at the end of the movement the tool feed decreases to 200 mm.min⁻¹.

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Application of innovative procedures for modification of surface topography

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Abstract: The paper presents the results of research focused on the application of innovative procedures for surface topography modification. The experimental work was aimed at adjusting the microgeometry and surface topography of new and renovated shaped parts of molds for casting aluminium alloys under high pressure. In the phase of experimental verification of suitable surface topography, a group of samples from Dievar material was prepared. A multilayer nanostructured PVD coating of the 4th generation duplex nACRo⁴ was deposited on part of the experimental samples. The surface of the samples was ground and polished. The microgeometry of the surface of the samples was modified by low-energy laser radiation - microtexturing. The maximum interval was chosen to create a stochastic texture, also called a random texture crater distance up to 200 μm . The aim of this surface treatment was to analyze the adhesion effect of commercially used ones of lubricants in the technology of treatment of shaped parts of molds when casting aluminium alloys under high pressure on machines with a cold filling chamber. In the run-in of the mold, after the first cycles of spraying with a separating agent, a compact layer was created to increase the technological life of the shaped parts of the molds.

Keywords: nanostructured PVD coating, microgeometry of the surface, microtexturing

1. Introduction

Nanostructured coatings represent a new generation of coatings, or they are composed of at least two separate phases with a nanocrystalline or amorphous structure. The formation of the nanostructured coating is attributed to the segregation of one phase to the grain boundary of the second stage. This effect is responsible for preventing grain growth and structure formation at the nanoscale. The new functional properties of nanostructured coatings result from this microstructure, where the dominant role is played by the boundary regions that surround the individual grains. Due to the very small grains of less than or equal to 10 nanometers separated by a second phase (predominantly amorphous), nanostructured coatings are managed differently compared to conventional coatings that have grains larger than 100 nanometers [1,2].

The optimal thickness of the phase that separates the nanocrystals from each other is 1-3 nm, which corresponds to only a few monolayers. The optimal size of the grains forming the nanocrystalline structure is given in the range of 3-10 nm. The various borides, nitrides, carbides, or oxides forming the nanocrystalline structure together with the ceramic, metal or carbon amorphous matrix provide unique properties for each combination of materials. Such diversity of composition and properties of nanostructured coatings enables their wide use in various areas of engineering applications. The formation of coatings with a nanocrystal structure requires optimization of the deposition conditions to reduce the grain size and at the same time ensure the development of the segregation phase. Among the basic process parameters that affect the size and crystallographic orientation of the grains are the current, the temperature of the base material, the bias on the sample, the low current density of the base material and the partial pressure of the reactive gas used [3-5].

Grain growth can be effectively controlled through the kinetic energy of impact particles that are transferred to a very small surface area. Ion bombardment contributes to the minimal surface mobility of atoms, which is necessary for the formation of a crystalline phase and to sufficient diffusion in the segregation system. However, it is also necessary to regulate the temperature of the process, because exceeding the critical temperature value no longer prevents grain growth and segregation of grain boundaries. Like low-energy bombardment, the addition of one or more alloying elements to the base material has the same effect on the formation of the nanostructured phase. The Fig.1 shows a typical structure of a nanostructured coating [6,7].

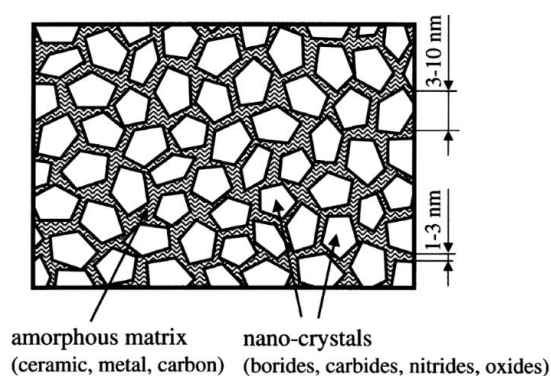


Fig. 1 Typical structure of a nanostructured coating [8]

Surface texturing refers to a series of regular micro-structures machined on the surface of a sample through process technology. The textures with suitable size can act as micro-bearing to increase the dynamic pressure between friction pairs, store lubricants, and capture debris produced during the friction process. The structure of the textured surface is given as a 3-dimensional topography of the given surface [9]. We know 2 types of surface texturing technology. The first of them is the laser beam texturing technology (LBT), which is used most often in practice. The second type of surface texturing technology is Electron Beam Texturing (EBT) technology. It is confirmed that the shapes are confirmed further reduction of friction and properties. On the surface shapes of the textures, simulations and experiments were carried out during individual studies, including a typical number of rectangular, circular, elliptical, triangular, and V-shaped textures as shown in Fig.2 [10]:

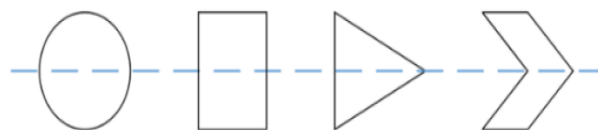


Fig. 2 Shapes of textures created on the surface of materials [10]

2. Materials and methods

For the experimental work carried out in the dissertation, a base material identical to the material of the mold was used. It is a tool steel called Uddeholm Dievar, which is alloyed with chromium, molybdenum, vanadium, and other alloying elements. It is intended for work at high temperatures. Molds for high-pressure aluminium casting and their shaped parts are most often made from it. This

type of material is produced by powder metallurgy technology. The chemical composition of the material is shown in Table 1:

Table 2: Chemical composition of Uddeholm Dievar

Element	C	Si	Mn	Cr	Mo	V
Weight. [%]	0.38	0.2	0.5	5	2.3	0.6

The surface texturing of the samples was performed by the LBT (laser beam texturing) method. The Yb fiber laser type Piranha II Multi FL205 with a power of 20 W was used. The creation of dimple textures was used, which serves as a reservoir for the separating agent in the process of high-pressure casting of Al and its alloys. Before the coating and texturing process, the surface of the base material was pretreated with wet sandblasting and polishing technologies. Two types of dimple textures were created, random and large. Three types of PVD duplex coatings AlTiN G, AlXN₃ and nACRo⁴ were deposited on the surfaces prepared in this way using PLATIT LARC technology. AlXN₃ is a duplex coating composed of: X=Cr; CrN layer + Al/CrN nanomultilayer + AlN layer. The nACRo⁴ nanocomposite coating consists of layers of layers: the first adhesive layer is formed by chromium nitride, on which a gradient AlCrN layer is subsequently deposited. Very thin AlCrN nanolayers are applied to the thus prepared gradient layer. The final top layer of nACRo⁴ is formed by a nanocomposite coating of nc-AlCrN/a-Si₃N₄. AlTiN is a hard coating that solves many tribological problems with components that can be coated at temperatures of 450°C - 475°C. PLATIT LARC technology® (lateral arc cathode), which is patented and unique worldwide, was used to deposit the coatings. PLATIT Pi411 equipment was used for AlTiN G coatings and AlXN₃ coating. A PLATIT Pi1511 device was used for the nACRo⁴ coating. The roughness recommended by the manufacturer was 0.3 µm. The AlTiN G coating is gradient where 2 stages are given: gradient 1 - where the deposition starts and gradient 2 - the deposition ends. The other coatings are multi-layered, where the parameters of Layer 1 and Layer 2 alternate during deposition. Microscopic analysis of the coatings was performed.

The microgeometry of the textured surface without and with PVD nanostructured coatings was captured by a ZEISS LSM 700 laser confocal microscope. The roughness profiles of the textured surface were defined according to EN ISO 4287.

Release agent Safety Lube 7815 is used in the high-pressure casting process. Safety Lube separators are based on an organic base and contain the basic element silicon in their composition. They are manufactured by ChemTrend. These release agents are sprayed onto the mold surface before each casting process to ensure easier removal of the castings from the mold and to create a thermal barrier between the melt and the steel surface of the mold. The standard separation agent used in practice is Safety Lube 7815.

The coefficient of friction of the non-textured and textured surface with PVD nanostructured coatings was determined by the Pin on ball method according to the ASTM G99-17 standard when dry and using the release agent Safety Lube 7815. A 6 mm ball traveled 500 m and the load on the ball was 5 N with a linear velocity of 0.10 m/s.

3. Results and discussion

Microscopic analysis of coatings

In Fig.3 a cross section of the AlTiN G coating is shown. The coating thickness was 1.55 µm. It is clear from the cross section that the coating was continuous over the entire surface without any pores or cracks.

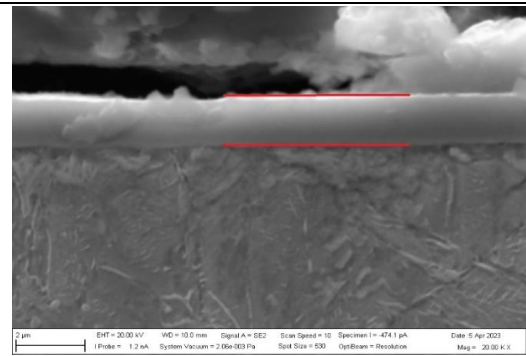


Fig. 3 Cross section of the AlTiN G coating

In Fig.4 an EDX surface elemental analysis is shown, which shows us the distribution of the coating element, i.e. titanium, aluminium, nitrogen, as well as the base material on the analyzed sample:

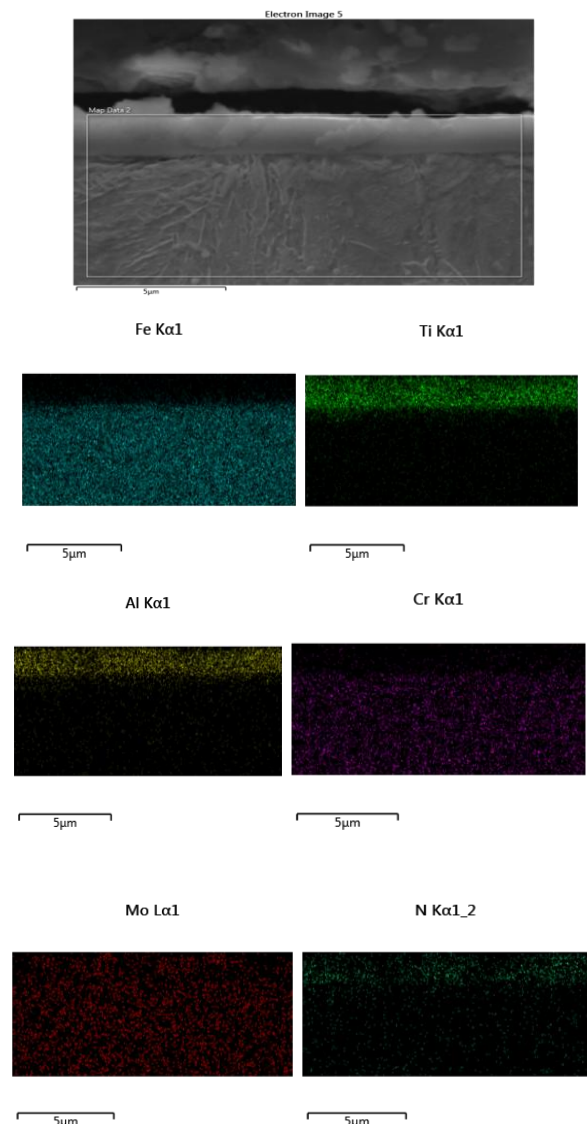


Fig. 4 EDX surface elemental analysis of the AlTiN G coating

During the microscopic analysis of the surface morphology of the AlTiN G coating, cracks in the form of drops, slimes and pores were detected. This heterogeneity is provided by the delivery of the coating after the deposition process. The mentioned phenomenon is typical for the coating on AlTiN and this phenomenon does not occur in the deposition process. The value of the Ra parameter reached a value of 0.142 µm. It is clear from the roughness profile

that the AlTiN G coating showed the highest roughness along the entire measured length of the analyzed coatings.

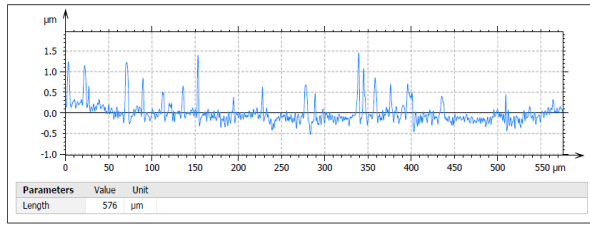


Fig. 5 Roughness profile of AlTiN G coating

The thickness of the AlXN₃ coating marked in red was 1.12 µm. From the cross-section the coating is not continuous, where cracks and pores are present in the layer.

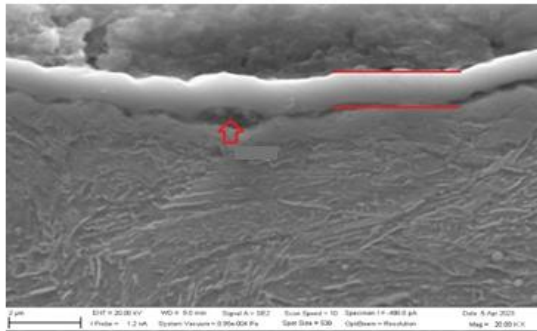


Fig. 6 Cross section of the AlXN₃ coating

EDX elemental analysis of the AlXN₃ duplex coating shows the distribution of the individual elements of the coating (chromium, aluminum, nitrogen) and the base material (iron, molybdenum) in the analyzed part.

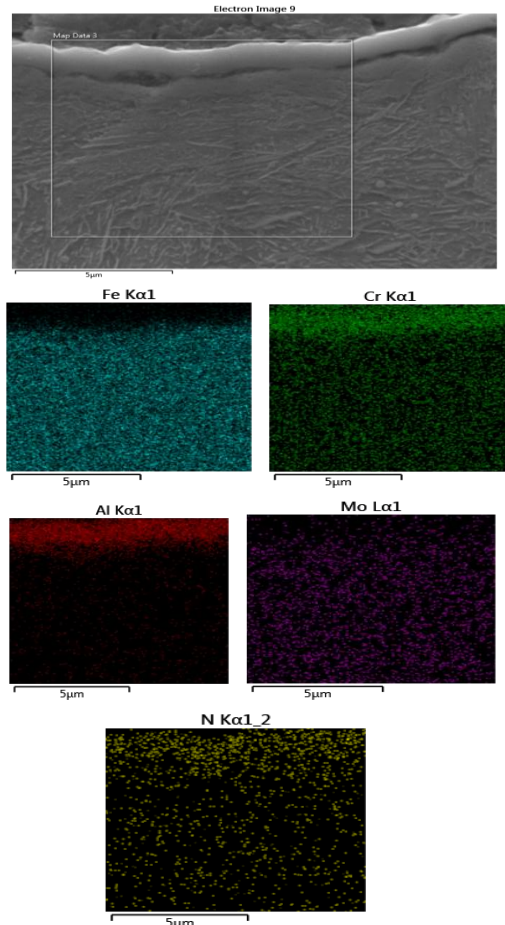


Fig. 7 EDX surface elemental analysis of the AlXN₃ coating

Inherent droplets and holes were also observed in the surface morphology of the deposited AlXN₃ coating. Equiaxial AlN grains were observed in the upper part of the coating. Under the upper zone there were multilayers of AlCr grains. An adhesion layer of CrN was identified, which was closest to the base material in the lower part and ensures better adhesion of the coating to the base material. The value of the parameter Ra reached a value of 0.126 µm. Compared to the AlTiN G duplex coating, it can be concluded that the surface of the AlXN₃ coating is less roughened along the entire measured length.

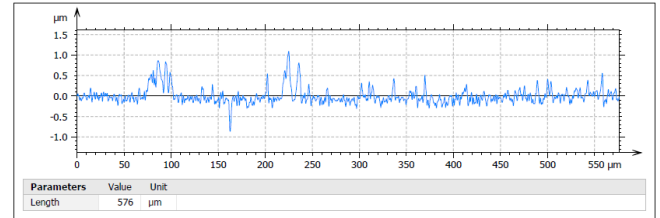


Fig. 8 Roughness profile of AlTiN G coating

The coating thickness of nACRo⁴ marked in red was 2.75 µm. This coating showed the greatest thickness compared to the previous two coatings. No pores and cracks in the structure were identified.

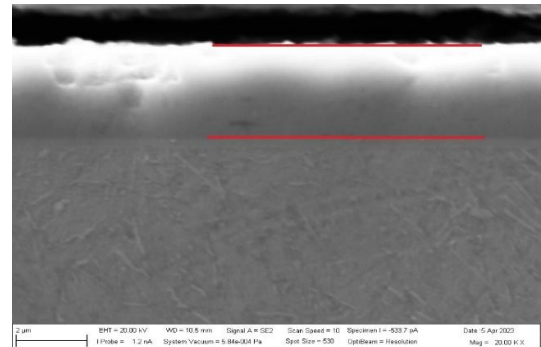
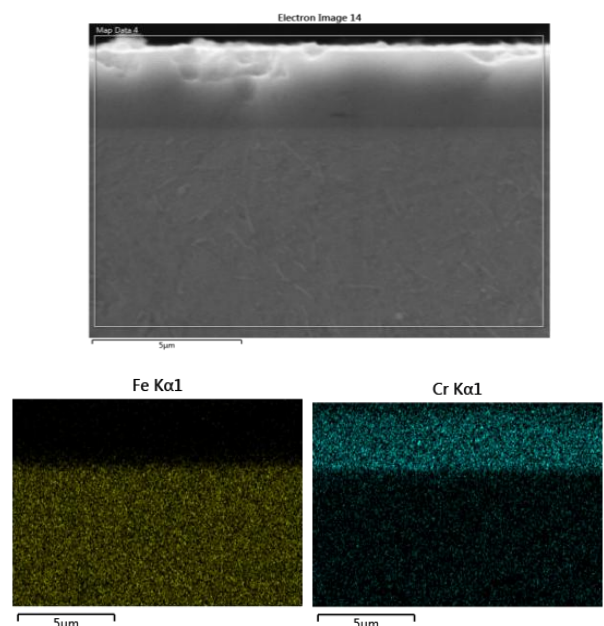


Fig. 9 Cross section of the nACRo⁴ coating

EDX elemental analysis of the nanostructured nACRo⁴ coating revealed the distribution of the basic elements contained in the coating (chromium, aluminium, nitrogen) as well as the elements contained in the basic material (iron, molybdenum).



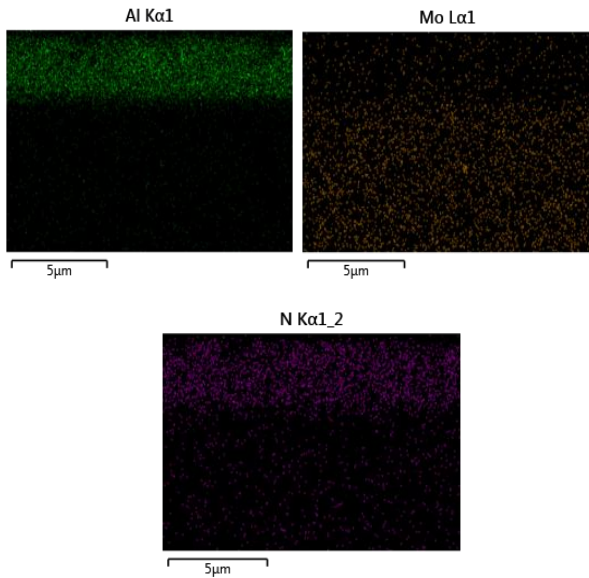


Fig. 10 EDX surface elemental analysis of the nACRo⁴ coating

Many microparticles were observed on the surface, which are inherent in cathodic arc deposition and originate from excess ions from the target during deposition. Si content was observed, resulting in the support and formation of the nc/Si₃N₄ nanostructured phase in the coating. The value of the Ra parameter reached a value of 0.0984 μm. From the given value, it can be concluded that the nACRo⁴ nanostructured coating showed the lowest surface roughness compared to the previous duplex coatings.

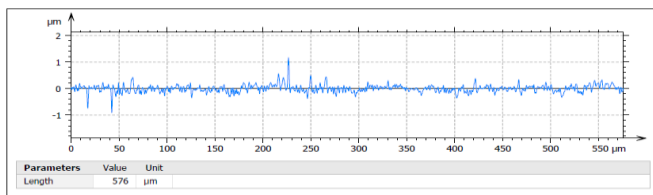


Fig. 11 Roughness profile of nACRo⁴ coating

EDX analysis of release agent Safety Lube 7815

A "dry" of Safety Lube 7815 release agent was prepared at 250°C in which silicon was detected by EDX microanalysis as evidence that the release agent remained on the surface with dimpled texture.

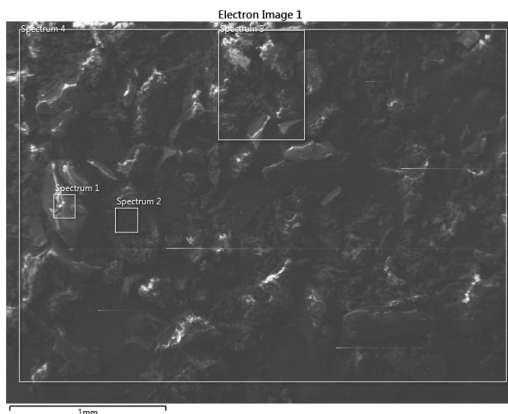


Fig. 12 Analyzed parts of Safety Lube 7815 release agent

In Fig.13 is the EDX analysis of the separating agent Safety Lube 7815 itself is shown, where the proportion of the main silicon component was detected, namely 9.8 wt.%. Carbon, oxygen, and sodium were also present.

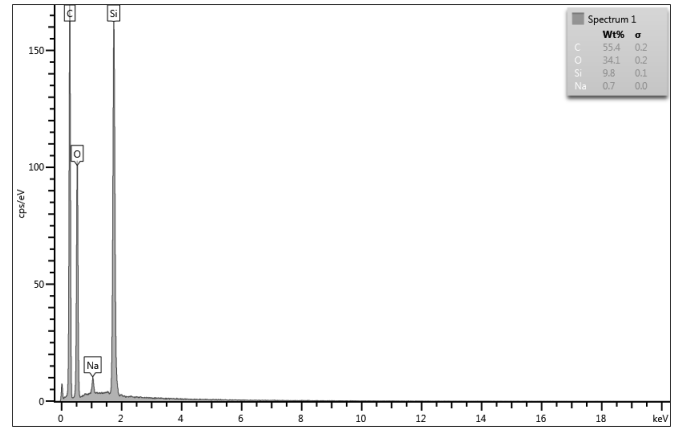


Fig. 13 EDX analysis of Safety Lube 7815

The percentage of Si in dimpled textures together with PVD duplex coatings is shown in Table 2:

Table 2: Si percentage in dimpled textures with PVD duplex coatings

Share of Si in dimpled textures [wt.%]			
Coating	AlTiN G	AlXN ₃	nACRo ⁴
10x	0.3	1.1	4.8
20x	1.1	1.2	5.1

From the table it is this, that with cyclic storage of the separating agent 10x and 20x the base element Si was present as a result of the residue of the release agent on the surface of the PVD duplex coatings. Increased values are detected in the nACRo⁴ coating because the coating itself contains the Si element in its microstructure, which provides us with a nanostructure embedded in the Si₃N₄ matrix.

Texturing of surface

In the case of random texturing, the depth of dimpled textures was different along the entire measured length of 575 μm (Fig.). The randomness of the process can be observed at a length of 100 μm, where the depth of the dimpled texture reaches a value of 3.5 μm. At lengths of 400 or 500 μm are dimpled texture depths of approximately 5 μm and 6 μm. From the depth profile of the stochastic textures, it can be said that during random texturing, the depth of dimpled textures varied depending on the measured length of the surface. Since the dimpled textures were created randomly, it can be assumed that the profile was measured in different parts of the dimples:

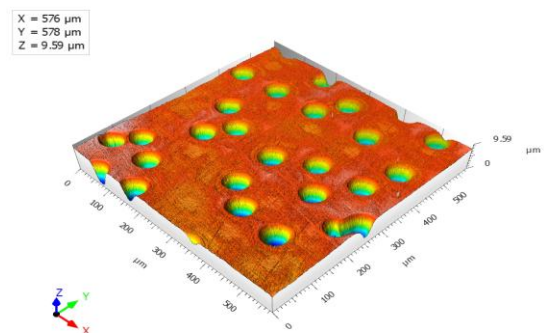


Fig. 14 AFM image of stochastic surface texturing

With ordered texturing, the depth of dimpled textures was found to be the same over the entire measured length of 576 μm, in contrast to random laser texturing. The depth of the dimpled

textures during ordered laser texturing was 5 μm . The analysis found that there was no degradation of the base material during the texturing of the dimple textures.

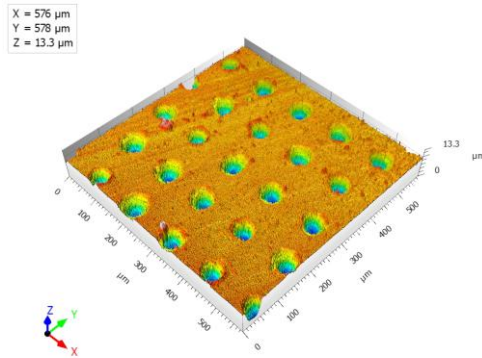


Fig. 15 AFM image of ordered surface texturing

Because the molds itself and its parts are complex in shape and construction, have sharp transitions, various roundings and bevels, it was found within the experiment that it is appropriate to perform random texturing of the surface by applying stochastic pit textures to the form's complex surface. The depth of the stochastic well textures was 5 μm . If the textures had more depth, they would also affect the surface quality of the castings. The texture imprint would remain on the surface of the casting, reducing the surface quality.

Coefficient of friction

Average COF values of PVD duplex coatings without and with laser texturing were measured:

Table 3 Average COF values without and with laser-textured PVD duplex coatings

COF	AlTiN G	AlXN ₃	nACRo ⁴
Without texture	0.45	0.42	0.53
With texture	0.43	0.39	0.42

It was found that a pitted surface with Safety Lube 7815 release agent applied resulted in a lower coefficient of friction value compared to an untextured surface for all three PVD coatings. The largest reduction in COF value was observed for the nACRo⁴ coating, where a value of 0.53 was measured in untextured measurements. By applying pitting textures and Safety Lube 7815 release agent, the COF of the nACRo⁴ coating was reduced to 0.42. The wear rate was also the lowest for the nACRo⁴ coating, which corresponded to its hardness value of 40 GPa.

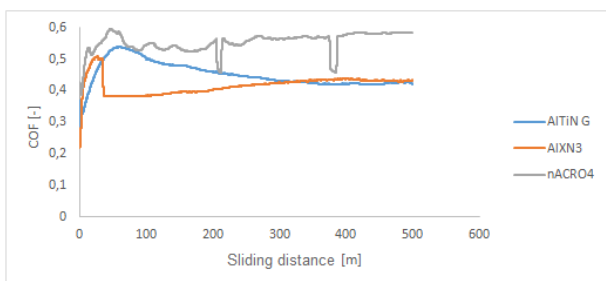


Fig.16 COF curves of duplex coatings without surface texturing

The course of friction coefficients of coatings without texturing is shown in Fig.16. Coatings with texturing achieved similar trends, but with a lower value of the coefficient of friction (Table 3).

4. Conclusions

The aim of the contribution was to propose a methodology for increasing the technological life of molds for high-pressure Al casting. Three types of PVD duplex coatings were designed to increase the technological service life. The surface of the base material before depositing the coatings was modified by laser texturing using LBT technology (Laser Beam Technology). The tribological properties of the coatings were evaluated by the Pin-on-ball method. A hypothesis was put forward about ensuring the supply of the separating agent in critical parts of the mold by applying pit textures on the surface of the material. The mentioned hypothesis was confirmed by tribological tests. The measured COF on textured coatings reached lower values.

Acknowledge

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The impact of the crisis as an accelerator of changes in managerial decision-making on corporate culture in the era of Industry 4.0

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Abstract: Decision making is a key characteristic of a successful organisation and one of the most important roles of a manager. Decision-making plays an important role during times of crisis. Any condition, even a crisis, can be handled by a manager equipped with the appropriate crisis competencies. In the theory of managerial decision-making, the various procedures and tools are explained through normative and descriptive theories, which should form the basis of decision-making even in times of crisis. Uncertainty and complexity are significant predictors of decision-making practices in such conditions. From a normative perspective, the characteristics of decision-making in times of crisis include complexity, political aspect and formalisation. From the perspective of descriptive theories, attention is paid to the psychological aspects of decision making and the influence of behavioural economics on managers' decision making. The Fourth Industrial Revolution, with its tools, supports decision-making. The creators of this support should try to reinforce the intended rationality of the target user and at the same time avoid introducing "irrationality" into the processes of analysis and decision making. Effective technologies must take into account the complex social and economic nature of decision-making. Related to this is a properly aligned corporate culture as a tool for implementing the changes and innovations needed to cope with the crisis. Changing corporate culture as a quick response to a crisis is, according to many authors, impossible. That is why there is talk of preparedness in the form of gradual introduction of Industry 4.0 tools in order to build a digital corporate culture that can support the introduction of necessary changes in enterprises in times of crisis. The aim of this paper is to examine the impact of the crisis on changes in managerial decision-making in the era of the fourth industrial revolution and to discuss what role corporate culture can play in crisis-induced changes.

KEYWORDS: CRISIS MANAGEMENT, DECISION MAKING, INDUSTRY 4.0, CORPORATE CULTURE

1. Introduction

Crises, as they have been perceived since around the middle of the last century and especially in recent decades, are gradually changing form. They are becoming more complex, more interconnected, more interconnected, more (secondary) crises, more interrelated, more multidimensional. Even as they change their form, they retain one thing in the future - a combination of uncertainty, unpredictability of course, combined with threat and catastrophic consequences. Most of the scientific literature and expert advice on crisis management is based on knowledge of how previous crises have evolved, how they have been managed, the experience of overcoming obstacles, and recommendations for future crises. The decisions made by managers affect the lives of many other people. There can therefore be no doubt about its importance. In a crisis situation, a manager is expected to make the right decisions, supported by relevant information and supplemented by his or her good judgment. Successful managers have a high proportion of good decisions, but the path to achieving them is by no means easy. The history and current practice of decision-making in crisis conditions shows many wrong choices that have led to negative outcomes. There is nothing more important than knowing 'how to make the right choices'.

In the course of historical development, a greater number of decision theories have been gradually conceived, differing in their understanding of the decision process, different procedures for measuring the utility of options, and different approaches to the rationality of decision making. These are e.g. utility theories, where the focus is on determining the overall valuation of options in the case of a larger number of evaluation criteria, decision theories of well-structured problems, which are quantitatively oriented with the application of mathematical models and methods, or decision theories based on psychological and sociological approaches, which deal with the influence of various psychological factors on decision-making (habits, character traits, personal interests of the individual) and sociological factors influencing the decision-making process (group decision-making, conflict situations, etc.). The differences of the existing theories stem from their normative and descriptive nature. They differ in such basic assumptions as rationality (perfect or limited), available information (full access or limited access), decision choice (optimization principle or satisfaction principle). The evolution has been long and it is unthinkable that the accumulated experience and methods that experts have been presenting to us for years have not been used, even in conditions of

crisis. However, if we take into account the abundance of domestic and foreign literature dealing with management and individual managerial functions in times of crisis, it can be stated without hesitation that managerial decision-making as one of the most important functions of management is not given sufficient attention.

What causes this imbalance? After all, we encounter opinions that decision-making is the core of management, even some authors identify it with management. In our view, decision-making is focused on a very wide range of problems. It manifests itself in considerable diversity in terms of time, space and content. On the one hand, it is linked to the decision-making process as a decision-making procedure, but on the other hand, it represents an important managerial skill in terms of the manager's individual abilities. Therefore, it is difficult to identify key areas to focus on when studying it, and difficult to establish certain universal truths applicable to all areas of managerial decision-making in crisis conditions.

2. Crisis managerial decision-making

The normative strand in decision theory aims to provide guidance on how to solve decision problems, what procedures and models to use in different types of decision situations in order to achieve the desired quality of decision-making processes. According to Bačova, normative models of decision making have long been recognized as a yardstick, a criterion, a standard against which the degree of "rationality" of individual and group decisions are compared and evaluated [1]. In the eyes of many researchers, they still have this important role today and have an irreplaceable place in decision-making processes during crises.

The basic starting point of normative models is the rational-logical model of decision-making, respecting in today's conditions, instead of unreal objective rationality, subjective rationality, which considers working with the information that is sufficient and true according to the decision-maker at the moment. In this way, rational decision-making could be useful even in times of crisis, as long as it is not directed only towards the application of the optimisation principle, which presupposes comprehensive knowledge of all options, the ability to obtain all the necessary information and to process it perfectly. The crisis does not provide such conditions for decision-making. Therefore, using the satisfaction principle, a rational decision-making process can be effective during a crisis. The understanding of rationality is now shifting to flexible,

uncomplicated, adaptive decision-making processes, where there are not too many regulating rules under which the whole process collapses under its own weight. The most effective decision-making processes are based on concrete foundations, are simple and can be adapted if necessary. The new rational models highlight critical points that can cause the decision-making process to slow down and become inefficient. It is these models, by identifying the key roles in the decision-making process rather than defining its phases, that make them suitable for a crisis environment. They emphasise speed and adaptability in decision-making, clarification of responsibility for sub-tasks in the decision-making process, and the implementation phase, because the decision-making process does not end when the decision is made. At the same time, they stress the need to involve the people who are involved in the implementation of the decision in the processes. They attribute an important place to dialogue, discussion and consultation [2,3].

Some authors see a rational approach to decision making in the form of Evidence-based-Decision Making and argue that the most important thing nowadays is to direct the decision making process towards getting the maximum value from the information available. Today's challenging pandemic and even more challenging post-pandemic times require business managers to make the right decisions to ensure that businesses are resilient, able to survive and operate successfully post-crisis. This is not possible without leveraging data. Information Technology and Business Intelligence play a key role in EBDM. On the other hand, even when analytics are generated, executives ignore them in favor of intuition or comfortable practices of the past. Most companies don't know what their most important decisions are and how technology and information can be used to inform them. Proponents of EBDM include Davenport and Harris [4], who argue that analytics can provide input for human decisions or can drive fully automated decisions. According to the authors, this kind of decision making can be used in proactive decision making. It may not be effective in crisis decision-making processes that are reactive. Aravopoulou et al. [5] confirmed their research hypothesis about the link between rationality and crisis strategic decision making. However, they conducted their research at the time of the Greek financial crisis, where the conditions for decision-making were different from the current Covid 19 pandemic.

3. Industry 4.0

The development of markets, the rise of globalisation and internationalisation, the increasing competitiveness of businesses and the huge increase in technological breakthroughs have led to the emergence of the so-called Fourth Industrial Revolution, known as "Industry 4.0". This term is associated with the optimisation of production processes, using the latest technological knowledge, in order to increase production and competitiveness. Huge changes are causing traditional "mechanical chains" in production to be transformed into "digital chains". This process is happening, for example, thanks to 3D printers, which make it possible to produce spare parts locally and at the time when production needs them. This is already making many traditional manufacturing and logistics processes obsolete.

The very concept of Industry 4.0 originated in Germany, which initiated the project in order to determine the impact of the introduction of new technologies on its economy. Slovak industrial production is very closely linked to that of Germany, and we will therefore be significantly affected by this process. In order to ensure the competitiveness of Slovak industry, it is essential to recognise the need to implement the Industry 4.0 process, which, however, is extremely dependent on investment, as innovation and research are very costly. Currently, according to statistics, only 18% of small and medium-sized enterprises in Slovakia are dedicated to innovation.

We expect the impact of Industry 4.0 to be deeper, irreversible and much faster than the impact of the previous three revolutions. The high increase in demand for technology, (especially

information and communication technology), by industrial firms may drive the future of Industry 4.0 and may result in positive spillover effects in various areas [6]. The very term "Industry 4.0" has literally become a popular slogan used to define the changes affecting the industrial sector as a new stage of development called the 4th Industrial Revolution emerges [7].

In this context, terms such as Industrial Internet, mainly promoted by General Electric, or terms such as Integrated Industry, Smart Industry or Smart Manufacturing are used with a very similar meaning in the literature [7].

Some authors even consider the term IoT as synonymous with the term Fourth Industrial Revolution [8,9]. Others strictly underline the fact that IoT is only one of the tools of the Fourth Industrial Revolution, but not synonymous with it [10].

Industry 4.0 or the Fourth Industrial Revolution is a complex concept as well as a new trend of large-scale changes that are rapidly entering contemporary industry. The main driver of these changes is the digitalization and automation of products, all business processes and services. It is very likely that the current wave of digitisation and automation will affect quite a large part of our daily lives.

Schmitt [11] confirmed five reasons why Industry 4.0 is important and revolutionary at this time:

1. The challenges faced by entrepreneurs in manufacturing are easing - especially the need to be flexible and respond quickly to new trends. All this
2. by digitising the entire product lifecycle, allowing companies to use information from manufacturing, commerce and social media, which will help to quickly implement the required changes leading to product improvement. Thanks to technology, companies can react faster to demand and implement changes in production much faster. This can effectively address the challenges of shortening product life cycles, declining labour productivity and market volatility in particular.
3. Pressure for innovation and productivity growth. Many products are already bundled with complementary services - for example, predictive maintenance. Cost savings are also expected to come through the sharing of production capacity between manufacturers.
4. The consumer is at the centre of all activities. Product customisation is the most important activity in the product value chain. Consumers demand individually manufactured 'Made-for-Me' products and services. Smart technologies will enable manufacturers to make products tailored to the customer's needs, but at no additional cost.
5. Industry 4.0 puts people - the employees - at the centre of production. They will be assigned to where their work is currently needed. Work on production lines will be humanised considerably. Any manually intensive work will gradually disappear. Employees in production will only be coordinators who ensure the smooth flow of production. Employee flexibility will be the key to success. A great deal of emphasis will be placed on the ability to self-organise and self-create. On the one hand, this should lead to higher employee satisfaction and commitment, on the other hand, this process will lead to increased demands on many employee skills.

The Fourth Industrial Revolution will enable sustainable prosperity. Concepts such as making a profit and realising growth must be put into a long-term perspective. It is therefore worth considering what is actually the goal of a company - whether just profitability or long-term sustainability. The authors Morrar, Arman and Mousa published a study entitled The Fourth Industrial Revolution (Industry 4.0): A Social Innovation Perspective, where they confirm the importance of the link between social and technological innovation [6]. The internet has become a key success factor of the Third Industrial Revolution. It was designed as a

technology falling under public infrastructure. We expect the Internet to continue to deliver major innovations, particularly through the so-called Internet of Things. However, previous technological revolutions have failed to meet the challenges of social inequalities, climate change and other sustainability issues. The rapid depletion of the Earth's resources at the expense of future generations and the continuous pollution of the environment have created a global challenge. Concepts such as sustainability and social innovation have emerged and quickly attracted global attention.

4. Corporate culture in crisis context

Several authors [12–14] have proposed different models of culture change during turbulence and instability. Nelson and Cohen suggest that leaders should prepare for change and take the necessary steps to protect and adapt their culture through effective planning before, during, and after turbulent times [13]. To meet the challenge and achieve successful culture change, they recommend identifying the existing culture; proactively influencing the organization's culture; rethinking the core purpose and values; and communicating and reinforcing the values. Nadler and Tushman presented a model that leaders can use to examine their organization's culture and determine if change is needed [12]. The model views the organization as a system that draws inputs from internal and external sources (strategy, resources, and environment) and transforms them into outputs (activities, behaviors, and performance) at three levels-individual, group, and organizational.

In the process of transformation, the organisation consists of four subsystems that are interdependent: work, people, formal and informal organisation. To achieve effective change, Nadler and Tushman suggested that leaders should address all four components, not just one or two [12]. Recklies introduced the seven S's model (stuff, skills, systems, style/culture, shared values, strategy, and structure), which presents the organization as a set of interrelated and interdependent subsystems and offers another starting point for organizations facing culture change [15]. To be effective, an organization must have a high degree of internal alignment between all seven elements, which are distinguished into hard actionable elements that can be found in strategy statements, corporate plans, organizational charts, and other documents, and soft hidden and ever-changing elements such as capabilities, values, and elements of corporate culture.

However, Recklies argues that the soft elements are determined by the people in the organisation and can have a major impact on the structures, strategies and systems of the organisation [15]. Among the most commonly cited models about culture change during a crisis is Schein's model of leadership culture change. Schein proposed five primary mechanisms and five secondary mechanisms by which leaders can directly achieve culture change [14]. The "primary mechanisms" originate in the ways that leaders affect culture change through their actions: attention, crisis response, role modeling, reward allocation, and selection and dismissal criteria. The secondary mechanisms are the means by which leaders can indirectly affect culture change: organizational structure, systems and procedures, facility design, stories, legends myths, and formal pronouncements.

5. Discussion

We find ourselves in a situation that is unfamiliar, in many ways ungraspable and uncertain. The market is experiencing uncertainty and the working conditions of most of us have changed. The economic impact of the spread of the virus is affecting all segments across markets. Uncertainty is created, in particular, by the turbulent change in the behaviour of companies, the state and employees, which in turn affects consumers, resulting in postponed consumption, stalled projects and investment. Business owners, managers and tradespeople are facing challenges that may completely change their businesses and operations. Many small and medium-sized enterprises are making decisions in conditions that

are outside the standard market requirements, and we have never seen these conditions before. Healthcare managers are also facing challenges as they grapple with difficult decisions about how to operate hospitals in crisis and provide for people's health problems on a regular basis at the same time.

Decision-making plays a significant role during a crisis period. In managerial decision theory, various procedures and tools are explained through normative and descriptive theories, which should form the basis of decision making even in times of crisis. The analysed results of studies and opinions of scholars in this field show that uncertainty and complexity in times of crisis are significant predictors of decision-making practices. However, the degree of severity of the crisis is also an important factor, as other decisions are made in times of individual corporate crises and in times of local crises, and other decisions are linked to the current global crises triggered by the pandemic.

From a normative perspective, the characteristics of decision-making in times of crisis include complexity, political aspect and formalisation.

The complexity of decision-making as a feature of a complex and uncertain environment has been refuted by studies. It is not considered as a predictor of decision-making processes. As the level of uncertainty and severity of the crisis increases, the principle of satisfaction in decision-making comes to the fore. Satisfactory options are adopted because of resource constraints (time, money, people) which may not be optimal in the long run. In our view, however, the complexity of decision-making is significantly related to the current pandemic crisis. We understand complexity as the knowledge of all conditions affecting business and corporate decision-making processes. It is difficult to make decisions in the absence of a vision and plan by EU governments to recover economies and to increase the investment appetite of companies once the epidemic is contained. There is no indication of the government's intentions in the longer term, only packages of measures to calm the sudden situation have been communicated. The business community should be assured of the government's crisis thinking, that it will encourage diversification of the economy so that the country is not dependent on one sector. What we are seeing in Slovakia is that the shutdown of the automotive industry is a huge drain on the country's economy. As we did 10 years ago, after this crisis we should use the potential of Slovak science and research and ensure that it develops sufficiently. The complexity of conditions necessary for effective decision-making by managers is currently lacking. Paralysis caused by fear of the future is perceived as the biggest problem. Complexity also implies a broad focus, which, from the management perspective, means monitoring not only oneself and the problems of one's enterprise, but also the entire economic and social system, which is under the same stress and strain. In this situation, decisions that focus only on oneself, to the detriment of other companies, can expose the company to many risks in the long term, bring mistrust from suppliers, customers, partners and damage the company's reputation.

The political aspect enters significantly into decision-making, especially in the type of crises of a national and transnational nature. In these crises, stronger decision-making power and authority are essential. Formalisation as an established system of corporate governance is also relevant in times of crisis. Formal decision-making processes are related to the creation of crisis staffs, the formation of crisis plans and the specification of tasks related to the measures taken to deal with the crisis. In this case, they support the speed of decision-making and communication of decisions among business staff. Formalisation is also linked to legal arrangements, which should be developed in an expedited procedure and respect the urgency of the solution. In the case of Slovakia, there is currently a lack of legislation that would institutionalise the attitude of the state towards entrepreneurs, consumers and employees in times of crisis. There is a lack of a manual of sorts that would determine what measures the government will take and under what conditions, with an analysis of

the negative and positive impacts. The government would transparently follow this manual and would not have to adopt ad hoc measures at short notice. The market, including businesses, employees and consumers, does not like uncertainty and tends to react rashly in crises (lay-offs, cutbacks in consumption, unnecessary bankruptcy proceedings, etc.). Business decisions could therefore move from complete uncertainty to more concrete decision-making conditions. However, formalisation must not be linked to bureaucracy, which is counterproductive in a crisis. A crisis team of different experts is a great advantage; on the other hand, when it is over-composed in an attempt to solve problems as best as possible, decision-making can become a cumbersome, slow process, with conflicting views being resolved and over-emphasis on self-importance. Assembling a small, trusted team and giving it enough leeway to make quick tactical decisions is critical to decision-making in these crisis conditions.

In an environment of agility and dynamism, bottom-up decision-making, participation and the use of various digital platforms are advocated. These tools respond to the need for rapid decision-making, based on data and analytics of various kinds. They bring the possibility to delegate decisions with the ability to work with data and thus contribute to the implementation of actions taken by the formal decision-making process. At the same time, in conjunction with resilience in crisis dynamic and unpredictable conditions, the issue of focusing decision-making on the resilience of the management system in terms of its ability to survive without lasting consequences arises. Classical efficiency, typical of decision-making in times of calm and stability, is inapplicable in a crisis.

From the perspective of descriptive theories, attention is paid to the psychological aspects of decision making and the impact of behavioural economics on managerial decision making. These aspects have a significant impact in health crises, such as the current corona crisis, associated with initial surprise, followed by apprehension, fear, and waiting. Overwhelmed by a variety of miscommunicated or distorted information, decision-makers can fall into a variety of psychological traps that devastate their decisions. However, in an attempt to react quickly, decisions can be short-sighted. Although from a normative perspective a quick decision is necessary, descriptive theories talk about slowing down and using reasoning-generating judgments instead of perception-generating impressions. For the future of one's business and for rapid adaptation in post-pandemic conditions, it is essential to seek new perspectives, new angles on current business. Waiting is the wrong tactic.

Any condition, even a crisis, can be handled by a manager equipped with the appropriate crisis competencies. These, in addition to effective communication and leadership, undoubtedly include the ability to make decisions in such a way that current problems are dealt with effectively and in a timely manner, while at the same time addressing issues of future direction in the post-pandemic business space. This presupposes in managers a problem orientation, a view of the current problem in line with the strategy/vision/values of the business, quick decisions with accountability for them, the ability to critically evaluate information, the ability to perceive information in context, the ability to analyze different options for solutions, the ability to learn on the fly from different unexpected situations, caution when opportunities arise, and preparedness for even worst-case scenarios. Every decision involves risk. Therefore, the ability to make decisions at risk is an important management skill. Practical experience reveals surprising differences between science and practice in building resilience for a community exposed to serious risk. They also reveal inconsistencies between information and action among organizations responsible for protecting citizens exposed to extreme hazards. With the Covid 19 pandemic, scientists were aware of the threat spreading from Chin Wuchan as early as December 2019 or January 2020, and epidemiologists were able to predict the size, direction, severity, and likely impact of the evolving epidemic. The failure was not a lack of communication in

the early days, as everyone outside of China was constantly monitoring developments and the dire situation. Rather, it was the recognition of the risk that the spread of the coronavirus in China posed to other countries. The decision, with clear recognition of the threat and its likely consequences, came only on 11 March 2020 with the WHO announcement and came as a shock to residents, businesses, employees, entrepreneurs who were not prepared for the day-to-day change in the situation. The decision to prepare for a situation that was new to everyone was missing. In the early days, key risk communication capacity building failed.

A pandemic can come again, and unexpectedly. Lessons need to be learnt from today's situation and, first and foremost, there needs to be a sufficient supply of protective equipment for everyone on the front line. Have a continuously updated crisis plan and respond quickly. To be proactive, to have backup scenarios ready, to use relevant information for analyses of various kinds for possible ways of faking in times of possible crisis. Managers should build up their crisis competences and at the same time it should be remembered that it is not possible to let the economy collapse by long-term, across-the-board measures.

Industry 4.0 is also revolutionising management decision-making processes through a high degree of automation and digitisation of work tasks. This will have a significant impact not only on competition from businesses, but also on competition from individual countries that need to make significant changes in preparation for business transformation. These changes also create new challenges for business management and for the adaptation of new tools and techniques applied in the implementation of the various management functions. Research on the Fourth Industrial Revolution has neglected the profound managerial challenges underlying its implementation. The most important issues we have delineated within the decision-making function for the era of the fourth industrial revolution are:

- Decentralization of decision making, related to the ability of cybernetic systems to make simple decisions and to be autonomous,
- building on evidence rather than information and data,
- a greater need for critical thinking and reasoning, debate, the ability to interpret,
- focus of decision support not just in rational models but in complex cognitive and analytical decision support systems,
- advances in neuroscience, decision support through the use of brain function as a predictive organ capable of using mood, context and social cues for active inference.

The Fourth Industrial Revolution supports decision making with its tools. The creators of this support should attempt to reinforce the intended rationality of the target user while avoiding the introduction of "irrationality" into the processes of analysis and decision-making. Effective technologies must take into account the complex social nature of decision-making as well as the multifaceted nature of evidence. Understanding and responding to these creates scope for understanding other contexts and impacts, particularly in the social domain. The authors agree that the Fourth Industrial Revolution will have an impact on all areas of our lives, disrupting existing socio-economic structures. There will be a general change in the forms of service provision, including new forms of education and professions - probably as many as half of today's professions will disappear in 15 years' time, and entirely new ones will be born that we do not yet know exactly what they are. Lifestyles will change, and so will the ways of managing public affairs in general. Technological innovation, which is growing exponentially, will also lead to social innovation. It is therefore a major challenge for managers and researchers alike to examine what strategy to set when implementing the 4.0 concept, not only within the boundaries of their own company, but including the entire corporate ecosystem..

Corporate culture also plays an important role in setting strategy. Culture cannot be changed in short periods of time and it is therefore important to look at corporate culture as a tool for prevention. By the time the crisis itself arrives, we can no longer manage culture in the short term. Getting the corporate culture right in the context of a crisis means, above all, being prepared. All components of the corporate culture across the entire structure of the company must work synergistically with each other from the first to the last phase of crisis management. It is clear that some types of corporate cultures are not suitable for dealing with a crisis. If we look at corporate culture as one of the factors for successful crisis management, it is clear that its effect will be significant and should be the subject of further research also in the field of managerial decision-making in times of crisis.

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Identification of possible cheating on computer-based exams.

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Abstract: In this paper we will explain a solution to identify the users which poetically are trying to cheat the computer-based exam. Nowadays, the online exams are very useful to identify the people with right knowledge to do a job or to certificate them based on their knowledge. One of the major concerns for the organization of computer-based exams is the potential for cheating in collaboration with employee responsible of monitoring or due to the lack of human invigilation. The proposed solution will analyze in real-time the behavior of student and will alert the monitoring employee for suspicious activity of any exam.

Keywords: Computer-Based Test, CBT, Real-time analyzes, Online testing, exam cheating

1. Introduction

Information technology has changed our lives in every aspect, so even on exams there are so many possibilities to implement the technology to make more easy and efficiently the way we check the knowledge of people. Exams are very important for students, teachers, and for people who are seeking to get a job based on their knowledge.

Many companies like Cisco, Oracle, Microsoft, etc. have their focus on teaching their technologies and certificating people after passing the exam. To minimize the cost of training and assessment of knowledge of candidates they are using information technology.

An exam may be administered in two ways, formally or informally. An example of an informal test is a reading test administered by a parent to a child. A formal test might be a final examination administered by a teacher in a classroom. [1] The first one usually is used by students/candidates to evaluate their knowledge and the second one often results in a grade or a test score or a certificate.

Computer-based Test (known as CBT) are very used methods to do tests using computers as an alternative to paper-based tests. Such a test can be conducted online using the internet or a computer-aided facility. Usually, this test or examination is carried out by organizations to evaluate or analyze a candidate's performance, skill, or capability.[2]

With the integration of features like multiple-choice questions, descriptive answers, analytics-based questionnaires, etc., the CBT online test simplifies the evaluation task of teachers. The faculty can be assured of the knowledge level of students based on the tests mapping & results. [2]

Nowadays, online exams are very useful to identify the people with the right knowledge to do a job or to certify them based on their knowledge. One of the major concerns for the organization of computer-based exams is the potential for cheating in collaboration with employees responsible for monitoring or due to the lack of human invigilation. The proposed solution will analyze in real-time the behavior of students and will alert the monitoring employee for suspicious activity in any exam.

2. Technics, Advantages and Disadvantages of CBT

There are different exam formats and some of them like Multiple choice, completion type, Alternative response, etc. can be implemented 100% with CBT technics there are some formats that need to be assessed by humans like essays, written tests, etc. where the way we solve the problem is important. In any case, information technology can help us to do exams.

CBT technology offers multiple advantages for both the instructor/test organizer and the students/candidates who will take the exam. Some of the most important advantages of the CBT test are as follows.

- **Large Scale number of tests generation:** Suppose there is a vacancy in an organization, and several job aspirants have come for an interview, a part of which is to give a written assessment, how long would it take for the entire procedure to conclude? It is reasonable to assume that it will take an entire day, but the CBT test hosts a large-scale assessment online without having to wait individually. [2]
- **Time respect:** In some types of tests the time is very important, and respecting the time of the test will affect the result of testing. For example, there are some tests for driving licenses where we must answer within a minute in some visual situations. If we do this kind of question on paper-based we cannot ensure that the candidate will respect the time and in CBT it is a very easy task
- **Real time assessment:** One of the most important advantages of CBT is the real-time assessment of the test. Suppose we have a test for one hounded student and after the exam, the teacher needs to assess one of the tests in the last 10 minutes; in this case, the students must wait to get the results of the test for the last 2 days. But with CBT they can get results in real time.
- **Remote Test Feature:** This feature gives CBT another dimension. Online testing nowadays is a common way to test knowledge prior to interviews or other exams. With this feature, there is no need to physically attend the places where the organizers organize the tests. So, at the same time, there is no limit on the number of students to attend the exam. Computer-based tests can be taken at any time from any place, given that there is a stable internet connection. The students can appear for the exam at a suitable time and from a convenient location, they do not need to go to a test center to take exams. [3]
- **Cost effective:** The preparation of tests with classical paper-based methods costs more than CBT methods because it needs more people to be involved, the preparation of testing ambient and the students to spend time and money to attend the test on the classes prepared by organizers.
- **Increases Security:** In a CBT, multiple sets of questions are prepared with similar questions and difficulty. And these questions are given to the candidates randomly; it lowers the risk of cheating in examinations. [3]

CBT exams have some disadvantages as well. Some of the few of the disadvantages of CBT Exams are as following:

- **The initial cost:** The initial cost of acquiring the CBT technologies is expensive and the number of tests must be bigger and continue to be cost-effective. That is a reason for many governments and private organizations to stay away from integrating it into the education system. But there are places where it is a must like test for driving

license tests, where the tests are going on every day and the number of candidates is big enough to minimize the cost for a test.

- **CBT Limitation:** Computer-based tests have their limitations because they can be affected by other factors like internet connection, power problems, or other systems failures.
- **Cheating:** Cheating on a test is the process of using unauthorized means or methods to obtain a desired test score or grade [4]. This is another big problem for online computer-based tests. The cheating issue also is a problem for paper-based tests but usually, those kinds of tests are observed by humans during the testing.

Several common methods have been employed to combat cheating. They include the use of multiple proctors or invigilators during a testing period to monitor test takers.[3] Test developers may construct multiple variants of the same test to be administered to different test takers at the same time, or write tests with few multiple-choice options, based on the theory that fully worked answers are difficult to imitate.[3] In some cases, instructors themselves may not administer their own tests but will leave the task to other instructors or invigilators, which may mean that the invigilators do not know the candidates, and thus some form of identification may be required.[3] Finally, instructors or test providers may compare the answers of suspected cheaters on the test themselves to determine whether cheating did occur.[1]

On online CBT there is another problem to avoid cheating is identifying who is the person behind the computer. Even for this problem, there are different techniques to identify the candidate by using different technologies like face recognition, fingerprint, camera monitoring, etc. Those techniques do not guarantee 100% that the candidates do not cheat, for example, their computer can be installed with a remote-control application and another person behind can solve the tests.

In different cases, big companies like Cisco, Microsoft, Oracle, Cambridge, etc. which offer the possibility to test and certificate candidates online via CBT in collaboration with local companies have opened licensed test centers and the tests are monitored by local employers and with cameras.

The same form of CBT organization is also used by government institutions that do tests very often. They prepare offices with computers, CBT systems and monitoring infrastructure like cameras, and candidate verification devices using biometric data and some instructors also physically monitor the testing process.

Usually in those conditions, the collaboration between the candidates and instructors will be a real problem, and it will be very hard to identify the cheaters. In this paper, we proposed a new technique to identify the possible cheating candidates during the CBT testing process based on their behavior compared to different prototypes of the behavior of candidates who did the same tests before.

3. Analyze of human behavior during CBT

To avoid cheating during the CBT process, camera monitoring is one of the most used techniques. But also, analyzing every video recorded for every test is very difficult because it takes too much time and when the number of candidates is very big it is almost impossible to check every candidate's video. In those cases, the best option is to select randomly some candidate's video and do the analysis.

To identify the possible cheating cases, we propose an algorithm that is based on the candidate's behavior during the test. The algorithm analyzes the history of candidates during the computer-based tests (log analyzer) and generates different candidate behavior profiles. After many tests, the profiles become

clearer so those models can be used as references in the real time test monitoring process.

As we mentioned before there are different types of CBT, so it needs to have different rules for each type of CBT. Our algorithm is based on the type of "Alternative response (true/false)", and it can be used also for multiple choice, etc.

To generate candidate profiles the algorithm needs too much data, and it will be more and more effective with increasing numbers of tests. To realize it we used the data provided driving license testing system in Albania for the last 10 years and about 700,000 tests data.

The algorithm takes different parameters as input and generates the profiles, some of the parameters are explained as follows:

User activity during the test: The system takes logs of every user action and based on those logs we can have different profiles.

- The first profile is a test where the candidate takes questions one by one and gives the answers. After passing all the questions he will review questions when he is not sure of the answer he gave. The user activity is continuous, and this profile is a normal one.

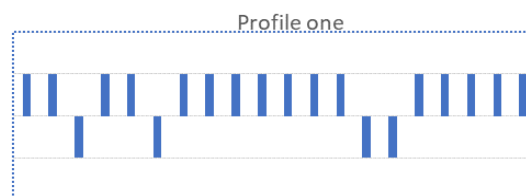


Fig. 1 User activity, first profile

- The second profile is like the first one, but it takes less time, and most of the questions are answered correctly but the time from one question to another is very short. This profile identifies very well-prepared candidates also the candidate also is suspected of cheating. The shorter test time is considered with a bigger probability of suspicion.

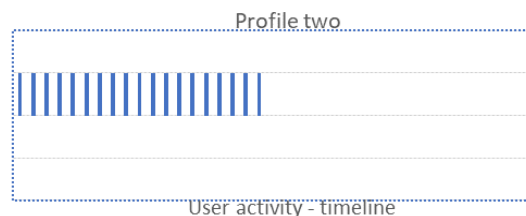


Fig. 2 User activity, second profile

- The third profile is a test with a positive result that does not have continuous activity during the test. The candidate does not have activity most of the time and in a short time, he responds to questions with correct answers. Also, in this profile is considered the test in which the candidate answers a group of questions in a short time and has a big pause before the answers of the next group of questions. This profile is the most suspicious for cheating.

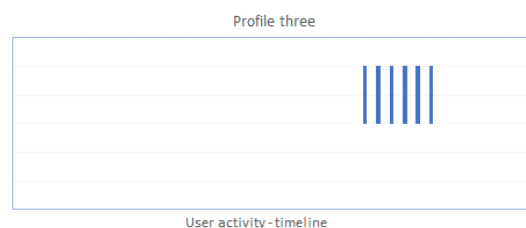


Fig. 3 User activity, third profile

- The four profile is a test with a positive result that has continuous user activity but during the test number of

correct answers is at the same level as incorrect answers, so the candidate chooses the alternatives of answers randomly, and at the end of the test he reviews and answers just the incorrect answers in a short time and test gets a positive assessment.

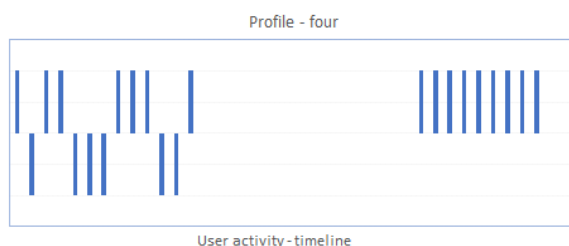


Fig. 4 User activity, fourth profile

Question statistics: Some questions have been answered incorrectly more often than others and in case the test contains some of them and the candidate answers correctly in a short time and rechecks the questions it provides a profile with weak suspicion for cheating.

Position of computer: The camera monitoring process does not cover all the computers of the same quality, some of them do not have the same focus or view on camera as others. The probability of positive results when there are many tests must be approximately the same on all computers. So, when the algorithm detects some computers, with positive results better than the historical rate will consider this position a suspicious one.

Candidate's tests history: This profile analyzes the history of the candidate's related tests. For example, when a candidate has some tests with weak results in the last week and the new test, he gets much better results and teaching all the questions to get a better result takes months. This profile is considered a weak suspicion.

4. Candidate profiles generation and real time test monitoring to avoid cheating during exams.

The dataset used to train the algorithm contains about 700,000 tests for four types of tests where 90% of them are with the same structure of 40 questions per test and the rest is in structure of 30 questions per test and 10 questions per test. The number of questions used to generate all the tests is about 6500. So, the dataset fulfills the criteria to train the proposed algorithm.

The dataset used to generate profiles which will be used in real-time to check candidates' behaviors is not a clean one, we do not know if there are cheated exams. To generate more effective profiles, we proposed to generate profiles from all the tests of the dataset and profiles only from tests with negative results but those tests which fail for a few points. For example, a test with 40 questions where each of them has one point and the number of points to pass the test is 36 will be taken into consideration only if the candidate has scored 30-35 points. So, the test has a negative result but with a little difference from the pass result.

The generated profiles from algorithm were compared between them in two different ways as follow:

- The first one is a human comparison by analyzing the data of each generated profile and they decided the profiles generated by taking into consideration only the tests with negative results are better by a small difference to other profiles.
- The second comparison is done by computer. A simulation software generated some tests from the same test questions and structure and simulated the candidate testing process. During the simulation, the software acted like a normal candidate and by using the proposed profiles acted like cheating. The results generated by simulation were analyzed and compared and the result is

the profiles generated from tests with negative results were better.

The analysis of new tests on the proposed algorithm and profiles of candidates' behavior to avoid the possibility of cheating is implemented on a real testing system and works in real-time on the background. During the process of testing the system generates logs and the logs are analyzed in real-time and classifies the tests from 1 to 10 as suspicion of cheating. The classification changes during the testing process.

To optimize the performance of the system for the proposed technique we used the trigger-based solution when the cheating detection algorithm is fired when the candidate generates user activity.

5. Conclusion

The proposed technique has been implemented in the last three months on a real testing system and after more than 20,000 tests the process was analyzed in real-time and after the process of the test it began to give the result on prevention of cheating. More than 150 cases from the tests which were considered suspicious for cheating from the algorithm were cheated after being verified by the camera monitoring system.

Also, there were some false detections as suspicious for cheating from the algorithm. After analyzing the data and candidates' education, age, and a simple interview we conclude, to obtain better candidates' behavior profiles we must add two new parameters, the age of the candidate divided into groups and the candidate's education (bachelor's degree or master's degree have better results compared to others).

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The impact of interactive software on teaching

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Abstract: In this scientific paper, we investigate the impact of interactive software on teaching a specialized subject at a vocational school based on research conducted. Interactivity is now one of the fundamental components of ICT and digital education. Interactive software can be useful for teaching specialized subjects because it allows students to interact with the material and gain practical experience, which can enhance their learning. In the 21st century, students are increasingly identifying with the use of ICT in education, and it is necessary for teachers to continually educate themselves in their use and incorporate them into their lessons.

Keywords: TEACHING, EDUCATIONAL, INTERACTIVITY, ICT, SOFTWARE

1. Introduction

We live in a time when the couch and television have become the most popular members of households, and the mobile phone is an inseparable accessory of our purses and pockets. We spend several hours a day "chilling" on the couch and surfing, "Facebooking," and playing games on our phones. In such an environment, it is very difficult to engage our children in learning through books and notebooks. Therefore, it is evident that modern techniques are being implemented and used in education, which leads to its modernization. Proper preparation and use of interactive educational materials and didactic applications is not an easy task. In many cases, it is the educator themselves who create these materials and must first select suitable educational material for processing into an interactive format, determine the amount of data to be used, and design it in a way that supports the clarity and illustrative nature of the material, so that the resulting interactive material is not just an electronic copy of a textbook.

2. Interactivity

The word "interaction" itself is a foreign word and expresses the mutual action of two or more factors. The term "interactive" means enabling mutual communication, active input into a program or activity. Interactivity can be understood as mutual influence or a certain activity between several subjects. Interactivity is also used to refer to such types of media that allow the recipient not only to immediately respond to the received information, but also to enter its creation, control, guide the progress of work, or even complete the processed material [1].

The development of digital technologies and ICT tools has enabled and simplified communication within the internet. Depending on the applied technology, we can primarily speak of interactive communication, i.e., an immediate reaction to a stimulus, and especially two-way communication. The changes directly resulting from the integration of ICT elements into teaching consist of software applications designed to support teaching, where dynamic systems are at the forefront. These respond to changes in input conditions by changing graphics, numbers, or symbols. Today, there are already devices on the market that enhance existing applications. This level utilizes ICT and other technical means to bring deeper interactivity to the environment, such as interactive boards, moving robots, VR glasses, and so on.

3. Positive Technological Development

Creating and transforming digital worlds for student, where they can play, interact and, above all, learn, is a very current topic. The designs of virtual environments are currently motivated more by commercial needs than by a desire to positively influence the development of our students. To develop such a digital environment, it is advisable to follow some predetermined rules that

will partially control our decisions. More than ten years ago, scientists at the MIT Media Lab and Tufts devised a set of recommendations called Positive Technological Development (PTD). The following selected concepts fall under PTD. PTD (Positive Technological Development) provides a framework that helps to understand how technologies can be designed and used to support positive behaviour, and how this behaviour can subsequently bring developmental assets. The theoretical model of the framework for positive technological development includes three components: individual assets, behaviour or activities mediated by technology, and applied practice. The diagram below (Fig. 1) shows how these components are interconnected and provides examples of how they can be implemented in sets.

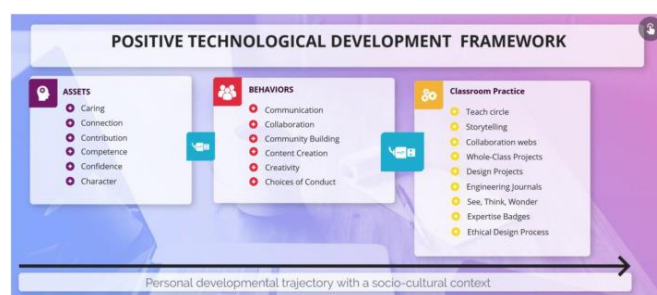


Fig. 1 Positive Technological Development [2]

PTD promotes collaboration instead of competition, supports shared resources and mutual care. Collaboration is integrated into the entire learning process. PTD encompasses the design of new educational technologies, technologically rich interventions, and their evaluation. Some activities could include sharing tools/materials, working on the same project, seeking help from other students, designing, and providing feedback, etc.

4. Python

Python is currently one of the most widely used programming languages, especially in the field of data analysis, and is a versatile programming language that community contributors have added an extensive library of scientific and data analysis resources to, making the range of problems that can be easily solved enormous. These resources are freely available online as numerical routine libraries, including SciPy, which includes algorithms for many classes of scientific problems such as optimization, integration, and interpolation, among others; NumPy, which includes a data structure of arrays and fast numerical routines; Matplotlib, which is a graphical package for visualizing data; and Pandas, which is built on top of Matplotlib and NumPy to allow access to both libraries with less code and fewer routines [3].

Interactive software for Python refers to a class of software that allows users to interactively run and test Python code in a convenient and user-friendly way. There are several popular interactive software tools for Python, including IDLE, Jupyter Notebook, and IPython. IDLE (Integrated Development and

Learning Environment) is a basic Python IDE that comes bundled with Python. It provides an interactive shell and a simple text editor, making it easy for beginners to write, run, and test Python code. IDLE also has features such as code highlighting, code completion, and debugging tools. Jupyter Notebook is a web-based interactive computing environment that allows users to create and share documents that contain live code, equations, visualizations, and narrative text. It supports multiple programming languages, including Python, and is widely used for data science, machine learning, and scientific research. Jupyter Notebook allows users to run code in cells and see the results immediately, making it easy to experiment with different code snippets and explore data interactively. IPython is an interactive shell for Python that provides an enhanced command-line interface with features such as syntax highlighting, tab completion, and object introspection. It also supports inline plotting and can be used as a backend for Jupyter Notebook. Overall, interactive software for Python is essential for learning, experimenting, and developing Python code in a more efficient and user-friendly way. Whether you're a beginner or an experienced developer, there's an interactive Python tool that can help you write better code and achieve your goals.

5. Result and discussion

The research shows that all interactions with visualization tools are more effective for learning than watching (non-interactive) video animations. The studies indicate that sophisticated interactivity in education has increased students' interest, but this did not translate into better academic performance.

The research sample consisted of 28 students. We obtained the responses to the questionnaire after the instruction with interactive software. Most of the participants (86%) stated that interactive instruction was better and more effective than previous teaching methods. 14% of participants described the instruction as average, and none of the participants reported that interactive instruction was worse than previous teaching methods. For the subjective measurement of cognitive load, we used a questionnaire developed by Paas in 1992, where mental effort refers to the number of cognitive capacities or resources that students allocate to meet the demands placed on them [4]. After completing the instructions, students were immediately asked to report the mental effort they invested in learning. Mental effort was rated on a 9-point Likert scale by selecting 1 (very, very low) to 9 (extremely high). It is possible to say that the use of an interactive program for teaching programming in Python had a positive impact on the cognitive load of the students. The use of interactive software reduces cognitive load, allowing students to achieve better results. Research indicates that a high level of cognitive load has a negative impact on cognitive capacity and performance [5].

6. Conclusion

Our findings that students found the interactive learning environment suitable and the interactivity itself had a positive impact on their learning are in line with the works of other authors in the same area [6,7]. For the teacher, it is necessary to master the didactics of interactive learning, which provides students with a deeper and easier insight into programming teaching. In future work, we would like to test a larger sample of students and assess the effectiveness at significant levels for knowledge transfer. In the case of simulations, we want to measure the level of impact on students and their improvement in complex programming structures. It should be noted that the sample size can affect the repeatability of the research and its conclusions. We recommend conducting a study examining the distribution of interactivity and its impact on cognitive functions.

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The education system in Romania and France. Comparative analysis

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Abstract: Following some theoretical investigations, through the analysis of educational policy documents, we will compare the education system in Romania and France. The motivation for choosing this theme for analysis was represented by the numerous similarities between the two education systems. The analysis criteria of the present study considered the following criteria: the structure of the education system, educational policy principles, purposes, costs.

KEYWORDS: EDUCATION SYSTEM, EDUCATIONAL POLICY PRINCIPLES, PURPOSES, COSTS

1. Introduction

The education system is a subsystem of the social system, which is subordinated and integrated into the framework and general structure of society. The education system, viewed as a whole, refers fundamentally to the institutional organization of education. In this sense, the education system includes all the institutions that aim to achieve some educational objectives. Following some theoretical investigations, through the analysis of educational policy documents, we will compare the education system in Romania and France. The motivation for choosing this theme for analysis was represented by the numerous similarities between the two education systems. The analysis criteria of the present study considered the following criteria: the structure of the education system, educational policy principles, purposes, costs.

2. The structure of the education system

The Romanian education system includes the following levels:

- *early education* (consisting of the pre-school level (0-3 years) and *preschool education* (3-6 years));
- *lower secondary education* (consisting of grades V-VIII); upon completion of this level, the students take a National Assessment exam;
- *upper secondary education* (consisting of grades IX-XII), having three streams: theoretical, vocational and technological; upon completion of this level, students take the Baccalaureate exam; *professional education* (having a minimum duration of 3 years, the graduates of this type of education having the opportunity to follow high school education courses); *non-university tertiary education* (includes post-high school, professional and technical education);
- *higher education* (consisting of bachelor's, master's and doctorate studies).

In Romania, education is a national priority (National Education Law, 2011/2022). The education system has an open character (it allows the mobility of students through transfer) and a pluralistic character (the existence of both public and private schools, the existence of educational alternatives).

The French education system is structured as follows:

- *kindergarten* ("Ecole Maternelle") - from 3 to 6 years old, even if it is optional, almost all children attend kindergarten. Kindergarten lasts 3 years, the first stage being called "des apprentissages premiers" where the child will learn how to integrate into society. Following that at the threshold called "Grande Section" they learn the

skills necessary to start the primary school "Ecole Primaire" (reading, writing and elementary notions of mathematics);

- *elementary school* ("Ecole elementaire") - from 6 to 11 years old;
- *general school* (College) - from 11 to 15 years old, where students are taught the same subjects;
- *high school* (15-18 years old) - there are 3 types of specializations: Language and Literature (L), Computer Science and Mathematics (S), Economics and Social Education (ES). Numbering of high school years: 2nde - Class X 1st - Class XI; Terminals - Class XII.

The baccalaureate exam starts as early as the 11th "Premiere" grade, where the French Language and Literature test is taken, the exam being written and oral. The last exams are held in the 12th "Terminal" class. An exam that all students in all majors must take is the Philosophy exam. If the student does not have a satisfactory grade in this exam, he can opt for two more subjects to raise his final grade. After graduating from the baccalaureate, the student has the right to enter a state or private college.

At the high school level, the French have three categories of baccalaureate exams: General Baccalaureate - allows the student to pursue his studies at the university; Technological Baccalaureate - for continuing studies at higher education institutions profile; Professional BAC - allows employment at companies, depending on the chosen profile. The general BAC and technological BAC exams can be taken after three years of high school studies, and the professional after two years.

The final baccalaureate exam is very important for French students. It is a very rigorous exam. The exam lasts from two to four days. Almost 30% of those who support it do not promote it.

- *higher education*

Students who have passed the baccalaureate exam are entitled to a free place at the university. There are 77 universities funded by the government. Universities in France are free for students, however, all students are required to take an exam at the end of the first year and only those who pass it have the right to continue higher studies. The degree of difficulty increases exponentially with the reputation of each university. Admission to a university is supported a maximum of two times.

The French educational system is characterized by a strong central presence of the state in the organization of education. It is regulated by the Department for National Education, Higher Education and Research. The state defines the details

of the curriculum at all levels of education; organizes the admission procedure for teachers, defines the content, recruits teachers who become civil servants, provides them with continuous training; recruit and train inspectors, responsible for quality control of the education system; is the main funding body of the public education system. Education in France is compulsory between the ages of 6 (the beginning of elementary education) and 16 (European Commission, 2022).

3. Educational policy principles

Romania. The principles that govern Romanian education are: the principle of equity (learning without discrimination), the principle of quality, the principle of relevance, the principle of efficiency, the principle of decentralization (the main decisions are taken by the people directly involved in the process), the principle of public responsibility, the principle of guarantee cultural identity, the principle of assumption, the principle of recognizing and guaranteeing personal rights belonging to national minorities, the principle of ensuring equal opportunities, the principle of university autonomy, the principle of academic freedom, the principle of transparency, the principle of freedom of thought and independence from ideologies, the principle of social inclusion, the principle of centering education on its beneficiaries, the principle of parental participation and responsibility, the principle of promoting health education, the principle of organizing religious education, the principle of basing decisions on dialogue and consultation, the principle of respecting the right to opinion (National Education Law, 2011/2022, art. 3).

France: The principle of equality of equal opportunities through the fight against social inequality (Education Code, 2023, art. L111); the principle of non-discrimination by ensuring inclusive education, through the social mix of the public educated in educational institutions; (Education Code, 2023, Art. L111); the principle of freedom of choice through the decision to continue studies after the compulsory period as well as through the case of people with severe hearing impairments who have the right to choose between bilingual communication, sign language and communication in French. (Education Code, 2023, art. 112).

4. Educational purposes

Vocational education and training within Romanian education has as its main purpose the formation of competences, understood as a multifunctional and transferable set of knowledge, skills and attitudes necessary for personal fulfillment and development, social integration and civic participation, employment, participation in the functioning a sustainable economy, the formation of a value-based conception of life, education in the spirit of dignity and respect for human rights, the cultivation of sensitivity towards human issues and moral-civic values (National Education Law, 2011/2022, art. 4).

The aims of the schooling levels within the French system aim to "provide basic knowledge and elements of a general culture, including scientific and technical data, to prepare for a qualification and contribute to its improvement and adaptation during working life". (Education Code, 2023, Art. L111).

According to the National Education Law, the ideal of the

Romanian school assumes: "the free, integral and harmonious development of human individuality, the formation of autonomous personality, the assumption of a system of values that are necessary for fulfillment and personal development, for the development of the entrepreneurial spirit, for active citizen participation in society, for social inclusion and employment on the labor market" (National Education Law, 2011, art. 2).

The educational ideals of the French system are: "permission to acquire a new skill", "preparation for professional life and for the exercise of responsibilities as a man, woman or citizen", "continuous training", "self-education"; (Education Code, 2023).

5. School education and quality of life

School education has a primary place in the development of society and its quality is an important factor. Thus, increasingly advanced tools for estimating the quality of learning have been developed, the Program for International Student Assessment (PISA) being one of them. Romania and France are participating in the PISA program (an international comparative study to measure the skills of 15-year-old students in which countries around the world can participate) (OECD, 2010). Among the results obtained by these two states in recent years, the following aspects can be mentioned:

Romania – in the year 2000 it occupied the 34th place out of 42; in the year 2006 it occupied the 47th place out of 57 participating countries; in the year 2009 it occupied the 49th place out of 65 participating countries; in the year 2012 it occupied the 45th place out of 65 countries participating countries; in the year 2015 it ranked 48th out of 72 participating countries; in the year 2018 it ranked 47th out of 79 participating countries (Balázsi, I., Ostorics, L., Szalay, B., 2008; OECD, 2010; Pantazi, R., 2013; Pantazi, R., 2016; Ofițeru, A., 2019)

France - in the year 2000 it occupied the 14th place out of 42 participating countries; in the year 2006 it occupied the 25th place out of 57 participating countries; in the year 2009 it occupied the 22nd place out of 65 participating countries; in the year 2012 it occupied 23rd place out of 65 participating countries; in 2015 it occupied 27th place out of 72 participating countries; in 2018 it occupied 18th place out of 79 countries (Balázsi, I., Ostorics, L., Szalay, B., 2008; OECD, 2010; Pantazi, R., 2013; Pantazi, R., 2016; Ofițeru, A., 2019).

According to an article written by Vasile, M., Muscă, M., Angi, D., Bădescu, G. (2020) a possible reason why Romania is in last place in the world ranking would be the alarming difference between the social environments of origin of the students. Several important indicators were analyzed: the results of the National Assessment, the passing rate of the Baccalaureate exam, the participation rate of the Baccalaureate exam, school dropout, the early school leaving rate, the existing school network. Following the analysis of the indicators mentioned above, it was found that: in the rural environment less than 65% of the students from the rural environment managed to obtain an average above 5, while in the urban environment more than 86% of the students pass this threshold; over half of the students in the urban environment have averages lower than grade 6, while in the urban environment only a quarter of the students are in this situation; in rural areas only 17.5% have averages higher

than grade 8, while in urban areas a quarter of students obtain averages above grade 9 and almost half having averages above 8; in the rural environment the pass rate of the Baccalaureate exam is below 42%, while in the urban environment the pass rate exceeds 70%; the school dropout rate is almost double in the rural environment compared to the urban one; early school leaving is six times higher in rural than urban areas.

6. The costs invested in education

Analyzing the costs that the two countries invest in education, in a study entitled "Costs of insufficient investment in education in Romania" (2014) carried out by UNICEF, it was found according to Eurostat (in 2013) that the Gross Domestic Product (GDP) per per capita did not exceed 54% of the average recorded at the level of the European Union, Romania spending only 4.1% GDP on education compared to the average of 4.7% recorded in Eastern Europe and the EU average of 5.4%, thus being the second poorest member state of the EU.

As for France, according to an article titled "How much do European countries spend on education?" carried out by Archip, A. in the year 2021, it was found according to Eurostat that France allocates a percentage of 5.3% GDP to education.

7. Conclusions

Contemporary education represents, for all European states, a very sensitive and extremely significant segment in relation to the social-political system as a whole and to the whole society. The fact that the European Union considers this field as a national priority proves that this aspect is an objective necessity. Today's society cannot function in good conditions without a well-developed education system. A competitive educational system is the one capable of developing the human resource through its contribution to the promotion of skills, creativity, intelligence, discernment, initiative, originality. In the end, taking some models and examples of good practice from the French educational system and multiplying them in the Romanian educational system can be a beneficial connecting element for compatibility and harmonization with international trends in this vital field of education. France has implemented programs that have helped improve the literacy skills of students and parents. They have made a major contribution to increasing the quality of the teaching-learning process and improving student results.

In conclusion, the analysis shows that the two states have a well-developed educational system and that the interest in maintaining it is a priority for each of them. The difference between them is given by the fact that schooling in the French system is at a much more developed level (having a lower illiteracy rate) compared to the Romanian educational system whose target is to combat illiteracy, in general, but also functional illiteracy.

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