ŽILINSKÁ UNIVERZITA V ŽILINE
STROJNÍCKA FAKULTA
KATEDRA PRIEMYSELNÉHO INŽINIERSTVA

And

AKADEMIA TECHNICZNO-HUMANISTYCZNA W BIELSKU-BIAŁEJ
WYDZIAŁ BUDOWY MASZYN I INFORMATYKI
KATEDRA INŻYNIERII PRODUKCJI

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INVENTION FOR ENTERPRISE

InvEnt 2021

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CONTENTS

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Ivan ANTONIUK[1], Martin KRAJČOVIČ[2], Vladimíra BIŇASOVÁ[3]

DIGITAL TWIN IN MANUFACTURING

Abstract
The fourth industrial revolution, which we call Industry 4.0, was caused by the advent of the Internet and the ubiquitous digitization. The well-known technology of the Digital Factory is gradually expanding into the Digital Twin (DT). The DT represents the interconnection of three worlds, namely: Digital Factory, Real Factory and Virtual Factory. The digital twin can be used in such areas as maintenance, scheduling, logistics, medicine, and many others.

1. INTRODUCTION TO A DIGITAL TWIN

With the development of new generation information technologies, e.g. cloud computing, the Internet of Things (IoT), Big Data and artificial intelligence (AI), the era of intelligent manufacturing is coming. Accordingly, various production development strategies have been presented, such as Industry 4.0, the Industrial Internet, Cyber Physical System (CPS) -based manufacturing, and others. Achieving cyber-physical fusion is a crucial step towards the implementation of intelligent manufacturing. CPS provides a framework and mechanism for seamless interaction between physical and cyber components [1].
There are several definitions of Digital Twin. One argues that the Digital Twin is a virtual representation of a physical product or process that is used to understand and predict the performance characteristics of a physical counterpart. Digital twins are used throughout the product life cycle to simulate, predict, and optimize a product [2].
The main value of the Digital Twin is:

- Support and monitoring of the production process throughout the life cycle.
- Closed loop between real production and virtual production model.
- Improved data relationships (improved data consistency).
- Decentralization of production.
- Shortening the commissioning time.

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- Improving management and optimization based on real up-to-date data.
- A complete overview of the current and future state of operation.

1.1. Types of a Digital Twin

A digital twin can be considered a small device, a production line, but also a large workshop or even an entire factory, so we divide the digital twin from several perspectives [5].

The concept of a Digital Twin can be divided into two forms:

- **Passive form of DT** a tool that does not interfere in production processes, but interprets them.
- **Active form of DT** has control functionality.

In the terms of simulation, it can be divided into:

- **Process DT** This type of digital twin usually relies on the detailed physics of each individual component of the machine and, in addition, emphasizes the optimization of the flow of materials along the entire production line.
- **DT at machine level.** These digital twins work on highly accurate simulation data of machine dynamics. They provide a wealth of new capabilities to accelerate development and keep costs under control while increasing performance requirements.
- **DT on a partial (or material) level** uses the properties of the material to perform complex simulations, where the actual performance of individual parts is simulated. They can also focus on how certain liquid materials will behave during their handling, relocation, or processing in different industries.

1.2. Pillars of a Digital Twin

The complexity of the digital twin can be divided into 5 basic pillars (PE – Physical Entity, VE – Virtual Entity, Ss - Services, DD - Data, and CN – Connections), each of which contains certain technologies Fig. 1. [3].

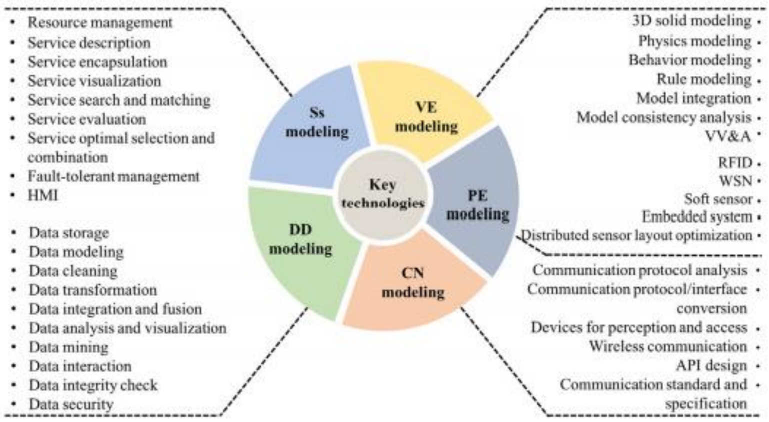

Fig. 1. Key technologies of a Digital Twin [3]

2. PROCEDURE OF A DIGITAL TWIN IMPLEMENTATION

To create a digital twin, it is necessary to introduce production data sources. The system can automate data collection, and such a system should be integrated with historical data to provide information on the performance of individual operations. In addition to historical data, the system also requires real-time data to support the creation of a digital twin.

The whole process is started by collecting data from the production plant, this data is then transferred to the digital twin. The digital twin obtains a starter kit of historical data, which serves as an initial data set and uses it to train the model. If the digital twin being created is based on technologies such as machine learning, deep learning, it will be able to generate recommendations or feedback. This gives us important and useful data that we can use to tune or adjust the operating parameters of the production system. This process is repeated throughout the life cycle until the production goal is reached or, for other reasons, a decision is made to discontinue the digital twin. The most important elements in implementation are 3 elements: physical, digital and integration. General approach to the implementation and realisation of digital twin is displayed schematically on the Fig. 2.

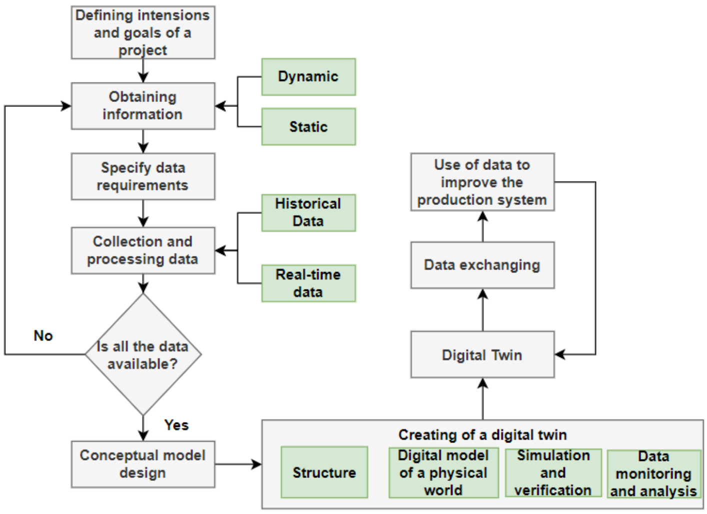

Fig. 2. General procedure of a DT implementation

3. EIGHT RULES FOR DIGITAL TWIN MODELLING

The following principles are important for successful modelling and use of DT:

- **Data and knowledge based.** The existing knowledge provides basic rules that should be followed during the modelling process, but real-time data need to be injected into the DT continuously, to feed the DT with new knowledge and to calibrate the initial virtual models, services, and data structures continuously.

- **Modularization.** Modularization is effective as it can separate and recombine compositions of the DT with benefits of flexibility and reusability.
- **Light weight.** A light weight model is essential for the DT to achieve a shorter transmission time, faster running speed, and better real-time performance.
- **Hierarchy.**
- **Standardization.**
- **Servitization.** Encapsulate functions provided by the DT into a standart service for easy and convenient usage.
- **Openness and scalability**. The DT should be open to integrate with various resources, which makes the DT have better compatibility to work with different systems.
- **Robustness.** DT is mainly applied to the industrial environment [6], which is characterized by uncertainty, dynamism, and complexity, it should be built with good robustness to deal with unpredictable changes.

4. CONCLUSION

The article focused on the digital twin in the industry, the definition, the most important theoretical knowledge, and the division of DT were mentioned. The third chapter describes our approach to the creation of DT twins in the factory. Eight principles were also mentioned which must be observed when creating DT.

This work was supported by the Slovak Research and Development Agency under the contract no. APVV-19-0305.

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Ivan ANTONIUK[1], Branislav MIČIETA[2], Marta KASAJOVÁ[3], Vladimíra BIŇASOVÁ[4]

EMOTIONAL INTELLIGENCE IN THE WORK ENVIRONMENT OF COMPANIES SELECTED RESULTS

Abstract

The aim of the survey was to find out how today's managers behave in common situations that occur in the daily work of managers. A questionnaire survey was attended by managers. The questionnaire contained two parts. Firstly, the filtering questions and secondly, the specific situations in managerial life were analyzed, from which the level of emotional intelligence of the given manager was evaluated. These results in the work served to suggest improving awareness and the importance of emotional intelligence in work environments.

1. INTRODUCTION

Emotional intelligence is the ability to understand and control one's own emotions and the emotions of others. The extent to which individuals maintain their abilities and skills in a particular social environment depends on that ability. It includes things like understanding how a person feels, the ability to empathize with others, and the ability to process emotions to improve the quality of life. Unlike IQ, we can say that EQ is one of the foundations of human success and satisfaction. In addition to the abilities intended for IQ (thinking, testing, decision-making based on logic), we also need those that fall under emotional intelligence for the normal and specific functioning of the personality. The structure of the quality of emotional intelligence includes competencies related to each other and competencies in the field of interpersonal relationships.

According to Daft [1], the success of all organizations depends mainly on the intelligence of each employee.

Yukl [2] understands management as an interactive process between managers and subordinates, in which managers try to influence the behavior of their employees in achieving the goals of the organization. In other words, managers motivate people to achieve a certain performance and use different methods to manage performance.

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From the available information in psychology and management literature on performance motivation, we know that there is currently no fully validated concept of performance motivation that could be widely used in a variety of settings.
Performance motivation is considered to be a personally typical, relatively constant tendency of a person to achieve the best possible performance, or at least to stick to the best in activities in which it is possible to measure quality, and which may or may not succeed, resp. in which people can achieve successes or failures.
According to Bar-On [3], emotional intelligence is a set of emotional and social abilities and skills that can help people cope with the needs of everyday life and help them achieve greater efficiency in personal and social life.
From a simplified point of view, if we look at a person in terms of his IQ, emotional quotient and ability of WQ (will quotient) as key character traits, then we get a young person and his image of readiness to succeed. A manager with high emotional intelligence can communicate effectively with others [4], [5], can tolerate and manage change well, solve problems and build relationships with and between his employees [6]. He can motivate them to work without management pressure [7]. Most of them have to have an open discussion with their superior and see him as a partner rather than a commander [8], [9].

2. METHODS

The aim of the questionnaire was to find out how today's managers behave in common situations that occur in the daily work of managers. We also found out to what extent they use EI and whether they are emotionally stable enough to work as a manager.
We used a questionnaire as a research method and, due to Covid-19, it was sent only in electronic form via e-mail and social networks. The questionnaire was sent to companies based in the Slovak Republic, more specifically in the north of Slovakia. The results of the questionnaire were continuously shown to us on the page on which we created the questionnaire, so the collected data are easy to process and very clear.
The questionnaire contained two parts. First were filtering questions in which adepts entered basic information such as age, education, gender, position, and the like. In the next part, we asked about specific situations in everyday managerial life, from which we can evaluate at what level the emotional intelligence of a given manager is and whether we can say what an important aspect of EI is in the manager's work.

3. RESULTS

The survey took place specifically from 16 March 2021 to 17 April 2021. The questionnaire was sent to 92 people, of whom 46 responses were returned. So exactly 50% of people completed the questionnaire. There are only a part of graphical results Fig. 1, Fig. 2, because of limited paper length.
It can be seen in Figure 1 that 39.1% of respondents have repeatedly failed to control their feelings and emotions. Another 34.8% of respondents got out of control only once and 26.1% have never been able to control their feelings.

Fig.1. The ability to control emotions

It follows from this question that 56.5% of managers can sympathize with others. 30.4% cannot describe their feelings towards others. 13% cannot sympathize with others.

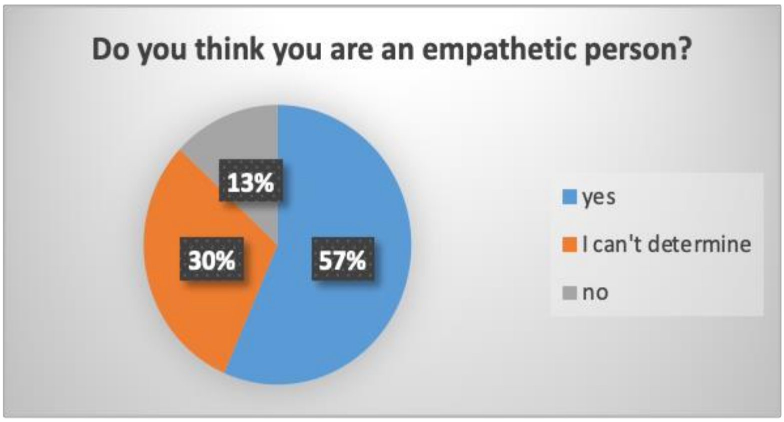

Fig.2. Do you think you are an empathetic person?

The knowledge gained from the questionnaire will help in possible further research to create similar activities and improvements to imply emotional intelligence in the smooth and more efficient operation of the company. One of the main factors in such an activity is to know not only yourself, but also the other party, i.e. not only the manager, but also everyone to whom this process needs to be applied. Therefore, it is necessary to be interested in the feelings of its employees. The most appropriate way to find out their perception would be a whiteboard with a writing tool on which employees could write constructive criticism of the company's management, their ideas for improvement, praise and suggestions for increasing efficiency. In this way, a sense of importance will be created in them and the employer and the whole team of managers will have a better overview of the work team. Another possible improvement would be the provision of benefits to employees in the form of remuneration, whether regular, i.e. monthly or annual or task-based. They could receive rewards for well-done work, motivational financial rewards or non-financial in the form of a product.

4. CONCLUSION

Employees would feel valued and would be more motivated to do their job. Stress is exceptionally not part of the job, so it is necessary to eliminate it as much as possible. Simple anti-stress aids could be used to make this more effective, such as available armchairs with cushions in company premises, coloring books, strengthening springs or rubber balls. The mentioned funds are not demanding for maintenance and do not significantly burden the company's financial budget. Simple objects could be used to break down this natural human emotion and would not have a negative effect on the work process. Ideally, to make the working atmosphere more pleasant, it would be appropriate to set aside a whole room with game consoles, coffee machines or sweets with a certain employee discount and spaces for closer socialization, which would benefit the building of interpersonal relationships in the workplace.

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Tomáš BALINT[1], Jozef ŽIVČÁK[2], Radovan HUDÁK[3], Marcel ORENIČ[4]

PRODUCTION PROCESS OF MEDICAL POLYMER - PLASTIC BIOPOLYMER

Abstract
This study deals with the production of Plastic Biopolymer, which has never been produced in such a composition of materials. Plastic Biopolymer is intended for medical applications. The filament was produced on Composer 450 filament makers from 3devo. During production, all necessary parameters and thickness of the extruding filament were recorded, which is also described in the graph of this study. Medically certified materials in the form of granules were used for the production. The filament was made of 3 types of polymers PLA, PHB and thermoplastic starch. A 25 percent amount of plasticizer was added to the polymers.

1. INTRODUCTION

When using the filament in additive technologies, it is essential that it meets the requirements necessary for high-quality 3D printing. Desirable properties of the filament include strength, good surface finish and constant diameter. All of these features contribute to the quality of the final print. Biocompatibility and biodegradability are important in medical applications. It is very difficult to produce a suitable medical filament that would meet all these conditions. In this study, however, it was possible after optimizing all the necessary parameters. At the beginning of this study, we made an overview of the market of companies involved in filament extrusion. The addressed companies did not have much experience in the production of medical polymers, which further underlines the complexity of the production of filaments from biodegradable polymers [1-4]. We addressed companies such as:

- 3Demon.
- Fillamentum.
- MAKERSLAB.
- MATERIALPRO3D.
- 3D PRINT.
- NEXEO Plastics.

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- Innofil 3D.

2. FILAMENT PRODUCTION PROCEDURE

The production of the filament is a several-step process from obtaining the material in the form of granules through drying the granulate in a dryer and the subsequent production process of the filament using a filament maker Fig. 1. After production of the filament, storage under suitable temperature conditions is important to prevent moisture degradation. The filament produced in this way is suitable for 3D printing of objects using FDM technology.

Fig. 1. Filamet production process

2.1. Preparation of granules for extrusion

The filament material was supplied in the form of granules, vacuumed in an opaque package to prevent degradation processes. Nevertheless, we dried the material in a dryer from 3devo. Drying parameters are in tab. 1.

Tab. 1. Material drying parameters

DRYING TEMPERATURE	160°C
DRYING TIME	180 minutes

2.2. Filament extrusion

The production of the filament took place on a filament maker Composer 450 from 3devo under ideal conditions in an air-conditioned room at a temperature of 18 ° C. Before the extrusion, it was necessary to clean the filament maker using HDPE transit material, which has a temperature range of 180 - 28 °C. After the pre-preparation process, we poured PLA / PHB / thermoplastic starch granules into the hopper. We set the melting point to 170 °C on the heater 4 and to 171 °C on other heaters. We reached this temperature by combining knowledge about the melting temperature of PLA / PHB materials. After stabilizing the filament flow, we placed the extruded fiber in a sensor that measured the diameter of the filament. Throughout the production process, the diameter of the filament was in the optimal range. Monitoring and optimization of all production parameters was followed by winding the filament into a spool. The parameters of the production of the Plastic Biolpolymer filament are summarized in Tab. 2. For the subsequent use of the filament in additive production, it is important to monitor the diameter of the filament over the extrusion time interval. We managed to maintain the optimal diameter of the filament, as can be seen in Fig. 2.

Tab. 2. Plastic Biopolymer filament production parameters

HEATER	4	3	2	1
REAL TEMPERATURE	170°C	170°C	172°C	171°C
SET TEMPERATURE	170°C	171°C	171°C	171°C
SCREW SPEED	2.0 RPM			
FAN POWER	80%			

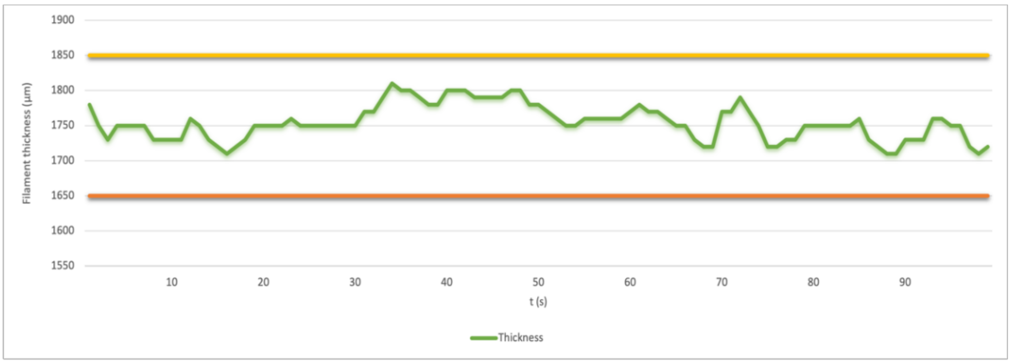

Fig. 2. Graph of the course of the filament diameter over time (t)

The parameters, Tab. 3. and the resulting filament, Fig. 3., are the output of the filament production process.

Tab.3. Parameters of the produced filament - Plastic Biopolymer

FILAMENT DIAMETER	1,75mm
FILAMENT WEIGHT	410,13g

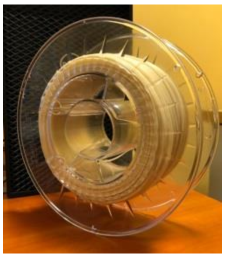

Fig. 3. Finished filament - Plastic Biopolymer

3. CONCLUSION

This scientific study is the theoretical output of the production of Plastic Biopolymer filament, which is intended for medical applications. The filament was made from PLA / PHB /

thermoplastic starch granules with the addition of 25% plasticizer. By monitoring all parameters and optimizing, we were able to produce a filament with a constant diameter of 1.75 mm along the entire length of the filament, which contributes to the excellent quality of the product made by additive technology in the future. With the Composer 450 from 3devo company, located in the Department of Biomedical Engineering and Measurement, we have achieved results that have a significant contribution to the production, testing and usage of medically certified materials.

This publication is the result of the project implementation: „Open scientific Integrated Infrastructure for the project: Center for Medical Bioadditive Research and Production (CEMBAM), code ITMS2014 +: 313011V358, supported by the Operational Programme Integrated Infrastructure, funded by the ERDF" and with the support of KEGA 040TUKE-4/2019 digitization methods to support the educational process in the field of aortotic prosthetics) and also by project VEGA 1/0179/19 Development and construction of low-cost modular prostheses of upper limbs manufactured by additive technologies.

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DEVELOPING EMPLOYEE CREATIVE THINKING IN PROBLEM SOLVING

Abstract
To be innovative and competitive, enterprises must use methods, techniques and tools that develop and support the creative potential of employees. Creativity is needed both to implement new concepts and ideas, and to solve everyday problems that arise in the company. Therefore, employees should be encouraged to participate in problem-solving and their creative thinking should be stimulated. The aim of this article is to recommend some methods, techniques and tools that can be used to develop creative and group problem solving in the company.

1. INTRODUCTION

Each company is struggling with problems that appear in the production area, as well as in any other. The problem can be defined as the difference between the current state and desired one. Taiichi Ono, a Japanese engineer known as primary developer of Toyota Production System and father of lean practices believed that "Having no problem is the biggest problem of all" [7]. This is true because ignoring existing problems generates more and more problems. Therefore, each problem should be solved at the lowest level or stage, to prevent its accumulation in further stages. Toyota company is a good example of how problem-solving methods are used in day-to-day activity. It presents a business culture focused on continuous improvement by increasing customer value and eliminating all kinds of waste (by 3M approach – Muri, Mura, Muda). Toyota's approach to management has been a benchmark for other organizations for years. One of Toyota's secrets is the way of thinking about problems as powerful opportunities for continuous learning and improvement [10].

2. METHODS AND TECHNIQUES OF CREATIVE THINKING

Companies should use the creativity of their employees when solving problems. It is the basis of activities leading from defining a problem to finding a solution.
There is no one simple definition of creativity it is a more complex concept that includes various cognitive, biological and social components [2, 3]. However, what is important, creativity is always

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associated with a person and defines a set of human features and skills that enable the search for new and valuable ideas, concepts, and associations. Creativity and problem solving are one of the essential skills of employee in the 21st century [6]. Creativity in products, services, processes, and procedures significantly determines the company's competitiveness [9].
There are many methods and techniques of creative thinking that can be used to develop problem-solving skills and engage employees in creative collaboration.
Brainstorming by Alex Osborn, is probably the best known and most popular of all creative problem solving techniques [8]. Its specific forms, such as Philips 66 or 635 Brainwriting, are also commonly used. The general goal is to generate as many ideas as possible and choose the best solution. Brainstorming uses free associations and is related to lateral thinking ("thinking sideways").
The Lotus Blossom was developed by Yasuo Matsumura, a Japanese management consultant. In this approach, the central theme leads to ideas that become the main themes for further concepts, and so on Fig. 1. The themes opening like flower petals iteratively create solution areas around the core box [4]. Therefore, the Lotus Blossom can be interpreted as a geometric pattern. As with other creative thinking methods, the aim is to collect a lot of concepts and ideas in the shortest possible time. The essence is to develop different approaches and take different perspectives, which makes it easier to see new possibilities and ideas. It is also possible to avoid "static" and routine approach to solving the problem, also go beyond the usual thinking pattern.

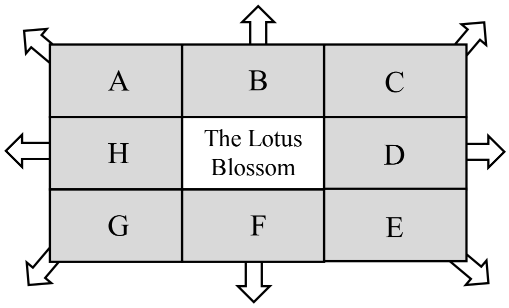

Fig.1. The Lotus Blossom idea (based on [4])

Another technique is the Six Thinking Hats by Edward de Bono. Each hat has a different colour and represents a specific thinking mode that encourages active mental switch [11]. Parallel thinking is the key to problem solving with this approach because it is useful to look at the problem in many different scenarios.
Synectics is a creative-solving method developed by William Gordon and George Prince. With this approach the users find relationships between apparently different and irrelevant objects to search for new ideas and solutions. By combining various elements, it allows to overcome mental blocks and increase divergent thinking [5]. With this approach the group follows three stages [1]: (1) Existing viewpoints of the problem (2) Mental trip (direct and personal analogies to move away from the real problem and look at it from new perspectives), and (3) Finding a solution.
The A3 report developed by Toyota is a universal tool that can be used to solve problems at every level and in every area of the company. A3 consists of several stages [10]:

- Problem's background (in the business context).

- Present conditions (where/when is the problem? how much/how many?).
- Targets/goals and measures (KPI, KRI measurements).
- Root cause analysis.
- Countermeasures (to address the problem).
- Action plan (and its implementation).
- Further actions (a follow-up review/learning process).

In the A3 report, the approach to a problem is based on the PDCA cycle. When solving problems with A3 approach, various methods and techniques of creative thinking can be used, in particular for cause-effect analysis and the searching solutions. Lean management tools such as Pareto diagram, 5W2H, Ishikawa diagram, 5Why and others are also popular in this method.

3. EXAMPLE OF USING CHOSEN METHODS AND TECHNIQUES IN PROBLEM SOLVING

The company belongs to the automotive industry and is a large enterprise. The analysed problem appeared in the purchasing department. It took too long to enter the new supplier's data into the ERP system. This resulted in delays in orders and production. To solve this problem, the A3 approach, methods and techniques of creative thinking and lean tools were used.
First, the problem's background was described. The current conditions were presented based on data collected from the last 6 months – the Gemba idea was followed here. The Pareto-Lorenza diagram allowed to determine the most often difficulties in the process. Then the general target and specific goals were defined. The main target was to shorten the time to enter the new supplier's data into the system from 3 weeks to a maximum of 1 week, depending on the supplier. The next stage was to identify the causes of the problem. The 635 Brainwriting technique was used Fig. 2a. Six members actively participated in the session. Each of them wrote down 3 suggestions in 5 minutes. Then, they passed them on to inspire others to further thoughts. The collected ideas were grouped into 5M categories (Man, Machine, Material, Method, Management) and presented in the Ishikawa diagram. Countermeasures for the most likely causes were then proposed. At this stage, the Lotus Blossom technique was used Fig. 2b. The main problem was put in the center, and then, the solution areas and related themes were expanded outwards (like flower's petals) in an iterative manner. This approach generated many interesting and valuable ideas.

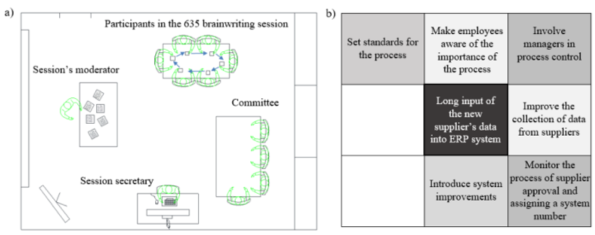

Fig. 2. Creative thinking techniques used in problem solving:
a) the 635 brainwriting b) the Lotus Blossom

Next, the solutions that were to be introduced in the first place were selected, and an action plan in the form of a Gantt chart was developed for them. Finally, as a follow-up, monitoring and regular process performance review were proposed to prevent the problem from recurring.

4. CONCLUSION

Companies will always face various problems, so it is important to learn to see problems not as undesirable, but as an opportunity to improve each day (in the spirit of kaizen), learn something new and gain more experience for the future. Effective problem solving is the result of using methods and techniques that stimulate the creativity of individuals and groups. Teamwork is essential in creative problem solving, as most methods and techniques require cooperation and collaboration, active discussion, exchange of insights and views, and full commitment of all team members. Problem-solving capabilities of the group are powerful and inspirable. In most cases, the greatest benefit is obtained if problem-solving group consists of a mixture of disciplines. Therefore, the role of leaders and managers is to motivate and involve employees in improvement processes, as well as to participate with them in problem-solving teams. This supports the development of a culture of continuous improvement.

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ARTIFICIAL INTELLIGENCE OF THINGS

Abstract
This article describes information about the development of the Internet of Things. Its connection with elements of artificial intelligence makes it possible to increase the security of information and people and improve managers' decisions in difficult working conditions. The Internet of Things will influence the methods of collecting, storing, processing, evaluating, selecting, and simultaneously delivering the necessary information in the required form and quality.

1. TRANSFORMATION OF THE INTERNET OF THINGS

Production systems are currently characterized by the ability and properties to process any type of components, parts with predetermined production procedures and customer requirements. The new generation of production systems is primarily about production systems that are intelligent and flexible [6]. Thanks to the massive development of technology and increased computing power of software, miniaturization of wireless sensors, high network capacity and large amounts of analytical data, it is possible to obtain an increasing amount of accurate, unbiased data from production. As other products become intelligent and connected, the software is emerging as a connective fabric for value creation, even for companies that sell physical goods. The convergence of the physical and digital worlds is beginning to use sensors and sensory data that automate and quantify a pattern for tracking product distribution and customer behavior in the physical world.

2. THE INTERNET OF THINGS

It could be said that the Internet of Things (IoT) is a system of interconnected computing, mechanical, digital devices, objects and, last but not least, people who are equipped with unique identifiers. These identifiers are able to transmit data over a network without the need for human-human or human-computer interaction. Sensors that one manufacturer provides usually create so-called intelligent networks that can communicate with each other without any need for human involvement. The collected data is then sent to the cloud infrastructure, e.g.,

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to a smartphone or computer, where they are subsequently processed. Devices can use any network to complete this step, be it LTE (Long-Term Evolution) networks, broadband WAN (Wide area) networks, local Wi-Fi connection, satellite networks, Bluetooth connection, etc.

2.1. Progress in the field of the Internet of Things

The process of developing the Internet of Things can be divided into several different phases. The first two phases of development could represent immediate opportunities and reasons that can be the basis for its adoption (e.g., high costs, tracking logistics routes, improving marketing, etc.). The third and fourth phases represent long-term structural changes that occur about three years from mainstream reception, Fig. 1. In these phases, the biggest changes in the economy (e.g., the impact of the introduction of the Internet of Things on various types of costs, such as return on investment, purchase of physical equipment or training of workers to work with the Internet of Things, etc.) and the human-machine relationship (e.g., training of workers when working with sensors, control of machines using the Internet of Things from a remote location, computer, etc.).

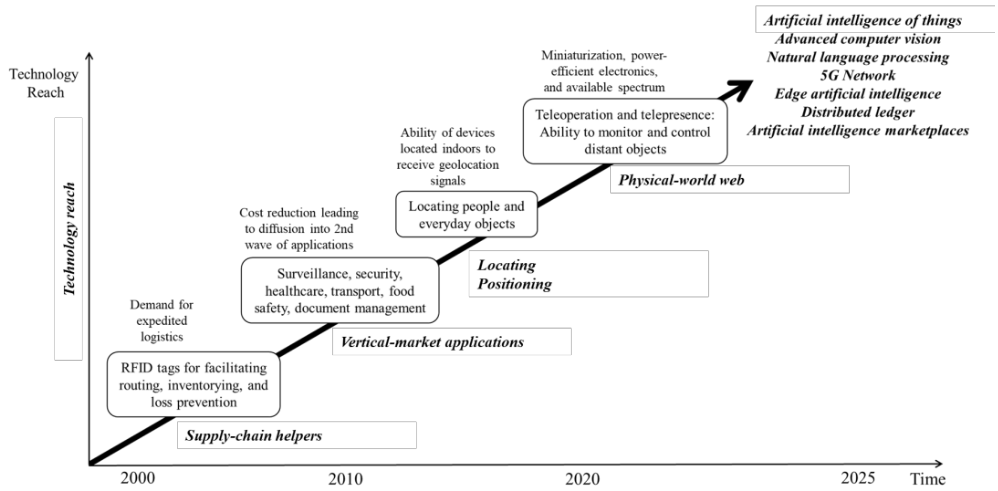

Fig. 1. Progress in the field of the Internet of Things [Authors]

In Fig. 1 is possible to see huge progress in the development of the Internet of Things and its connection to other technologies such as cloud computing, artificial intelligence, wearable, and mobile technologies. One of the most interesting areas may be the interconnection of the Internet of Things and artificial intelligence. This direction of development can also influence the further development of the industry [4].

3. ARTIFICIAL INTELLIGENCE OF THINGS (AIOT)

As already indicated in the second chapter of the article, the development of the Internet of Things allows the connection, control and monitoring of things from specified locations (for example, robotic devices). Combining the Internet of Things and artificial intelligence makes it possible to achieve a connection that the Internet of Things gives the physical world and brings data together. Then artificial intelligence uses that data to make sense out of the big amount of information and to control the overall system. In other words, the IoT systems are designed to trigger a signal, which may be machine control data, or data to mobile applications (e.g., mobile health control applications such as heart rate, talk, temperature, etc.). Artificial intelligence makes other decisions based on algorithms, learned data, or set rules from which the machine can learn to produce the desired output. Their combination will make it possible to make decisions without the involvement of people. In this way, these devices become intelligent, communication and powerful devices that could process data and make decisions faster and more accurately than ever before. This direction is developing mainly due to bridging the gap, which is people's distrust of new technologies. Options for this connection:

- **Wearables** – Connecting these devices allows regular monitoring and tracking of specified devices. These can be various virtual or extended reality devices, wireless headphones, health trackers and so on.
- **Smart Home** – Connecting and controlling home devices such as robotic vacuum cleaners, appliances, lights, thermostats, smart speakers and so on [5].
- **Smart City** – Such connections can be found in the future in traffic, also creating an Intelligent Transport Management System (ITMS) that can be used to make time real-time dynamic decisions on traffic flows' and thus improve the situation on the road.
- **Smart Industry** – The introduction of sensors and their connection to AIoT could significantly reduce human errors in the future, compensate for employee turnover, increase production efficiency, use supply-chain sensors, or reduce various types of costs associated with a product, warehousing, and logistics. Examples could be autonomous production facilities, automated supply chain management, predictive maintenance sensors, and so on [5].
- **Smart Retail** – The use of this link in smart retail is already being developed, e.g., in the form of a camera system, which together with computer vision capabilities can use facial recognition to identify customers when they walk through the store's door. Then the system can evaluate information about customers, including their gender, product preferences, traffic flow and more. Artificial intelligence can help to analyze the data to accurately and then predict consumer behavior. This information will help traders make decisions about store operations, from marketing to product placement and other decisions.
- **Drones** – This can be used in the form of traffic monitoring by drones. When drones are deployed to monitor a large area, they can transmit traffic data, and then AI can analyze the data and make decisions about how to alleviate best traffic congestion with adjustments to speed limits and timing of traffic lights without human involvement (for example The ET City Brain, a product of Alibaba Cloud).
- **Autonomous Robots** – Using a connection is useful when Robots have built-in sensors that gather information about the environment.
- **Autonomous Vehicles** – Connecting to IoT and retrieving data can help reduce fuel costs, track vehicle maintenance, identify unsafe driver behavior or help with autopilot systems. For example, autopilot systems that use radars, sonars, GPS, and cameras can gather data about driving conditions and then an AI system to make decisions about the data the internet of things devices are gathering [3].

- **Office Buildings** – The use of sensors connected to IoT will help, e.g., can detect adjust temperatures and lighting accordingly to improve energy efficiency. Also, a smart building can control building access through facial recognition technology along with connection to various types of cameras and sensors that can compare images taken in real-time against a database to determine who should be granted access to a building is AIoT at work [3].
- **Security Access Devices** – The connection to AIot can be created by the company. Access Control Technologies (ACT). AIot can help by using data to determine access patterns for every employee, understanding where they sit in the office and then predicting better office layouts for easier entry and exit, which can be helpful in the future with designing buildings and offices [3].
- **Voice and Vision** – This connection with AIoT is possible to see in innovation that will come with the development of technologies, such as natural language processing or ePayment voice authentication with mobile devices. In the Vision, this connection can be seen with creating super 8K resolution videos and then video analytics.

4. CONCLUSION

This article provides basic information about the Internet of Things and artificial intelligence. Companies will need more information technology managers and specialists to ensure a smooth transition to automation and the Internet of Things as companies move more and more of their business processes to cloud computing. Companies want to gather more and more information about processes, and they want to be able to evaluate them in a quality way and make better decisions [2]. The direction of the development of artificial intelligence connected to the Internet of Things will help, thanks to learning algorithms, make more accurate decisions and ensure, e. g. workspaces, improve working conditions, etc.

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ADOPTION OF TECHNOLOGIES IN WAREHOUSES AND LOGISTICS IN THE FUTURE

Abstract
This article deals with the adoption of new technologies in the processes of warehousing and logistics in the company. Due to world events and the pandemic situation, companies are forced to improve their warehousing and logistics processes. That situation paves the way for new technologies, automation, and intelligent devices in businesses. Based on the statistical results these trends are further described with examples of their further use in practice.

1. WAREHOUSING AND LOGISTICS PROCESSES

Warehouses allow companies to effectively bridge space and time. However, the present time is full of turbulence and reversals in developing ecological, economic, political, demographic, and environmental environments in medical facilities. Risks arise daily at the domestic and international levels, and they are associated with new technologies, problems with the supply of warehouses, innovations, natural elements, diseases and many other resources or factors. That is why the fundamental question arises as to how companies will cope with an unstable environment and the effects of diseases spreading worldwide, which prevent complete and sufficient supply logistics. Therefore, over time, companies began to lean towards modern technologies that should be used to balance the level of stocks in the warehouse and the turnover of workers in warehouses [4].

2. PREDICTED ADOPTION OF TECHNOLOGIES INTO PROCESSES

The basic function of the warehouse is to balance the volume and harmonize various dimensioned and complicated material flows. The warehouse has the most significant connection with problems associated with transport, internal logistics, supply and purchasing. Therefore, the most advantageous way to reduce the impact of risks on storage processes is

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automation. The most important part in the development of automation in warehouses and logistic processes is quality of software solutions, sensors, and obtained data, that gives answers on questions how to improve manufacturing processes [3].

2.1. Development in the industry

Based on the statistical report from the 2020 year, issued in the year 2021, by the MHI Annual Industry Report, we can say how technologies probably industry will change over the years [5]. These reports are divided into four timeline parts, and the first one is in use today; the second part is dated from 1 to 2 years, the third part is dated from 3 to 5 years, and the last part is dated from 6 years and more [5]. For example, in Figure 1, it is possible to see a result graph of the responses of 1000 supply chain and manufacturing leaders to find out what technologies they have focused on after the pandemic, how they have transformed and how they are trying to withstand the risks of downtime following the adoption of new digital technologies, Fig. 1.

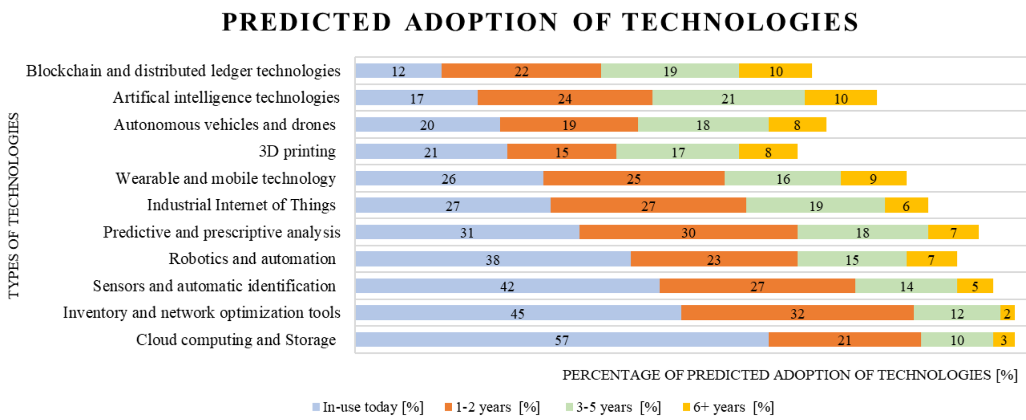

Fig.1. Predicted adoption of technologies [edited from MHI, org., 2021]

Based on the results in the graph, it can be seen that the companies addressed by the MHI organization for this research stated that in the next 1-2 years, they would address the topics of cloud computing, storage, predictive and prescriptive analysis, inventory and network optimization tools, development of sensors or robotics [5]. Also very interesting is artificial intelligence technologies and their connection to the Industrial Internet of things. The technologies are shown in the graph in Figure 1, their adoption over the years, trends and reasons for their development are listed below:

- **Cloud computing and Storage –** Cloud computing is the provision of computing services, including servers, storage, databases, networks, software, analytics tools and intelligent features. Customers can choose which type of cloud computing they want to use, which helps reduce operating costs, run its infrastructure more efficiently, and scale to meet the changing business needs.
- **Inventory and network optimization –** Developments in automated identification systems, such as intelligent sensors, RFID (Radio Frequency Identification), GPS, provide

comprehensive inventory visibility and operational intelligence through the data that these sensors collect and store in the process [2]. Between innovation could be included - new materials for the creation of more durable and versatile tags, increasing of memory will create smart tags, use sensor integration to streamline business information, securing data with new cloud-based capabilities and so on.

- **Sensors and automatic identification –** Technology development is moving towards sensor miniaturization, which causes further rapid developments in microtechnology and nanotechnologies, from microelectronics, micromechanics to bioelectronics, molecular and cellular technologies.
- **Robotics and automation** – The evolution of robotics will more resemble people to become more human-like in terms of memory, sensing, skills, and affinity for learning without being programmed for specific abilities (also artificial intelligent technologies). Between trends could be included collaborative robots, AI-enabled robots, self-healing robots, cloud robots, lightweight agile robotic assistant (LARA), robots that reduce carbon footprint or robots that help to secure supply chains and so on [1].
- **Predictive and prescriptive analysis** – Predictive analytics uses collected data to come up with future outcomes. Prescriptive analytics takes that data and goes even deeper into the potential results of specific actions, and also evaluate them. Between these developing applications is it possible to include - navigation apps, inventory planning, weather forecasts, market analysis, social media usage and engagement data such as Instagram or Facebook likes, and so on.
- **Industrial Internet of Things (IIoT) –** Development of Internet of Things (IoT) head for possibility remoting of monitoring and asset management from remote locations (for example, controlling robotic devices from a designated location). The next trend is artificial intelligence of things (AIoT) which combines artificial intelligence with IoT. It means that while IoT digitizes the physical world and brings data together, artificial intelligence uses that data to make sense out of the big amount of information and to control the overall system.
- **Wearable and mobile technology –** Between trends could be included nanowear's cloth-based diagnostic platform, smart jewelry, and any other wearable accessories (for example watches, small Organic Light-Emitting Diode displays, clothes) [6].
- **3D printing** - Its development refers to the fact that 3D printing can gradually replace selected steps in assembly. The main goal is to produce an increasing number of prototypes and components, primarily in one place, where products can be stored. That means that this technology will have a big impact on the designing of warehouses and building supply chains. The advantage of this solution is in lowering the number of steps in the handling of components, the number of warehouses, etc.
- **Autonomous vehicles and drones** – Drones is technology that is used for completing tasks in warehouse and manage inventory in less than one-third of the time needed to do it manually by worker. The autonomous truck will bring benefits in the form of eliminating long waiting times for delivery, reducing labor costs, reducing energy costs, and improving the road situation by improving safety or eliminating congestion.
- **Artificial intelligence (AI) technologies** – Between current trends is it possible to include cloud and AI collaboration, structuring data with AI, natural language generation, speech recognition, machine learning platforms, virtual agents, deep learning platforms, robotic process automation and many others.

- **Blockchain and Distributed ledger technologies** – Blockchain is connected with key technologies like Internet of Things, which is a kind of ecosystem for sensory devices (for example, for the location of devices or products, for monitoring selected information about the environment as humidity or temperature) that are interconnected across digital networks. Distributed ledger technology is a digital system for recording the transaction of assets in which the transactions and their details are recorded in multiple places at the same time.

The trends that have been described in this subchapter are not all, and there are many more. The development of these technologies is moving very fast.

3. CONCLUSION

In this article was described a statistical result, which gives us information about where companies will move in the future, in which technologies they will probably invest. That decision can change the speed and way of growth of the industry. Building supply chains, autonomous trucks, optical systems for picking of goods, drones, 3D printing, and new potentials for reducing energy costs represent so-called warehouses or factories of the future. These technologies do not entail only benefits, especially in reducing many types of costs, but the question is the security of obtained data with modern technologies. Another question is whether customers are prepared to accept such rapid and large technological progress, such as the delivery of products drones or autonomous trucks, or if they are informationally prepared enough to understand what these technologies bring into their lives.

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CHALLENGES OF FACTORY OF FUTURE IN THE CONTEXT OF ADAPTIVE MANUFACTURING

Abstract
The article deals with the changes in the production environment, what causes them and what technologies affect them. Four important challenges are described: interconnection and coordination of processes, integration of human and technical resources, transforming information gathered from a large number of sources into helpful knowledge, innovative manufacturing system.

1. INTRODUCTION

Adaptive manufacturing has recently emerged as a significant theme in academia and industry. The need for customization comes for many reasons and varies from application to application. In industrial production, customer requirements differ and lead to new products, different product variations and stages that require a departure from production and control. This requires the adaptation of the production system and its monitoring and quality control system. Together with the diagnostic processes that are more common in every industry, it places the strictest requirements.

Smart industry concepts represent a future form of an industrial network in which the physical elements of production environments are linked to IT services. Therefore, the introduction of Industry 4.0 concepts has significantly increased the complexity of the production environment and introduced many new challenges. New IT technologies, such as Big Data (BD), Data Analytics (DA) and Artificial Intelligence (AI) solutions, are needed to increase the potential of an interconnected production environment comprehensively. In addition, traditional strategies for solving industrial problems seem to be obsolete, as new requirements and more inputs can be obtained in real time. Instead of companies being good at doing some specific things, they have to learn new things.

Systems operating in unpredictable and turbulent environments must address the following issues [1]:

- Integrated production planning and scheduling (mathematical models and their combinations, operational research, estimation of the suitability of the type solution,

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parametrically scalable modules for production optimization, integration of intelligent technologies and hybrid intelligent systems).

- Real-time production management (recognition of situations and problem solving in context, decision support, reactive and proactive algorithms and management of production systems and their support).
- Management of distributed cooperation systems (multiagent systems in hierarchical architectures, models for describing the production network, functional interconnection of the network, analysis and discussion of mechanisms and communication protocols for effective behaviour related to interrelated spatial and temporal effects).

2. CHALLENGES FOR FUTURE FACTORY

The transition from the current state of production to the production of the future brings tremendous challenges or primary goals that would enable the realization of the vision of the enterprise of the future [2]. In addition to making a profit, all new production concepts strive to meet the main goal: adaptability, the ability to respond immediately to rapid changes in the environment, and turbulence. As the material flow rate increases, the information flow rate must necessarily also increase.

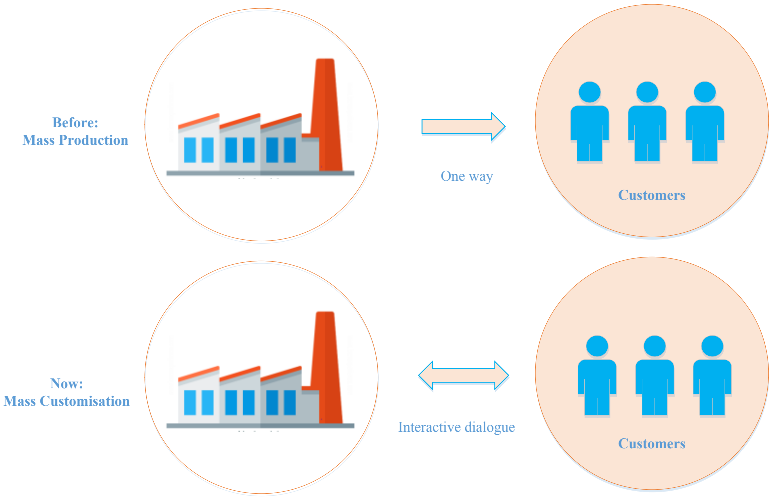

Fig. 1. Diffrence between mass production and mass customisation

The increasing availability of various sensors, in turn, is causing an exponential increase in business data. The individual activities and processes from order processing and production planning to managing an extensive supply and demand chain must occur in real time. For this reason, the timely circulation of data and their correct distribution must take place at the shortest possible intervals [3]. It is the intelligent process management, and ultimately the degree of added value that a company can generate, that depends on the accurate and timely distribution and processing of relevant data. An equally complex digital ecosystem is often created within the complex structure of an industrial enterprise and its various processes.

2.1. Interconnection and coordination of processes

In a cooperative system, dynamic events are inserted in parallel information processes. Customer order requirements, management decisions, and design phases are integrated into production planning and resource allocation tasks within a comprehensive production framework that includes a high decision-making level in planning activities. Every process performed must be transparent and recorded. Nothing happens randomly in production. Therefore, better coordination mechanisms improve the efficiency of production operations, leading to higher production network performance and sustainability in a competitive market. Interconnection across the automation (PLC), control (Smart Industry system) and administrative (ERP) layers is the essence of vertical integration [4]. The Smart Industry system manages production lines, transport equipment and warehouses, and material via the Internet of Things and Internet services. The same principle as the Internet guarantees the interconnectivity of things, which also ensures the interconnection of services, ie activities that struggle within or outside the company within the industrial and logistics processes. It thus works towards horizontal integration across companies.

2.2. Integration of human and technical resources

Human-machine interfaces must be optimized so that people can make dynamic improvements to planning, scheduling, maintenance, operation, and processes in real time. Technologies that enable people to enter and retrieve information orally, graphically and dynamically could significantly increase their ability to use computers efficiently. Some HMI technologies that will support Operator 4.0 are dialogue systems, control devices, multimodal displays, HDM glasses, headphones [5].

2.3. Transforming information gathered from a large number of sources into helpful knowledge

Manufacturing enterprises are fundamentally and necessarily dependent on information technology, including the collection, storage, analysis, distribution and application of information. The Big Data era has provided a stronger driving force for the development of AI technology. Artificial intelligence and decision support systems will manage the selection of data and information as well as system security [6]. Artificial intelligence, including professional systems, object-oriented technologies, intelligent agents, multimedia systems, voice recognition systems and neural networks, has already made a significant inroad into manufacturing technology and has the potential to make further progress very shortly.

2.4. Innovative manufacturing system

Here, the aim is to allow production operations to be adapted to rapid changes in the product or even to the production of different products. In terms of the development of theory as well as practice, new forms of strategies and methods of designing production systems have emerged in recent decades as a result of research and development studies focused on designing, specifying, modelling functionality and implementing intelligent self-learning, self-adapting, self-improving agile and adaptive production systems [7]. Implementing an adaptive factory requires tools that can flexibly combine basic operations to create a set of processes.

The degree of reconfigurability that can be achieved in this way far exceeds the degree of reconfigurability achieved by regrouping the device.

3. CONCLUSION

People, not technology, are the key to a successful transformation - and this is especially true in a smart factory. Increased digitization and innovative technology are unlikely to reduce staffing, but it will radically change the roles and responsibilities of your people as OT and IT becomes more integrated. Some roles will disappear, but they will probably be repetitive tasks that are best completed by robots. Other roles will emerge that will be highly valuable and knowledge-based for using data in the system. Agile and adaptive change management is needed to ensure that you move effectively between roles and gain access or develop the new skills you need.

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Target Costing, ETO, Unit production

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PRODUCTION PREPARATION PROCESSES OF NEW PRODUCTS IN THE CONDITIONS OF UNIT AND SMALL-LOT PRODUCTION

Abstract
Modern production processes are characterized by striving to shorten the product life cycle, an emphasis on reducing production costs and the time of delivery to the market. The article will present alternative production processes that also take into account the use of cooperative systems in a company producing winter recreation equipment of a unitary nature, where the product is personalized to the requirements of a specific customer. The optimal variant for the assumed parameters will be selected: own cost and production time.

1. INTRODUCTION

Evolution of a new product from the concept to the moment of realising is complex and determined by various criteria of utility [2]. The process requires a series of activities which depend on a kind and complexity of choices, seriality of production and technical – organisational preparation. The preparation of the production process, especially establishing the necessary work plays the biggest role [3, 5]. It must not be forgotten that producers are under the pressure because of the high demands of customers as for quality and competitive prices. Defining economical, organisational and technical activities significantly inflence the quality and cost of generating the product. In case of improperly designed production process, the concern puts itself at risk of generetion of unexpected costs which will be covered to eliminate faults [4].

2. THE PROCESS OF DESIGNING A NEW PRODUCT IN THE UNIT PRODUCTION – EXAMPLE

The unit production characterises a big emphasis on construction features of a future product, which will provide gaining previously stated level of costs and execution time. The attention must be paid especially to the executive capability of concern and production ability of cooperating parties [1]. Analysed example concern costs of production the constant unit of rotary carousel intended for recreational purposes Fig. 1. The production takes place in a unit method and the product is personalised exactly for specific customer's requirements. There are

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analysed various alternative production processes in order to find those which provide good quality with simultaneous minimisation of prime cost of production.
Before making a decision, there were determined a cut-off point, i.e. maximum prime cost 1650 PLN and maximum production time up to the mark of 10 hours.

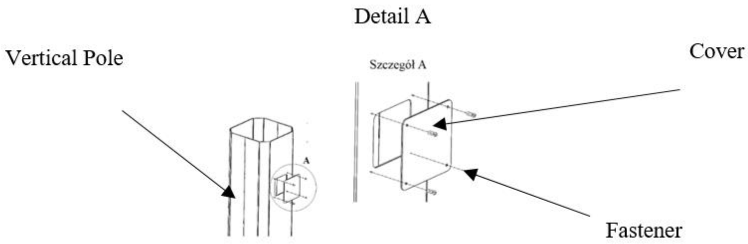

Fig. 1. The picture of the analysed example [Authors]

At the level of cogitating on the project in point of view of later production technology, there were assumed over a dozen different alternative ways of doing the lower construction of the device. The device consists of the vertical pole (1 piece), cover (1 piece) and fasteners (4 pieces).
There are many different ways to create foregoing elements, however while defining creating technology paid attention to production capabilities of the concern with using existing machines and cooperative systems.
The vertical pole can be created in 7 different ways, whereas the cover can be created in 4 ways. Tab. 1.

Tab. 1. Materials used to create the vertical pole and the cover

Element	Description of construction solution	Symbol
Vertical pole	Closed section 400x400x10	11
	Angle iron 200x200x18	12
	Pipe ⌀431,8 x 10mm	13
	Steel plate 4mm (4 straight pieces)	14
	Steel plate 4mm (2 pieces + 4 bends)	15
	Steel plate 4mm (guillotine + circumvolution)	16
	Steel plate 4mm (laser + circumvolution)	17
Cover	Steel plate 3mm (guillotine)	21
	Steel plate 3mm (laser)	22
	Steel plate 3mm (guillotine + circumvolution)	23
	Steel plate 3mm (laser + circumvolution)	24

Because of using the fasteners, the alternative production process was not presented (30 is the symbol of fastener in schema). There were created fourteen different variants from methods presented above. It should be noticed, that not every method of making the cover matches every vertical pole. In case of pole, which intersection is hoop (made of pipe or rolled sheet) for the element of cover it should be additionally rolled for appropriate radius (symbol 23 and 24). All alternative production processes are presented in Fig. 2.

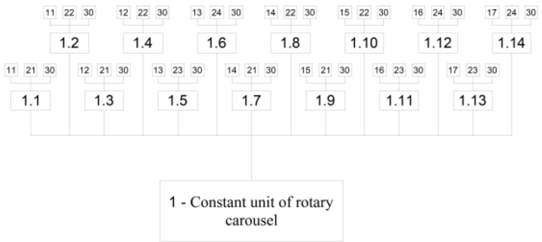

Fig. 2. Alternative methods of creating intermediate product [Authors]

After calculating the value for various configuration between elements presented and summation there were such results gained Tab. 2.

Tab. 2. Analysis of semi-finished product costs

Design combinations	Matherial costs	Labor costs	Services costs	Sum of costs	Work time [h]	Symbol
11+21+30	736,70 zł	522,00 zł	330,75 zł	1 589,45 zł	5,8	1.1
11+22+30	736,70 zł	436,50 zł	330,75 zł	1 503,95 zł	4,9	1.2
12+21+30	656,30 zł	1 134,00 zł	294,57 zł	2 084,87 zł	12,6	1.3
12+22+30	656,30 zł	1 048,50 zł	294,57 zł	1 999,37 zł	11,7	1.4
13+23+30	628,70 zł	558,00 zł	332,15 zł	1 518,85 zł	6,2	1.5
13+24+30	628,70 zł	472,50 zł	332,15 zł	1 433,35 zł	5,3	1.6
14+21+30	199,10 zł	1 602,00 zł	117,99 zł	1 919,09 zł	17,8	1.7
14+22+30	199,10 zł	1 516,50 zł	117,99 zł	1 833,59 zł	16,9	1.8
15+21+30	211,70 zł	900,00 zł	125,55 zł	1 237,25 zł	10,0	1.9
15+22+30	211,70 zł	814,50 zł	125,55 zł	1 151,75 zł	9,1	1.10
16+23+30	185,30 zł	1 017,00 zł	609,71 zł	1 812,01 zł	11,3	1.11
16+24+30	185,30 zł	931,50 zł	609,71 zł	1 726,51 zł	10,4	1.12
17+23+30	185,30 zł	585,00 zł	609,71 zł	1 380,01 zł	6,5	1.13
17+24+30	185,30 zł	499,50 zł	609,71 zł	1 294,51 zł	5,6	1.14

According to assumptions and gained results, there were created Pareto chart for minimising time and costs of production Fig. 3. As visible in the picture above, when including assumed time and final cost in the area of possible solutions there are such configurations as: 1.1, 1.5, 1.2, 1.6, 1.14, 1.10. Other alternative construction solutions belong to the set of solutions, however they run beyond assumed costs and final time. Solutions with symbols 1.2, 1.14 and 1.10 belong to the

Pareto set, so they cannot be improved regarding time and costs – improvement of one criteria would cause deterioration another. Such solutions are defined as optimal in the Pareto sense.

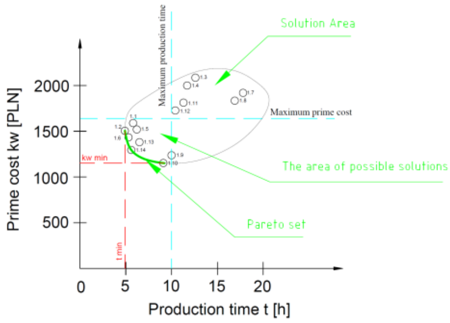

Fig. 3. Pareto set for minimisation

3. CONCLUSION

The notion of production preparation is complex and demands paying a lot of attention. Incorrectly designed process can be a source of appearing unplanned costs of eliminating the fault or necessity of improving the quality, which would be inconsistent with customer's expectation. Using the large knowledge of workers allow to create a wide range of possible solutions with design – construction assumptions. This is the most creative stadium in the whole process of design and is fully dependent on capability and experience of designers.

Presented example of production process of device basis analysis contain 14 possible production processes received incl. thanks to wide cooperative arrangement of corporation. The finally chosen solution is 1.10 because it provides the lowest prime cost of production and it fits final time (belonging the Pareto set). The cooperation process in condition of domestic industry is of great importance in realisation and production processes. While designing new products there is put a big emphasis on issues related to improvement of technology in point of view of supply, cooperation tooling, installation and sale.

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WORK STATIONS SAFETY DURING THE COVID-19 EPIDEMIC

Abstract

The COVID-19 pandemic has affected all areas of everyday life, including also work organization. The new reality - as it should be called - forced the changes that workplaces had to minimize COVID-19 infection among staff. The legal changes significantly influenced the way how safety work organization is designed now.

1. CHANGE DYNAMICS

Among the activities aimed at ensuring the safety and health of workers undertaken by the employer, the basic activity is the assessment of occupational risk and the use of necessary preventive measures to reduce this risk (Article 226 (1) of the Labor Code). According to this article, the employer, when assessing the occupational risk, is obliged to take into account all the factors occurring in the work environment and related to its performance. In connection with the COVID-19 epidemic, in addition to the existing risks, a new risk has appeared in workplaces caused by the SARS-CoV-2 coronavirus. Therefore, the employer was obliged to take measures to reduce the risk associated with exposure to this biological factor. As it poses a serious risk to the health of the general population, including working people, the risk associated with exposure to SARS-Cov-2 should be assessed and all available measures should be taken to reduce it. Preventive measures applied by employers and entrepreneurs should ensure that the performance of work does not increase the likelihood of contracting the SARS-CoV-2 coronavirus in workers above that estimated for other members of society who, in their everyday life, comply with the restrictions, orders and bans introduced in connection with the epidemic. Changes in the legal status can be tracked based on subsequent revisions of the published Ordinance on the establishment of certain restrictions, orders and bans in connection with the occurrence of an epidemic. The high frequency of publications of legal acts influencing the manner of organizing workplaces was a novelty for employers. So far, such

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changes have occurred sporadically throughout the year, and from March 2020, employers had to introduce adjustments to the new legal requirements several times within one month.
Examples of legal regulations on occupational health and safety in the time of epidemics are: Art. 207 Act of June 26, 1974 - Labor Code; art. 3, 4h, 4ha of the Act of 2 March 2020 on special solutions related to the prevention, prevention and combating of COVID-19, other infectious diseases and the emergencies caused by them; § 9 clause 16, § 10 and 25 of the Regulation of the Council of Ministers of May 6, 2021 on the establishment of certain restrictions, orders and bans in connection with an epidemic; § 7 of the Regulation of the Council of Ministers of March 19, 2021 on the establishment of certain restrictions, orders and bans in connection with the epidemic - repealed on May 8, 2021; PiP, Rights and obligations of employees and employers in the period from April 2, 2020 to April 11, 2020 [3].

2. NEW GUIDELINES FOR DESIGNING A SAFE AND HYGIENIC WORK STATIONS

Legal changes introduced in connection with the epidemic can be divided according to types of workstations - changes in the office work or during the organization of manual, dynamic work. The content of the regulations refers to the principles of general employee safety, ensuring the proper organization of office space, application of preventive procedures in the case of suspected infection and in the case of suspicion of a client / contractor / supplier. The changes relate to the rules of ventilation, organization of meetings and employee training, the need to disinfect common parts, use of toilets and to a large extent consisted in providing work remotely with the use of computer communication techniques. In the case of industrial plants, the most significant was the possibility of introducing employee interviews and self-health checks by employees, providing security services and employees in contact with customers access to personal face protection, such as: protective masks or protective visors, as well as protective gloves or preparations for disinfection. Disinfection fluids availability in the initial stage of the pandemic was very problematic in industrial practice. Technical measures in the form of glass panes, plexiglass (for customer service), distance barriers, protective visors, goggles, protective masks, protective gloves and other tools or methods to protect the worker against the possibility of contamination began to be widely used. It has become mandatory that external suppliers and visitors who move around the plant wear mouth and nose protectors. The possibility of performing traditional audits has been significantly limited in favor of remote audits. The duration of audits, controls and meetings has been shortened, which also forces changes to the forms themselves and the checklists used. In industrial practice, in connection with the recommendation of the Chief Sanitary Inspectorate, the use of air conditioning was limited in favor of airing rooms and drawing air from outside the building. A very important change was the requirement to maintain a distance of at least 1.5 m between employees, unless it is impossible due to the nature of the activity performed in a given workplace. Such a legal requirement has a large impact on the organization of work in a place where until now it was performed as a team. If it is not possible to perform work at a distance, it is now obligatory to use individual or collective protective equipment. A limitation of the time spent in the common space has been introduced - holding different hours of breaks, if it is possible due to the organization of work, limiting the number of places in the canteen (maximum one person sitting at a table or keeping a minimum distance of 1.5 m between people) or introducing, if possible, take breakfast breaks at the workplace. In the case of baths and changing rooms, the number of people using them at the same time should be limited, with a distance between them. These places should undergo regular cleaning and disinfection of touch surfaces (handles, handrails, handles, countertops, etc.). Adjusting shift work in such a way that the teams do not have physical contact with each other; introducing different hours for starting and finishing work, if it is possible due to the organization of work. If it is not organizationally possible, it should be limited direct contact between teams from individual shifts to the minimum necessary, while maintaining appropriate security measures. Introduced a recommendation to work remotely for all positions where it is possible; reducing to the necessary minimum the number of employees necessary to maintain the operation. Preparation of a procedure to be followed in the event of a suspected infection and effective training of employees. One of the challenges for employers was also organizing vaccinations at workplaces [1, 2].

3. SUPPORT SAFETY CORONAVIRUS CHECKLIST

The employer, when assessing his level of safety development during the covid epidemy, may use tools developed independently on the basis of his experience, corporate and industry guidelines or use the available checklists developed by other units. The proposed solution is to use the checklist "Safety and health protection of people working during the COVID-19 epidemic - general guidelines and checklist". This tool was developed by the Central Institute for Labor Protection in Warsaw. The questions with a "no" answer indicate measures that have not yet been introduced. In this case, it is recommended to introduce them as soon as possible in order to reduce the risk of contracting the SARS-CoV-2 coronavirus. Tab. 1 contains the proposed main part on checklist.

Tab. 1. Safety coronavirus checklist – main parts [4]

1. Action plan to reduce the risk of contracting the SARS-CoV-2 coronavirus at work
2. Actions to ensure physical distance in the workplace
3. Performing works that require direct contact
4.Organizing remote work in a manner consistent with the principles of OSH
5. Limiting direct contact of employees with people outside the workplace during work and on the way to / from work
6. Compliance with hygiene rules in the workplace
7. Personal protective equipment and work clothes
8. Actions to reduce the mental burden caused by the SARS-CoV-2 coronavirus
9. Communicating on topics related to SARS-CoV-2
10. Rules of conduct in the event of suspected infection and access to an occupational medicine physician

In each main part there is next detail question – for example for 3. Performing works that require direct contact: Is there a permanent composition of teams carrying out work requiring direct contact between employees? Are there any partitions (transparent screens, e.g. made of glass or plastic) that separate employees from these people at workplaces that require long, direct contact with people outside the workplace (e.g. customers, suppliers)? Has there been a requirement to limit the time of direct contact between employees and people outside the workplace (e.g. customers, suppliers) to max. 15 min? Has there been a requirement for the use of personal protective equipment (protective masks, helmets, disposable gloves, goggles, as well as aprons and coveralls) by employees performing work requiring long direct contact with people outside the workplace (e.g. customers, suppliers)? Have meetings and conferences requiring the physical presence of employees been replaced by tele- or videoconferences? If a meeting with the physical participation of employees is absolutely necessary, is the number of participants limited to max. 15 and ensures a distance of at least 1.5 m between them?[4].

4. SUMMARY

Employers regularly review the entire management system of the organization in connection with the outbreak. Safe and hygienic design of workplaces is an incomparably greater challenge than in previous years. Constantly emerging legal changes and guidelines for employers can be supported through a self-assessment checklist.

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DISCRETE AND PROCESS INDUSTRY SCHEDULING PROCESSES

Abstract
This article deals with complexity of production scheduling in different industries. As Scheduling is part of Manufacturing Operations Management, its plays important role in day life of production. There are some major differences between Discrete industries and Process Industries which can be identified also on planning and scheduling level.

1. INTRODUCTION

Scheduling decisions may be very different from one company to another from industry to industry, but all they share several common features. These features to obtain certain degree of abstraction that may serve to formulate a generic framework useful for different companies. These features are:

- There are complex decisions, as they involve developing detailed plans for assigning tasks to resources over time. Although this may vary greatly from one company to another, there is a universal trend on increasing the sophistication of the products and on their customization, which in turn affects to the complexity of the manufacturing process.
- Scheduling decisions are short time interval decisions to be taken over and over. The average lifetime of a schedule is very short, and indeed many authors refer to a continuous scheduling decision process. Here we mean that what is repeated is the decision process, which is different from stating that the outcome of a single decision is put into practice rhythmically again (cyclic scheduling).
- Despite being a short-time decision, scheduling is relevant for companies' bottom line, as it determines the lead times and the cost of the products, which on the long run affects the service level of the company as well as its ability to compete both in manufacturing costs and on delivery times.
- As a decision process at the core of the operations of a manufacturing company, the constraints and objectives affecting scheduling are extremely company specific. The nature and usage of the resources in a plant producing chemical commodities has little in common with manufacturing ball bearers, or assembly of highly customized electronic devices.
- Finally, scheduling decisions are—as we already discussed—relatively structured decisions at least as compared to other decision problems within the company.

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Management methods in the field of strategic and operational complexity management are usually conceived for the discrete manufacturing industry and are hardly transferable to the process industry. In this paper, complexity management practices, as well as complexity drivers, in the discrete manufacturing industry and the process industry are identified and collected. Furthermore, an analysis is conducted regarding similarities and differences between the approaches in the two industries. Crucial for the design of a product and process is the understanding of the complexity drivers. These drivers are influencing factors which affect the complexity in various functional departments. In general, the drivers can be distinguished between internal and external factors. To gain an understanding of the complexity, these external and internal drivers need to be identified first and their dependency on products and processes needs to be described subsequently. Complexity management is a business methodology embracing engineering as well as exploitation of variety and guidance of complex systems, hence complexity management can be understood as mastering complexity. Furthermore, it embraces the activity fields prevention and systematic reduction.

2. MANUFACTURING SCHEDULING INTO CONTEXT

Production management is a managerial process in which many decisions are taken over time to ensure the delivery of goods with the maximum quality, minimum cost, and minimum lead time. Given the different nature and timing of these decisions, and the different decision makers involved, production management has been traditionally decomposed by adopting a hierarchical structure in which the different decision problems are successively solved. At the top of this structure, there are decisions related to the strategic design of the manufacturing network, and include the selection of providers, the location of the plant(s) to manufacture the products, the design of the plant layout and the structure of the distribution network, among others. Broadly speaking, these decisions—called strategic decisions—serve to establish, on an aggregate level, the capacity of the manufacturing and distribution resources, including the co-operation with the providers. Once the manufacturing and distribution structure has been designed, there are several decisions related to how to make the best usage of this structure. These decisions are again usually decomposed into medium-term decisions (tactical decisions), and short-term decisions (operating decisions). When planning the usage of the manufacturing resources for the next year (something that must be done to decide on the workforce required, to plan the contracts with the providers, etc.), the key information driving the whole manufacturing process is not known and it can only be guessed or estimated (even for the best of the cases) via historical or casual data. However, the quality of this estimation decreases with the level of detail, as it is easier to estimate the yearly sales of a model of a car than to estimate the weekly sales of the cars of a certain model including left-side steering wheel. Therefore, this aggregated production plan will serve to estimate the (aggregated) capacity to be used, the number of raw materials to be purchased, etc. This exhaustive plan is usually left for a later stage in which a detailed status of the shop floor and on the firm orders to be processed is known, and this is precisely the mission of manufacturing scheduling: matching the jobs (tasks) to be executed against the resources in the company. The result of this process is, ideally, a schedule where it is specified which job should enter each resource, and when. In this section the complexity drivers for the two subsamples of the process industry and the discrete manufacturing industry are described and the differences statistically analyzed. Complexity drivers are influencing factors which affect the complexity in various functional departments. In general, the drivers can be distinguished between internal and external factors. Those factors are influencing also scheduling and planning on long term vision. External drivers, like legal and political factors as well as the number of suppliers and the dynamic of competition, can only partly be controlled by the companies. Outcomes of several research indicate that especially political and legal factors have a stronger impact in the process industry than in the discrete industry. Furthermore, companies in the process industry have a higher number of suppliers which has an impact on the coordination of external and internal processes.

2.1. Typical example of Process industry is Food and beverage sector

In the process industry continuous and batch production systems can be distinguished. There exists also semi-batch production which combines features from both. Plants producing only a limited number of products each in relatively high volume typically use special purpose equipment allowing a continuous flow of materials in long campaigns, i.e.,there is a continuous stream of input and output products with no clearly defined start or end time. Alternatively, small quantities of a large number of products are preferably produced using multi-purpose equipment which are operated in batch mode,i.e., there is a well-defined start-up,e.g., filling in some products,well-defined follow-up steps defined by specific recipes, e.g.,heating the product,adding other products and let them react,and a clearly defined end,e.g.,extracting the finished product.

The food and beverage sector faces a set of unique demands that result in an environment that is particularly challenging for planning and scheduling. There are many challenges faced by the Food and beverage sector including:

- Variation in raw materials and demand – Seasonality and reliance on crop yields means that the quantity and quality of raw materials and demand can fluctuate a lot. The planner needs to be able to plan for many eventualities and respond easily to the current situation.
- Short shelf life – Perishable materials and produce mean that it is essential to optimize the timing of production to avoid waste.
- Strong price pressure from customers – In order to remain profitable in the face of pressure to reduce prices, it is necessary to ensure that the production process is running as efficiently as possible.
- Complex quality and packaging requirements – Often there are complex relationships between the grade of the goods and their suitability for customers or product lines.
- Complexity of production process – A mixture of discrete and process pro-duction modes can result in complex planning and scheduling requirements, often with contradicting goals for different parts of the process.

Food and beverage industry is quite broad, as it encompasses notably diverse raw commodities and final products, which consequently entails different transformation processes. Production planning starts with a good forecasting system that looks at several years of historical orders, calculates seasonal variations in demand and allows you to adjust based on customer or market specific information. The purpose of the production planning is to make what is needed to meet customer demand and maintain minimum inventory levels based on the finite capacity of the plant. Unique challenges of food production:

- Reduce sequencing time.
- Optimize line changeover times (setups).
- Have a visual management of raw material status for each product.
- Generate different scenarios for sales forecasts.
- Improving transparency and communication among departments.

- Improve visibility across the whole supply chain.
- Optimize manufacturing processes.

3. CONCLUSION

Scheduling is the complex process of balancing demand from Sales deparment with a company's available resources for the purpose of creating a valid short term plan. Companies which successfully implemented APS solution are declaring faster reaction on orders sequencing (reaction on change). They are saving working times to schedulers. They are gaining higher production transparency and collaboration between departments. Last improvement might be also in customer services as sales department might be much accurate with forecasts. Difference between Process and Discrete industry in scheduling processes are mostly in constrains planning, capacity of the processes, variation of raw materials, factors which influence production (internal - external) and similar. The importance to move from cheap alternative scheduling in Spreadsheet table software to more advance methods with Advance planning and scheduling software stays valid across type of companies and industries. Some key achievements after successful implementations of APS solutions are almost same across industries and type of industries. Key achievements which can be taken to consideration are like saved cost and working time of planning department, higher transparency, and higher scheduling accuracy.

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Supplier management, IATF 16949, Product quality, Automotive industry

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REGULAR EVALUATION OF SUPPLIERS IN ACCORDANCE WITH THE AUTOMOTIVE INDUSTRY IATF 16949

Abstract
Effective supplier management according to the standard for use in the automotive industry IATF 16949 is necessary to ensure the stability and effectiveness of the implementation of production processes in the company. This article presents the assumptions of the developed system of periodic supplier evaluation, based on the requirements resulting from the management systems implemented in the iron foundry. The concept of the created periodic supplier evaluation aims to guarantee the required quality of the manufactured products and to guarantee the continuity of the production processes.

1. INTRODUCTION

Quality is one of the determining factors in order to assert oneself competitively in the market, which is why this term is gaining a special meaning in the age of globalization. The primary responsibility of companies is to meet customer needs for product quality, reliability and availability. In order to increase their competitive advantage over other companies in the market, organizations attach importance to increasing their effectiveness and efficiency through the introduction of management systems. The functioning of companies according to the IATF 16949 standard in the industry of production plants that supply products, semi-finished products and services for the automotive industry is a standard that is found in the organizational culture of the vast majority of economic units from the field of large and medium-sized companies [1].

2. IATF 16949 REQUIREMENTS

The latest update to the IATF 16949 standard for the automotive industry has increased the focus on the process of monitoring processes, products and services that are externally provided. This change is in line with a risk-based approach across the enterprise [2].
According to the requirements of the IATF 16949 standard, it is the responsibility of the organization to ensure that externally supplied processes, products and services meet the requirements. In order to meet the requirement of 8.4. In addition to defining and applying

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the criteria for evaluating and selecting suppliers, the company also needs to monitor their results and the principles of supplier reassessment. An initial and re-evaluation should be performed based on the ability of the suppliers to provide processes or products and services according to the defined requirements. The criteria for evaluating the performance of suppliers should be geared towards ensuring compliance with the company's internal and external requirements. The technical specification IATF 16949 lists the following performance indicators for suppliers that should be considered in the regular assessment:

- Compliance of the delivered product with the requirements.
- Occurrence of events with special transport costs.
- punctual deliveries.
- Influence of the supplier on customer disruptions and delivery stops.
- a complaint caused by the supplier.
- Customer notification of special status related to quality or delivery.

As part of the process of regular supplier assessment, a supplier audit program based on documented criteria should also be implemented to determine the need, frequency, type, and scope of an audit by the other party. The second party audit program is preceded by a risk analysis that takes into account the requirements of the interested parties, including legal and product safety requirements, supplier performance and the certification level of the management system [2, 3].

3. EXAMPLE OF REGULAR SUPPLIER EVALUATION

According to the requirements of the technical specification IATF 16949, organizations must implement a supplier monitoring system both in the qualification phase and during the collaboration. Therefore, companies have to develop their own system for regular supplier evaluation. The proprietary concept of periodic supplier evaluation introduced in the iron foundry is presented below.

Tab. 1. Qualification groups

Interpretaion	Points	Status
The supplier meets organization's requirements at a satisfactory level. The cooperation may be continued. Continue the supplier development process.	80-100	A
The supplier meets organization's requirements with some reservations. Necessity to implement a quality improvement plan (removal of nonconformities, improvement of indicators, achievement of supplier A status)	50-79	B
The supplier does not meet organization's requirements. There are critical issues which should be immediately removed by action plan implementation consulted with Metalpol. In case of lack of cooperation from the supplier, there is a necessity of elimination from the qualification list.	0-49	C

In accordance with the assumption of the implemented supplier evaluation system, each supplier is subjected to an evaluation and approval before the first order is placed and then to a periodic evaluation. Suppliers on the Qualified Supplier List can have the following statuses: Active, Conditional, Suspended, Potential. Providers with active status and conditional

qualifications are subject to regular evaluation after the trial period. Suppliers are divided into 3 qualification groups according to the Tab. 1.
Suppliers are assessed with regard to quality indicators (PPM, number of customer complaints due to poor quality of the purchased products, amount of quality information and certificates), punctuality of deliveries, environmental pollution and price conditions according to tables 2-5.

Tab.2. Qualitative criteria

Integrated Management System	**Points**	**PPM**	**Points**
IATF 16949; ISO 9001;14001 certificate	25	≤5000	20
ISO 9001; 14001 certificate	15	4999-10000	15
ISO 9001 certificate	10	10001-25000	10
No certificate	0	≥25000	0

Tab.3. Timeliness and pricing criteria

Pricing conditions	**Points**	**Timeliness**	**Points**
Competitive price, fair pricing with respect to raw material price fluctuations in the market, flexible payment terms, extending payment terms, price reduction policy, discounts given.	15	≥95%	20
Competitive pricing, flexible payment terms including extended payment terms.	10	90%-94%	15
Competitive prices, short payment terms.	5	75%-89%	10
Higher prices than competitors', short payment terms, no discounts or price reductions.	0	<75%	0

Tab.4. Quality and environmental incidents

Quality information	**Points**	**Environmental incidents**	**Points**
No incident occurrence	5	No incident occurrence	5
Incident occurrence	0	Incident occurrence	0

Tab. 5. Customer Service

Customer Service Level	**Points**	**Customer Complaints and Disruptions**	**Points**
The Supplier provides technical support to the Customer, responds flexibly and effectively to the Customer's requests, including securing the Customer's production by maintaining a safety stock.	10	No incident occurrence	5
The Supplier provides technical support to Customer.	5	Incident occurrence (including any process downtime, special shipments, stops etc.)	0
The Supplier does not support the Customer with technical support, does not respond to Customer requests.	0		

In cooperation with the management system officer, the purchasing manager carries out a semi-annual supplier evaluation based on records from the ongoing monitoring of deliveries and audits by the counterparty. The suppliers will be informed of the result of the periodic evaluation and the goals for the next cooperation period up to 30 days after the end of the period.

Other assumptions of the periodic scoring system:

- When a supplier is demoted to a lower qualification group, it is the supplier's responsibility to establish a quality improvement plan. If a supplier qualified for Group C does not cooperate in the context of quality improvement, the supplier should be removed from the list of qualified suppliers.
- A supplier with whom the organization has not worked for more than a year is given the status "suspended".
- If the organization has not worked with a supplier from the list of qualified suppliers in the past two years, the supplier qualification process should be repeated before the order is placed.
- Limit criteria: <75% for topicality (including shortages and identification errors) and> 25,000 PPM for external defects.
- In the event that O-points are received in PPM, the supplier is obliged to take immediate corrective measures, otherwise he receives category C regardless of the total number of points.

4. SUMMARY

Quality is one of the fundamental issues organizations focus on these days once they have implemented management systems. The adaptation of the requirements of the IATF 16949 standard in a production plant increases the effectiveness and efficiency of the company in achieving the goals set, in particular in meeting customer requirements. According to the technical specification IATF 16949, it is the responsibility of the company to ensure that the external processes, products and services provided do not have a negative impact on the ability of the organization to continuously provide products and services in accordance with customer requirements. The article presents a practical example of the implementation of the concept of periodic supplier evaluation in a company that supplies semi-finished products for the automotive industry. This concept of cyclical supplier evaluation is intended to guarantee the expected quality of the deliveries in order to meet customer requirements and to guarantee the continuity and stability of the production processes.

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TECHNICAL SERVICE DIGITISATION PROCESSES IN SMALL AND MEDIUM-SIZED ENTERPRISES (SMES)

Abstract
The article deals with the digitisation of the maintenance process in the technical service department in the selected factory. The article describes in its introduction the paper and electronic form of data in the factory. The first part also shows the current state of gather information in paper data. The second part of the article deals with the image of the digital form of gather information.

1. INTRODUCTION

Execution maintenance is associated with the use and elaboration of many documents, called maintenance documentation Fig. 1. We define this documentation as a set of all documents processed and used in the factory during the operation of production facilities. This standard specifies the whole set of documents and information to be considered in the factory, during the equipment and its acquisition, to organise its maintenance. Documentation in factories can be divided into three qualitatively different groups [1]:

- Paper form in the form of papers placed in folders.
- Passive electronic form in the form of drawings in DWG or PDF format.
- Active electronic form in the form of a structured data model.

Today, despite the expansion of digitisation, many factories still use paper documentation. However, this form has many disadvantages compared to digital. In some countries of the world, digitisation is compulsory, and fines can be imposed for non-compliance with the regulation on the use of digital documentation Fig.2. However, international studies show that electronic document management can reduce the document processing time by up to 70%. The introduction of this type of documentation also has many advantages, we can mention for example [2]:

- Reduction of the factory costs (costs of purchasing paper, printing materials, etc.).
- There is no need to set aside an ample space in the factory for document archiving.

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- Speed of viewing documents.
- Simple search, etc.

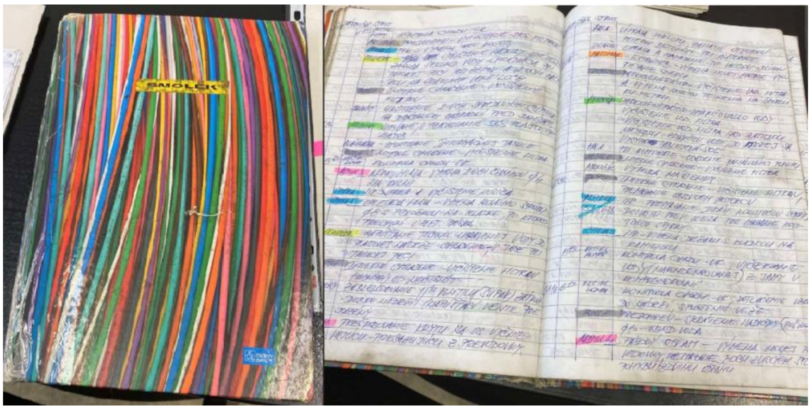

Fig. 1. Gather information from maintenance processes in paper form [Autor]

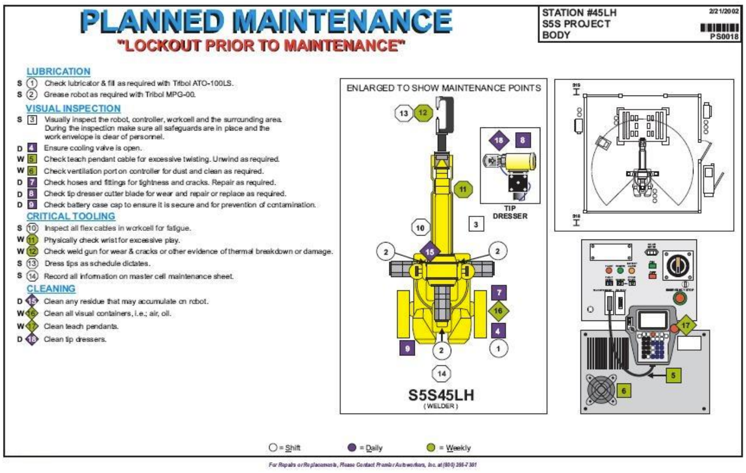

Fig. 2. Example of a paper standard [3]

Although this type of documentation has many advantages for the factory, the most significant disadvantage is the need for hardware. We will view the electronic documentation and storage for the amount of data we need to store.

2. EXAMPLE OF DIGITISATION IN SMES

Digitisation is an essential part of modernising and advancing factories [4-6]. With the digital standards of technical service activities, employees would have all the necessary information in one place (e.g. Cloud). They could easily navigate in it and help them reduce downtime on

machines and equipment. Standards serve as a guide for personnel to perform inaccuracies, reducing inaccuracies and undesirable situations.
When implementing digitisation in small and medium-sized enterprises (SMEs), it is appropriate if the factories first try to manage their processes, manage documents and evaluate the gathered information via MS Office combined with ICT (information and communication technologies). The following figures show the planned maintenance standard for the machine for the whole year Fig. 3 and the planned maintenance standard for a specific month Fig. 4.

Planned maintenance: TRACTION MACHINE

Checkpoints		Januar	Februar	March	April	May	Jun	July	August	September	October	November	December
1.	M85	Standard 1/01	Standard 1/02	Standard 1/03	Standard 1/04	X	Standard 1/06	Standard 1/07	Standard 1/08	Standard 1/09	Standard 1/10	Standard 1/11	Standard 1/12
2.	R 500	Standard 2/01	Standard 2/02	Standard 2/03	Standard 2/04	X	Standard 2/06	Standard 2/07	Standard 2/08	Standard 2/09	Standard 2/10	X	X
3.	VSA2000	Standard 3/01	X	Standard 3/03	Standard 3/04	X	Standard 3/06	Standard 3/07	X	Standard 3/09	Standard 3/10	Standard 3/11	X
4.	Winder	Standard 4/01	X	Standard 4/03	Standard 4/04	Standard 4/05	Standard 4/06	Standard 4/07	X	Standard 4/09	Standard 4/10	Standard 4/11	X
5.	Drawing	Standard 5/01	Standard 5/02	X	Standard 5/04	X	X	Standard 5/07	Standard 5/08	X	Standard 5/10	X	X
6.	SNH1800	Standard 6/01	Standard 6/02	Standard 6/03	X	Standard 6/05	Standard 6/06	Standard 6/07	X	Standard 6/09	Standard 6/10	Standard 6/11	X
7.	Electric parts	Standard 7/01	Standard 7/02	Standard 7/03	Standard 7/04	Standard 7/05	Standard 7/06	Standard 7/07	Standard 7/08	Standard 7/09	Standard 7/10	Standard 7/11	Standard 7/12

Machines for planned maintenance

Maintenance activities in the factory

Fig. 3. Planned maintenance for traction machine [Autor]

Planned maintenance standard for January

Standard number	2/01	Machine part	R 500

Checkpoints		Reasons for control activity: Impact on safety	Reasons for control activity: Fault occurrence	Reasons for control activity: Impact on quality	Activity classification	Place of inspection	Standard number	Service procedure	Management tools	Duration of action	Interval	Workers: Maintenance	Workers: Operator	Output working	Output layoff
1.	Check the air circuit for leaks														

Maintenance report

No.	Performed maintenance	Planned date	Real date	Spare parts	Downtime	Notes	Taken over by the operator	Checked by the maintenance manager
1.								

Maintenance activities in the factory

Planned maintenance for traction machine

Fig. 4. Planned maintenance standard for January [Autor]

The standard from figure 4 is divided into two parts. The first part is a table that should serve as a guide for the worker to execute maintenance. The second part is for recording the maintenance report. The table also includes pictures. The buttons on the right are used to return to the previous sections of the digital document.

3. Conclusion

The created digital document is used in the factory for the more accessible performance of activities [7] in technical service, the main part of which is the maintenance of machinery and equipment. As the selected factory is just starting with digitisation, such digitisation should increase the efficiency of the staff of the technical service department and reduce machine failures. This digital document will test the gathered information from the machines and write them directly to the digital document via tablets. Based on the implementation of a digital document, several benefits can be reflected:

- With the digital documentation, the factory would not have to solve archiving a large amount of paper, which can save space.
- The security of digital documents guarantees the security of information.
- As maintenance workers will have all the documents in the tablets, possibly stored in the Cloud, they will be easy to navigate in them and will be able to find historical records of maintenance performance more quickly; this should help to reduce fault downtime.
- And other.

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THE SYSTEM OF MAINTENANCE KPIS FOR SMALL AND MEDIUM-SIZED ENTERPRISES (SMES)

Abstract
This article aims to point on fundamental key performance indicators (KPIs) for SMEs. In maintenance, we determine KPIs measure the performance of a given task. They can measure anything from the time that elapsed during a shutdown (whether it is due to programmed maintenance or not) to the evolution of production processes.

1. INTRODUCTION

Key performance indicators (KPIs) measure a person's performance, department, project, or factory overtime and how effective they are at achieving their aims. Maintenance KPIs measure how well the operation is doing at achieving its maintenance goals, like reducing downtime or cutting costs. They are benchmarks for the factory and highlight where teams are now, how far they still need to go, and what they need to do to get there. They are an endpoint, and many factories and their departments are reaching for many KPIs [1]. For example, the ultimate factory goal might be to cut costs by a certain amount. There are several ways maintenance can impact this goal, like departmental spending or production waste. When we attach numbers to these components, they become KPIs. This might be as simple as saying that the factory will reduce maintenance spending by 10% or committing to reducing production waste by 20% [2]. Although every facility will have different targets, some of the most common maintenance KPIs revolve around a few key elements, including:

- Efficiency.
- Costs and spending.
- Safety and compliance.
- Asset performance.
- Downtime.

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- Work order management.
- Inventory management.

Today, with the help of information and communication technologies (ICT) and digitisation, we can easily display and edit this data in various internal systems, such as. SAP. For SMEs, such large systems are often costly and complex. Therefore, if they want to start with the gradual digitisation of their data, it is more advantageous for SMEs to gather information for KPIs and evaluate them, e. g. in Excel.

2. EXAMPLE OF KPI PERFORMANCE ASSESSMENT OF PRODUCTION SYSTEMS IN SMES

If we want to start something in the maintenance improvement or transform maintenance on a higher level, we must first evaluate the existing system maintenance. For the evaluation, we use various parameters, for example, MTTR, MTTF, MTBF, OEE, R(t), F(t), 5S and others. Some of these KPIs are shown in dashboards Fig. 1, Fig. 2 and Fig. 3. Necessity is the care of the production facilities, because the more they produce, yet often neglected on maintenance and this we arise disorders and unwanted situations. Because is a great potential in reducing failures in better maintenance planning which will increase the efficiency of production systems.

Fig.1. Example of maintenance KPI Dashboard in SME

Integration of maintenance into manufacturing organisation is partitioned into "hard integration" and "soft integration" variables. The "hard" issues deal with integration supported by technology and computers. "Soft" integration, on the other hand, deals with human and work organisational integration issues. An integrated management system technical service (IMSTS) is necessary to increase the availability and reliability of manufacturing systems to reduce unnecessary investment in maintenance without a significant increase of investment. The integration is achieved by combining optimal maintenance types to benefit and avoid the shortage of individual maintenance types. Thus, the proper maintenance program must define different maintenance plans for different machines.

- Reduction of the factory costs (costs of purchasing paper, printing materials, etc.).
- There is no need to set aside an ample space in the factory for document archiving.
- Speed of viewing documents.
- Simple search, etc.

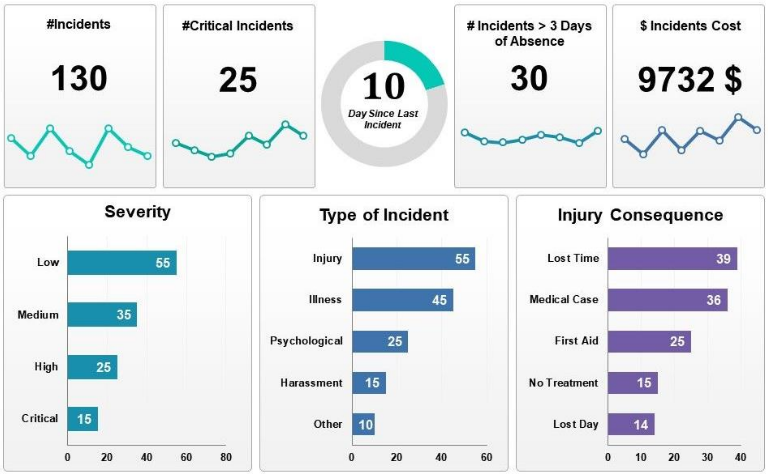

Fig.2. Example of health and safety KPI dashboard in SME [3]

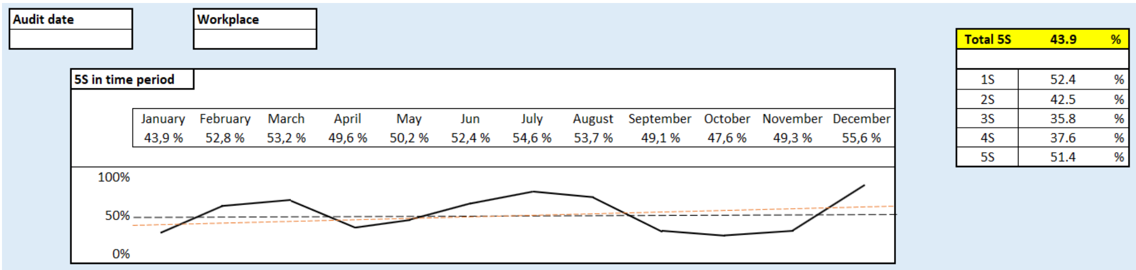

Fig.3. Example of 5S dashboard in SME

We also included 5S among the classic KPIs because the 5S method is based on the assumption that factory, order, purity, standardisation and discipline in the workplace are the basic conditions for the production of high-quality products and services, characterised by minimal or no waste and high efficiency of production processes. Some main benefits [4, 5]:

- Reduction of the working range 20 - 40%.
- Reduction of inventory at the workplace by 80%.
- Quality improvement 10 - 20%.
- Reduction of the search time 50%.
- Reduction of the time of assembly operations by 30%.
- Improving corporate culture.

The method aims to improve employees' working environment, reduce losses, and eliminate repeated movements. It is suitable as a stand-alone method or as a primary method in basically any type of factory. Thorough implementation of 5S guarantees the factory's survival, increased process efficiency and the sustain of jobs.

3. CONCLUSION

Arguably, the biggest advantage in calculating and applying maintenance KPIs is the deep knowledge and insight the factory will gain on internal processes and activities [6, 7]. Thus, the factory can understand what is really working (or not), and where there's room for improvement. Establishing, complying, and measuring the factory goals through maintenance KPIs is not just about ensuring the factory will be productive, it also plays a significant role in motivating and growing the team. Profit will stay healthy and within projections, without downfalls or losses. The factory will also improve its reputation since reliability tends to increase with the reduction of both risks and downtime.

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EXPERIMENTAL TESTING OF PRESSING TOOL SERVICE LIFE

Abstract
This paper deals with design of new experimental method for testing the service life of thermal sprayed coated pressing tools. The input material for pressing is very coarse and consists of high abrasive particles. Therefore, the pressing tools needs to have as long service life, as possible, because the products are often pressed in series of thousands or even hundreds of thousands. New type of coating was developed, but there was need to test the specific properties and modifications of the coatings. This paper deals with the basic research of the testing methods and describes the fundamentals behind experimental testing method design.

1. INTRODUCTION

Thermal sprayed coatings have been developed for applications where high surface service life, wear and corrosion resistance are required. The pressed products are made of a very abrasive material. A number of experts have been involved in the development of these coatings in the past, and tungsten carbide coatings have been selected as the most suitable.
One of the main motivations for the development of a new methodology and new equipment for testing the service life of pressing tools was especially the high cost of operational tests on real orders, unsuitability to use standard tests due to impossibility to simulate extreme conditions in real operation, shortening test length of testing cycle to 5 seconds (on a standard

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hydraulic press, the cycle length is approx. 40 seconds) and also comparable evaluation and results of the wear.

First, it is necessary to deal with the characteristics of the mechanism of pressing tools wear. Furthermore, it is necessary to determine the limiting conditions of the new experimental method. Based on the analysis and limiting conditions, the design of the test equipment was performed, including the design of the method of evaluating the amount of wear, and in the end the evaluation of the experiment was performed by comparison with the amount of wear of production press tools with a reference sample corresponding to them.

2. DEFECTS IN PRESSING TOOLS

In connection with the wear of pressing tools, the mechanism of this wear can be understood as the degradation of the functional surface of the pressing tool by pressed refractory material. As part of the analysis of the mechanism of wear of pressing tools, the pressing process itself and the associated process of pressing tool wear were analyzed. The output of the analysis is primarily to determine the durability of existing pressing tools, when 5000 working cycle corresponds with the wear on the surface of 0,5 mm. Abrasive wear, corrosion and adhesion are the main causes of wear of press tools. Of these three fundamental phenomena, the most important is abrasive wear [1,2].

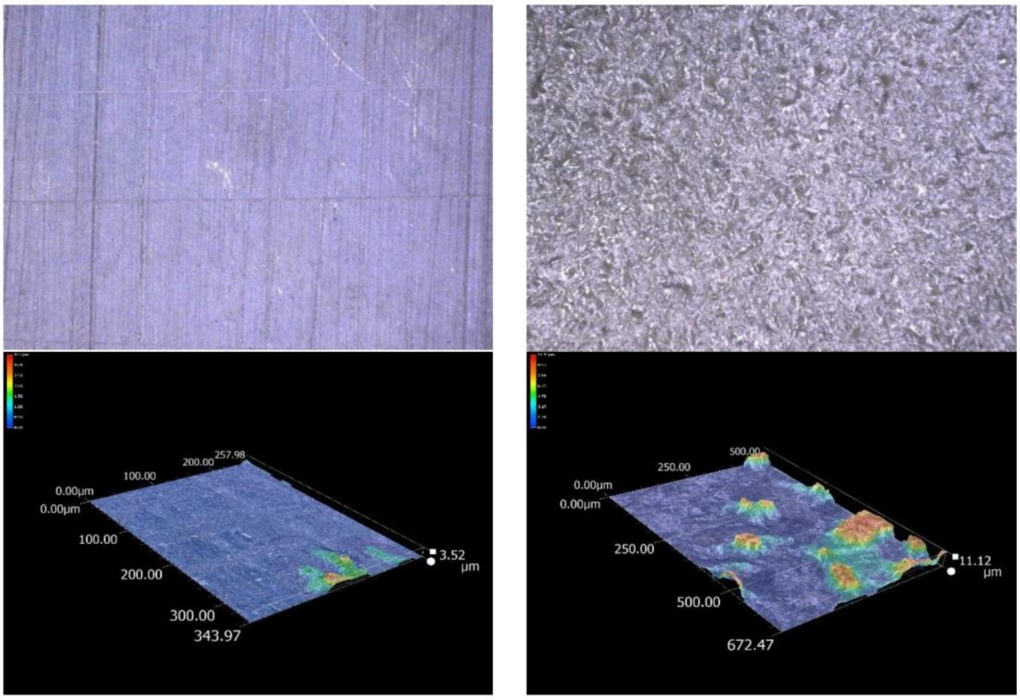

Fig. 1. Pressing tool before (left) and after (right) 5000 working cycles [Authors

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Hard abrasive particles on the functional surface of the press tool cause micro-cutting. The particles behave as cutting tools which are cutting its functional surfaces during the relative movement of the pressed material and the pressing tool. This type of wear noticeably appears on the experimental pressing tool after approximately 1000 working cycles. It is obvious that for higher pressing series the existing mold materials are insufficient from the point of view of abrasion resistance and therefore unsuitable [2,4].

As proof of this fact and substantiation of the mechanism of wear formation, which is based on the needling of the pressed material into the functional surface of the pressing tool, an experimental observation of punches is performed, which confirmed the hypothesis of wear formation. The Fig. 1 shows the observation of the punches before and after pressing. The figure shows the surface of the new punch on the left and the surface of the punch used after pressing 5,000 products on the right. The picture shows significant wear of the punch [4].

3. DESIGN OF EXPERIMENTAL TESTING METHODICS

Existing normalized methods for abrasion resistance tests could not be used due to productivity and test results comparability. These are, in particular, the test on a device with a rubber wheel, the test on a device with a grinding roller, the test on a drum device and the test with an intermediate layer of abrasive particles [3].

The basis of the new methodology is a new experimental test equipment that would be able to wear the tools quickly and correctly at the same. When developing the device, it is necessary to proceed from the assumption of the simplest possible device. The scheme of operation of such a device is shown in Fig. 2. The yellow part is the material, the rest is the tool. For the actual construction of the device, this then leads to additional requirements, namely the requirement for gravity pouring the material into the pressing tool and after pressing, the spontaneous disintegration of the fitting [4].

From the point of view tool's wear, it is possible to achieve very extreme conditions in the experimental device designed in this way, which exceed the standard method of pressing. During the actual pressing in this experimental device, a pressure peak will be achieved, when at the same time during the compression of the material the pressed material and functional parts of the experimental pressing tool move relative to each other and hard abrasive particles of material are inserted into the functional parts.

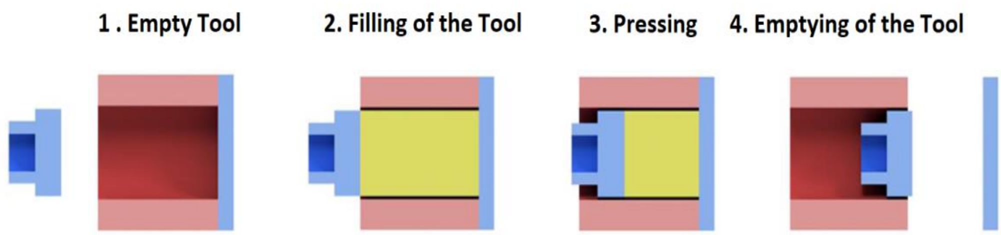

Fig. 2. Working process of the experimental testing device [Authors]

4. CONCLUSION

In this article, the issue of wear of pressing tools was introduced. Due to the nature of these products, their raw material is very abrasive, it is necessary to address the issue of durability of pressing tools. Current hardened and tool steel tools are not suitable for high series production batches. Therefore, a new type of HVOF coating was developed, which, together with its variants, had to be subjected to extensive tests. For this purpose, a search and a design of such a device were carried out. This device is used for accelerated testing of the service life of thermal sprayed pressing tools. It simulates maximum pressing forces and thus accelerates the abrasive action of the material on the pressing tools. Thanks to this, it is possible to choose a suitable type of coatings on pressing tools and further optimize the durability of pressing tools.

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DIGITAL ENTERPRISE AND ITS DEVELOPMENT TRENDS

Abstract
Industry 4.0, as the latest stage in the production of products as well as the provision of a variety of services, brings with it a huge amount of change towards improving business processes at all levels. One of the milestones of this industrial revolution is the Digital Enterprise, which is one of the most important factors of this era. The paper focuses on development trends within the digital enterprise and its various forms.

1. INTRODUCTION

Today, it requires maintaining a competitive market, a great deal of flexibility. Customers have high requirements that manufacturers are forced to meet. Who can adapt to new market trends has a great advantage over the competition. The customer wants the product to meet his and the special requirements, but that it is not necessary to pay large sums of money for them. Today, technologies offer the possibility to create a digital form of the product and customer requirements for a specific product when entering requirements for production directly to customers or sellers. These digital technologies, whether in the field of production, or also in the field of designing entire production workplaces or production lines, have gradually evolved into their current form.

2. DEVELOPMENT TRENDS THAT HAVE CONTRIBUTED TO THE FORMATION OF THE DIGITAL ENTERPRISE

As part of the development of the digital enterprise, this technology had to go through stages of development in several areas.

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2.1. Globalization

In the last two decades, the field of world trade and global production has undergone a very dynamic and turbulent development. There is more and more talk about the era of the new economy, where digitization, the global market environment, innovation activities and fast and free communication play a huge role.

Developed countries retain know-how and strongly strengthen the knowledge base. Within the global world order, the knowledge base, where the development of new products is carried out, has been separated from the production base - it can be hundreds or thousands of kilometers away. Knowledge and efficiency play a crucial role - not location.

Falling production costs have sharply reduced the demands on the required durability of products - faster replacement of products has ceased to be the prerogative of the rich. The periods of the cyclical period of decline and recovery are getting shorter and shorter. Thanks to globalization, the economy is increasingly interconnected and any major local intervention (terrorism in developed countries, war in a particular strategic area, financial crisis, or pandemic today) brings fear and uncertainty to the world and thus slows the desire to invest.

2.2. Informatics

Today, we all have a higher performance value in our mobile phones than we had 10 years ago in our desktop computers, which we use a lot at work to this day. Most PCs today have higher performance than previous mainframes, despite networking options. After the rapid development of mechanical automation and later the development of electronics and electronic automation (NC systems and robotics), which took place in the second half of the 20th century, factories without the need for workers (CIM) were expected in the late 1980s. At that time, however, it became clear that human creativity could not be replaced by the artificial intelligence of machines. This trend continues to this day, although this area has been moving forward at a great pace in recent times. Today, we can already see the first production plants without the need for a human factor. However, even these units do not work completely without the intervention of people, it is still necessary to apply the already mentioned creativity of people who organize, modify and control these production units. Emphasis is placed on the creativity of employees, rapid innovation, continuous small improvement of technical and organizational structure, teamwork, training of employees and their high motivation.

2.3. Cooperation

Unfortunately, many small and medium-sized enterprises still use a single philosophy - to overturn the competition, that is, to defeat it. They do not realize that with the departure of the company from the economic scene, tradition, know-how, often an established brand also leaves, and that it is better to agree on what knows better, what it has better conditions and by agreeing on, i.e. use a modern form of philosophy win win.It turns out that the most important factor in today's global world is the speed with which we can get new ideas in the realized form on the market. It will block the possibility of a more technically advanced solution, which did not reach the stores in time. A new well-established and marketable product can quickly reduce production costs and thus the price, so a new, often more technically advanced solution to the competition, which of course could not compete with the price at first, has no chance to penetrate for some time. Increasingly, they usually do not enter the market at all and pose a serious financial problem for the company.The speed of pre-production stages therefore determines the success of the company. Acceleration of pre-production stages usually brings cost reductions and earlier market entry. This usually brings about an increase in the profitable field throughout the sale period and allows further innovative activities during the life of the product, which usually prolongs its remaining in the market. For example, we can ensure a good marketing campaign for the saved costs from the pre-production stages. Along with the shortened time, we have a much better chance of finding a foothold in the market and at the same time our company will get enough funds not only to prepare new innovations, but also to enter new markets, acquisitions of other companies, etc.

2.4. Competitiveness

The basis for innovation is the ability to absorb new ideas, and the entrepreneur must be motivated to introduce and use innovation. The subsequent profit from the effective use of innovation must not only be at the level of knowledge but must also create sufficient resources for the search for and implementation of new innovation. Closely related to this is advanced knowledge management - purposeful handling of sources of information and knowledge, their sharing and application to other processes. The launch of this carousel must be made by society by investing in education, research and human resources.

2.5. Digitalization

Today, advanced software packages are able to provide extensive product support with many knowledge circuits (PLM - Product Lifecycle Management) throughout the entire product cycle and guarantee a smooth flow of data through all stages of engineering work
PDM - Production data Management).The field of construction and technology has been associated with computer support (CAD / CAM - digital design) for more than 20 years. There are a number of high-quality 3D systems that can gradually work with uniform data, from the first design to the programming of NC machines. Also, the area of business management has been the focus of software companies in recent years, and today we can talk about relatively advanced digital planning and management systems (ERP - Enterprise Resource Planning). In the 1990s, there was strong pressure to create supply chains. The aim was to remove barriers between trading partners, increase mutual trust and cooperation.

It turned out that the ERP information systems used, which were focused on in-house planning, did not promote better relationships with customers and suppliers. APS (Advanced Planning and Scheduling) systems were created, the Internet was joined with B2B, B2C, etc. techniques, and the techniques of TOC constraint theory began to be promoted, which focused on eliminating essentially unnecessary hedging stocks along the entire chain. CPFR (Collaborative Planning, Forecasting and Replenishment) systems are emerging, which means joint planning systems, demand forecasting and replenishment of stocks throughout the entire supply chain or cluster.

2.6. TestBed 4.0

The digital transformation of industry is increasingly showing that different paths lead to Industry 4.0 solutions in different companies. The concept of Industry 4.0 in companies is characterized by finding new ways and trying different solutions. Testbeds also help them with them. They are not only a testing tool, but also a platform to support research, development and innovation and a catalyst for transformation. At the same time, they support information, education and skills development on the Industry 4.0 concept, which includes digital enterprises. Testbed is a technology that runs in parallel with the digital enterprise and creates a platform for Industy 4.0.The range of testing areas is wide. From robotics, cyber security and big data processing to technologies supporting the creation of cyber-physical systems, individualized mass production, artificial intelligence or augmented reality systems. In the European environment, projects are already underway, in which test runs are interconnected and simulate the real environment with a large complex of factories, entire industrial ecosystems and address the practical challenges that are part of them, such as logistics or synchronization of operations.

3. CONCLUSION

The gradual development of technology has led to the current stage of Industry 4.0 and within it to the Digital Enterprise, with which the parallel technology can be considered Testbed 4.0, which are advances in PLM and PDM technology. Within these technologies, it is necessary to consider the creative process of the human factor in production as well as in knowledge management. It is questionable what progress will be made after this industrial revolution in the future. It must be borne in mind that information technology and human thinking will move into higher spheres of research and development.

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Key words Cloud, Production management, Factory of the Future

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USE OF CLOUDS TO SUPPORT PRODUCTION MANAGEMENT IN MANUFACTORING

Abstract
Cloud computing technology brings change and innovation in all industries around the world. This is stated in the report from the market research of the future. The rapidly evolving market and the need to keep up with customer requirements present many challenges and opportunities for the manufacturing industry. For these reasons, manufacturers are beginning to use cloud computing technology to improve processes.
This article describes the possibilities of using cloud systems in the management of companies of the future. This is also an overview of the benefits of using cloud systems. The main benefits include economic benefits, technical benefits, and the benefits of mobility.

1. INTRODUCTION

The manufacturing of the future is a complex ecosystem of self-regulating machines and workplaces capable of adapting. The companies themselves can communicate with other plants and combine existing industrial infrastructure with cloud computing and IoT. By adopting advanced technologies, the businesses of the future will be more human-centred, making it easier to share knowledge across platforms. Robotic technologies allow workers to work with machines on processes that involve repetitive tasks [1].
The most important feature of the company of the future is cloud services. These services are gaining in popularity and companies are therefore abandoning their own infrastructure. Experts claim that companies could operate in the so-called all-in-cloud mode by up to 50% by 2025 [1].
With the use of Cloud processes, which is necessary in the management of the business will be possible to process easier, faster, and more efficiently. The cloud will ensure data collection,

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analysis, and subsequent evaluation. IoT will provide the interconnection of individual operations, so there will be no errors in communication that would lead to losses.
In the management of the company today, the use of cloud systems in conjunction with individual processes works almost without problems. However, the individual processes do not communicate with each other completely and in the future such use could be inefficient for the company.

2. USE IN THE FACTORY OF THE FUTURE

It is necessary to look at the company of the future. This unit consists of parts, ie processes that constantly communicate with each other. For such communication, a connection between cloud computing and IoT is required. The company of the future should operate in the so-called all-in-cloud mode, to ensure everything in the cloud, to ensure continuous data collection and evaluation. Thanks to this, it is possible to connect individual processes in the company and thus facilitate the management of the company [2].
The business process is almost one of the most important processes in a company. There is communication between the company and the customer or between companies. Communication using cloud systems will ensure a smooth exchange of information. The information obtained must be kept safe. There is cloud storage for that. Today, cloud storage is equivalent to storing in your own infrastructure. In the factory of the future, the security of such storage will certainly increase thanks to intelligent technologies and biometric systems connected to the cloud.
The purchasing process is very important for production. Lack of material for production will cause downtime, which is responsible for losses. In the factory of the future, it is possible to eliminate these losses thanks to cloud solutions. Thanks to cloud technology, effective communication between suppliers and manufacturing companies is ensured. Cloud supply chain management provides a more strategic approach to inventory deployment [2].
The process of production planning and product development requires enormous attention. Today, this includes manual prototyping, experimentation, and testing. This process is time consuming, but mainly financial. With the help of cloud computing in this process, manufacturers can combine planning information with product development information into data. AI technology based on cloud systems will then enable the creation of rapid analyses of data files. Thanks to the ability to access data immediately, manufacturers can move very quickly from idea to production of the products.
Productivity management is also closely related to the production management process. One of the problems that businesses currently must deal with is productivity. Businesses must constantly adapt to changing customer requirements and demand. Cloud software solutions will ensure that companies have the constant material resources for production.
Thanks to information in the cloud and connection to IoT, production will be efficient in combining the work of humans and collaborative robots. Production information will be constantly collected on the cloud, where productivity analysis will be created in real time [3].
Predictive maintenance is an essential part of the business of the future. Thanks to predictive maintenance of machines and equipment, companies can achieve a new level of production efficiency. In conjunction with cloud technology, it is possible to record cost savings for device management. Intelligent machines in cooperation with cloud systems and IoT can, thanks to the appropriate software, detect device errors and immediately integrate them into

the system. Subsequently, thanks to the created database, to which technicians will have access, equipment repairs will be accelerated, and production downtime will be shortened. If the fault does not occur directly in the device, but the device detects a fault or wear of the tool required during production, it adds this component to the list of parts to be inspected. Thanks to this technology, errors and damage to machines and products are prevented.

Bad or chaotic arrangements can occur when storing products. This is easy to prevent in the businesses of the future. By combining cloud systems and IoT, it is possible to create a comprehensive storage system. The warehouse will be divided into individual sectors. Data on individual storage areas are then recorded in the cloud, where an occupancy analysis is created for individual sectors. Pallets or other storage facilities are then assigned a code specifying the location of their storage and information on what content is contained in them. Subsequently, the software allocates storage space as efficiently as possible depending on the distribution process of the goods. In this way, high storage efficiency is achieved, and errors are avoided. Thanks to the cloud and IoT, the system will constantly record the occupancy of warehouses and the number of products stored in them [3].

In the distribution process, it is important to know what equipment and products are in stock at the time and where exactly they are located. If we did not have this information, it could happen that the goods in question would not have to be in stock at all or would be there and we would not know about it. Thanks to cloud systems and IoT, such a situation may not occur in the company of the future at all. With the technology used in the storage process, it will be clear where and in what quantity the product is stored [4].

If a request comes from a customer to purchase one of the products due to an analysis of the state of the warehouse, it will be immediately clear whether the product is currently in stock. If there is a situation where the product is not in stock, the system notifies the production planning and management department of the situation, and it will be possible to produce it as soon as possible and deliver it to the customer.

3. BENEFITS OF USING CLOUD

The biggest benefit of cloud systems in the field of technology, if we use external providers of this service, is that external providers can ensure a high degree of scalability of services. If the demands on the user increase, the provider may connect external additional computing resources. If these demands decrease again over time, the provider can remove them from the user and assign them to another user who currently needs them. The company could use the saved funds in another sector [4].

However, if a company opted for its own infrastructure and purchased highly computing resources, it would not be able to use them efficiently. It could be prepared in the event of heavy workloads and data processing requirements, but in times when it would not be necessary, their use would not be optimal.

Because data, applications, and computing resources are accessible to cloud users from anywhere, the user has constant access to them. All it takes is an internet connection, a web browser, and a device with sufficient performance. Under the term device, we do not have to imagine only a classic computer. Nowadays, it can also be a laptop, tablet, or smartphone. As a result, the employer can save significant costs that he would have to incur to provide the working environment for the employee and the necessary equipment [5].

However, if a company decides to use cloud computing, the company will save financial costs. The company does not have to ensure the purchase, maintenance, and operation of the components of the given cloud system only for its own finances, but part of the responsibility passes to the external company. The financial costs of using the cloud and its services are therefore lower than the costs of your own infrastructure [5].
If we are talking about a private cloud, the operation, maintenance, and operation of which is provided by an external company, the costs are even lower. The company does not have to spend any funds to run the cloud. The only thing they pay for in this case is the use of cloud services. It is not even necessary to incur high financial costs for qualified staff

4. SUMMARY

The article provides an overview of what management could look like in future companies using cloud systems. Described use of the cloud to streamline production management processes. So was the descriptive benefit of using the cloud for dilution. Probably not all the article describes the benefits of using the cloud and cloud systems for companies.
So, for the use of the Cloud, we must also consider the threats that the cloud has.

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DIGITAL TWIN, VIRTUAL REALITY AND AUGMENTED REALITY AND THEIR USE

Abstract
Virtual reality and augmented reality are key technologies for virtual engineering. They are the basic for functional virtual prototyping, which enables engineers to analyse the shape, form and functional behavior of future products in an immersive and interactive virtual environment. Applying these technologies greatly improves the communication in product design and production development. It helps to identify and avoid design errors in early stages of the development process, it reduces the number of physical prototypes and saves time and cost for enterprises. Virtual reality and augmented reality are considered as valuable tools for improving and accelerating product and process development in many industrial applications.

1. INTRODUCTION

Virtual reality (VR) and augmented reality (AR) are becoming more mature with the development of related technologies, such as the advanced sensors, computer graphics, real-time registration and tracking, etc. The VR and AR technologies play important roles in the seamless integration and fusion of the physical and virtual worlds, which is crucial for digital twin (DT) implementation. Based on the existing and potential applications of VR and AR in DT, a general framework work is recommended to integrate these technologies with DT so as to provide more absorbing and interactive services. In the current highly competitive business and manufacturing environment, manufacturing industry is facing the constant challenge of producing innovative products at reduced time-to-market [1], [2].
In our article, the increasing trend of globalized manufacturing environments requires real-time information exchanges between the various nodes in a product development life cycle, e.g., design, setup planning, production scheduling, machining, assembly, etc., as well as seamless task collaboration among these nodes [2].

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Fig. 1. Digital Twin

2. COMPARISON OF THE VR AND AR

Virtual Reality (VR) and Augmented Reality (AR) are key technologies of Virtual Prototyping. They are easy-to-understand user interfaces to a virtual design space and facilitate an interactive exploration of the functionality of a new product [3].

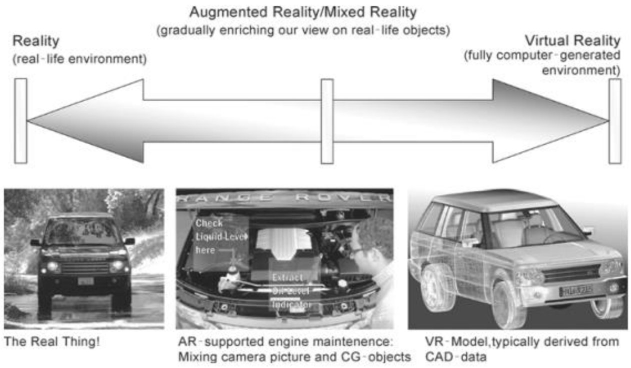

Fig. 2. From real-life to virtual reality

VR means a fully computer generated, three-dimensional environment, in which the engineer can interact with and manipulate a realistic representation of the product in real time. AR goes one step beyond: in contrast to VR, AR enriches the user's view on the real world with virtual objects, which are placed at right time and position regarding the user's perspective. Fig. 2 shows an example for the transition from Reality (the real Range Rover) to AR (mixing the real engine with computer generated object for maintenance purposes) to VR (a realistic 3D-modell of the car). In details, VR technology can be characterized by the following main aspects:

- VR stands for a realistic rendering of the product appearance (material, surface, colors) and behavior.
- VR makes use of advanced display technologies that allow the engineers to experience the virtual prototype like a real one.

Fig. 3. Oculus, PowerWall and Cave

Figure 3 (left) shows some typical VR-display systems: Head mounted displays (HMD) with small LCD-monitors in front of the eyes. They allow a spatial view on the virtual prototype but offer less image quality and wearing comfort.
In consequence, today most industrial VR applications use projection-based display systems that consist of several projections in different configurations. The typical configurations of such systems include PowerWall (Fig. 3, half) for group presentation or CAVE (Fig. 3, right) for more spatial immersion of the users [4].
The main challenge of AR technology is the context-sensitive mixture of real-world elements and computer-generated objects in the user's field of view. Therefore, an exact position tracking of the user inside the real world is needed in real-time [4].
Based on this information, the AR-system determines the virtual objects to be shown, their size and position in the user's field of view. Today there are two different approaches to display the mixed image of real and virtual objects: "Video-see-through" display devices have integrated miniature video cameras. The user sees a real-time video stream of his real environment, which is enriched with computer-generated objects. Fig. 4 shows a video-see-through HMD published by Canon and its application in car door assembly [4] [5].

Fig. 4. Use of Augmented Reality

In Fig. 4 (lower right), we see an example of "optical-see-through" display in a car. Thecomputer-generated objects are directly projected in the front window. Here, the complex and time-consuming video processing is not necessary. Fig. 4 (lower left) shows a high resolution optical-see-through HMD from Zeiss [5].
Based on the existing and potential applications of VR and AR in the DT, a framework that applies these technologies to the DT is proposed, as shown in Fig.5. In the DT, the physical entities (PEs), virtual entities (VEs), DT data (DD), and services (Ss) are connected with each other. The PEs (e.g., physical machine tool, robot, and materials) and Ves (e.g., virtual machine tool, robot, and materials) are kept synchronous and interactive through advanced sensory devices. The DD can store and fuse data from both the PEs and VEs to provide

valuable information for services. Based on this, the introduction of VR and AR can further enhance the interaction and fusion between the physical and virtual spaces, thus feeding users with higher quality services in design, planning, guidance, and training. Due to the different characteristics of VR and AR, their roles in the framework are also different [4] [5].

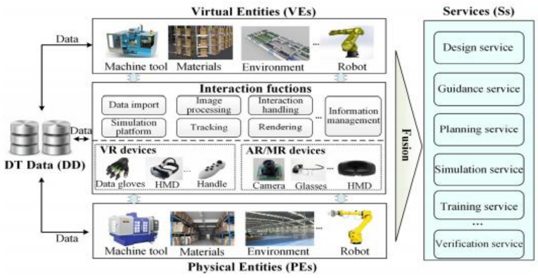

Fig. 5. Application framework of VR and AR in DT.

3. CONCLUSION

In this chapter, VR and AR are applied in the DT to enhance the fusion of the physical and virtual worlds, thus further improving the efficiency of the DT. The applications of VR and AR in design, manufacturing, and service are introduced, and the differences and similarities of these technologies are compared from multiple aspects. Based on the existing and potential applications of VR and AR in the DT, a general framework is proposed to efficiently integrate these technologies into the five-dimension DT to provide users with more interactive and immersive services. Based on this framework, an assembly process is discussed. Given the benefits brought by VR and AR, combining with these technologies will be a prevalent and beneficial trend for the DT.

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EVALUATION OF MAETROLOGICAL PROPERTIES OF A MEASURING MICROSCOPE

Abstract
The paper deals with testing and evaluation of toolmakers microscope from the viewpoint of Maximum permissible error. This evaluation can provide information about the validity of measurement results made on this device. Validity and reliability are the most important key properties of measurement devices for evaluation of state of the device. Both reliability and validity evaluate the quality of research. The quality of measurement process is very important for the making of decisions.

1. TOOLMAKERS MICROSCOPE

The toolmakers microscope can be effectively used for the verification for surface finish, measuring defects on surfaces, dimension measurement and also checking of gears and threated parts. For these purposes a crosshair or reticle should be implemented into optical systems, mainly into eyepiece of microscope. The checked thread or gear is compared with pattern on glass shown in eyepiece. This fast checking can be used for fast diagnosis of production processes and reduction of losses.
Maximum optical enlargement of the microscope can be achieved with combination of optical parts up to 200 times. Measurement on inspected object took place on XY position table coupled with micrometer slides for obtaining of position of the object in measuring plane. Micrometer slides have range 25 mm and resolution 1 µm. The inaccuracy of micrometer slides is declared with value of ±0.002mm. Micrometer slides have also digital output for another data processing and evaluation with external data units.

2. VERIFICATION AND CALIBRATION

The verification and calibration process needs some suitable etalons. Microscope micrometer calibration ruler and calibration slide are frequently used in practice, because of simple usage and manipulation with them. These etalons also frequently called as Stage Micrometer consist

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of length grades, lines with defined width, raster with defined spacing, circles with specified diameter, angles with specified value etc. The stage micrometer is used to calibrate an eyepiece reticle when making measurements with a microscope. Set of ceramic length gauge blocks have been used for calibration of optical toolmaker microscope. The calibration has been executed with gauges with nominal length in range from 1 mm to 25 mm with step of 1 mm.
CCD camera method has been calibrated in range from 1 mm to 6 mm and the maximum error is 29 µm. Graph of measured values (Fig. 1 left) shows growing tendency of measured error from gauge blocks. Reason for these results is probably low resolution of CCD camera system, which is only 0.01 mm. In this moment it is not possible to improve it.
Analogically, the micrometer head slide method has been calibrated with the same set of gauge blocks in range from 1 mm to 25 mm with step of 1 mm. Obtained errors Fig. 1. have also growing character in terms of absolute value. The maximum error is 11 µm. Mentioned calibrations have been executed only for X-axis and it is assumed that Y-axis will be similar. Resolution of micrometer head is 0.001 mm and it causes better results than previous method. These results show that CCD camera is useful for dimension range up to 3 mm and for larger distances it is better to use micrometer heads system.
Error in measurements is also affected by focusing and identification of searched edge or point on inspected part. This phenomenon is influenced by the amount of experience of an operator. The edge or point detection is the basic principle of the measurement on microscope.
In accordance with standard ISO 10360 it is possible to use this approach for evaluation of maximum permissible error – MPE. For our microscope MPE there are two lines, which are borders of our obtained errors from calibration process. This process can be used for estimation of this MPE achieved during the measurement via use of the microscope. This information is necessary for uncertainty balance because every measurement result also includes information about uncertainty of measurement. Normally it is described with linear model MPE = A + L/B, where A and B are constants of line equations and L is measured distance (in mm). After approximation and math correction it is possible to obtain math model of maximum permissible error MPE=5+L/2.5. Tolerance of used ceramic gauge block set (grade 0) is ±0.1 µm according to DIN3650 and DIN861.
Calibration process returns the answer about ability of measurement device to measure any quantity with requested accuracy. It means that it is needed to do the comparison of measured value with value represented on the etalon gauge. International standards (EALR-R2, ISO 3650) provide necessary steps for calibration process. This process evaluates validity of the device [1-4].

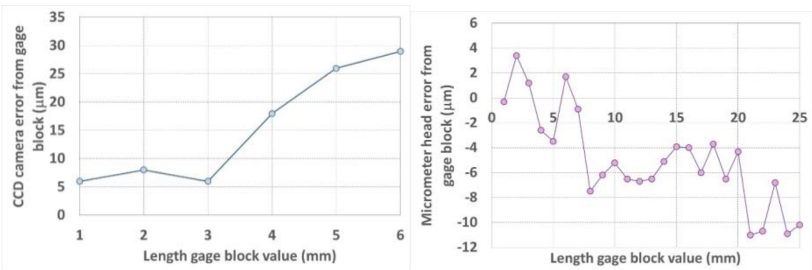

Fig. 1. Calibration of CCD camera measurement method (left) and Calibration of micrometer head measurement method (right) [Authors]

3. MEASUREMENTS WITH TOOLMAKERS MICROSCOPE

In this work one hundred measurements have been executed for six selected values in all the range of the microscope. These measured data have been analysed in histograms Fig. 2. It shows, that we can assume the normal (Gaussian) distribution law for obtained values.

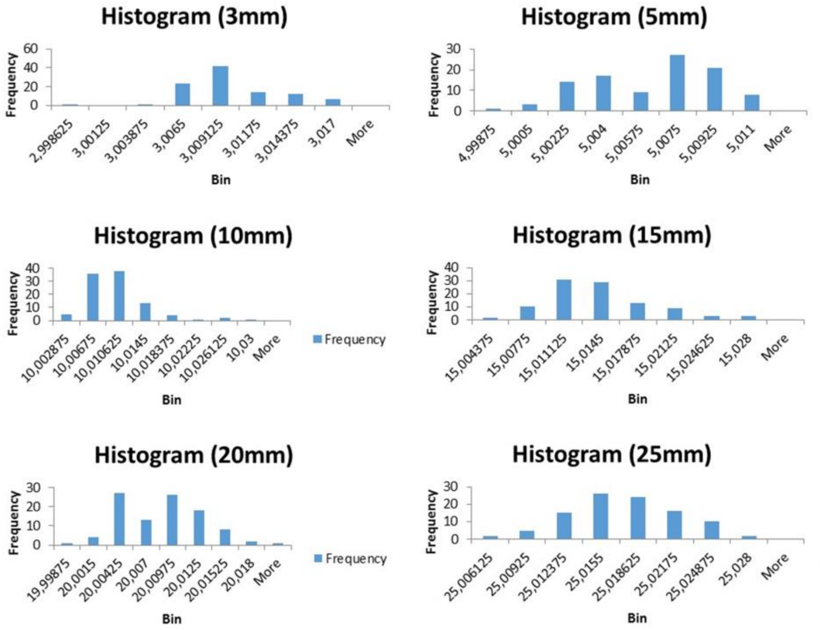

Fig. 2. Histograms for selected dimensions [authors]

Standard deviation from these values have been evaluated in Fig. 3. The best reliability of the examined microscope is obtained in 50 measurements.

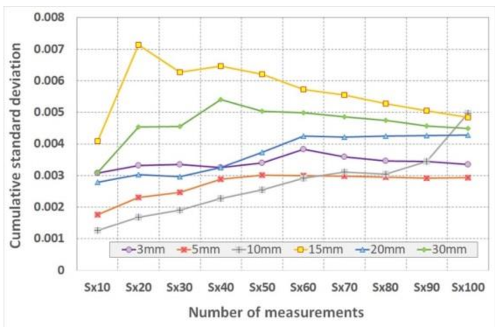

Fig. 3. Cumulative standard deviations for obtained values [Authors]

4. CONCLUSION

In practice the most frequently used devices are coordinate measuring machines CMM and computer tomography scanners, but measurement on these devices are very precise and very expensive too. These expensive devices need large place and need the air-conditioned room with special computer and software. Operating costs cannot be neglected.
Production practice frequently needs less precision but cheaper and faster measurements. The toolmakers microscope is suitable device for fast and cheap measurement directly in industrial conditions. The producer did not provide information about the accuracy of measurement on this device.
Validity and reliability of measurement device bring the information of how we can believe in measurement process with specified measurement device. Every measurement device should be verified for these metrological properties. Reliability obtained for examined microscope shows information about the number of measurements needed for effective measurement from the viewpoint of optimized inaccuracy and from the viewpoint of economic costs, which is 50 measurements for this microscope.
Verification process of the microscope has been executed for obtaining the information about maximum error of microscope. This information is also necessary for balance of the uncertainty of measurement made on this microscope.. The evaluation of MPE shows, that it has downward trend, and it can be partially compensated with separation of systematic error from this error balance. The main advantage of this microscope is fast measurement process and low overall costs in comparison to coordinate measuring machines.

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INFLUENCE OF COVID-19 ON SMALL AND MEDIUM ENTERPRISES

Abstract
The research focuses on the impact of Covid-19 on SMEs in Europe and the respondent's views and opinions. This paper also provides and develops a scheme for sustainability in SMEs. The implementation of social distancing makes people limit activities outside their home, consequently sales turnover decreases. Therefore, SMEs need to change the mindset in running business by using technology transformation. However, some SMEs do not have knowledge about digital skills that are relevant to their business.

1. INTRODUCTION

The outbreak of Covid-19 pandemic in various parts of the world gives a considerable impact on health and economy in terms of trade, investment, and tourism. Besides, in Indonesia, the application of social distancing makes people very careful by limiting activities outside their home so that it impacts on various business actors, including SMEs. The role of SMEs during all this time is believed to be able to drive the economy of a country. Anyway, since covid-19 pandemic, SMEs are most defenseless compared to other business [1]. It is because this type of business is very dependent on the velocity of money from merchandise sales, so that the decreased demand disturbs the company's cash flow. Government policy demands social distancing and physical distancing limits travel and consumption. Thus, it impacts on transactions in the market. Numerous elements affected are restaurants, markets, shopping centers, online transportation, and SMEs [2]. Therefore, people in several regions have changed their shopping patterns and achieved their basic needs online. Some SMEs are worried about the government's rule to stay at home or work from home (WFH) which can cause a decrease in productivity. Indeed, the WFH system can actually be run effectively [3].
The businessmen who rely on physical space, such as supermarkets, traditional food markets, restaurants, car dealers, cinemas, fitness centers, they suffer losses. It is in contrast to online markets. In a situation like covid-19, the adoption of technology is the best solution to keep

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the sustainability of SMEs. Some SMEs do not know about digital skills that are applicable to business, so this situation forces them to learn online business. The crisis due to the covid-19 pandemic has become the right moment for SMEs to boost the quality of their products or services and to establish various strategies for offering goods or services based on their business' concern. Covid-19 should not be a barrier for SMEs to increase sales, because the SMEs actors can promote their business through digital marketing [4] [5].

The digital approach will work well if SMEs have digital transformation so that they can compete effectively. The strategy is changing their offline store to online purchases for the sake of safety and convenience. During this pandemic situation, SMEs can escalate promotions through online applications both for logistics and sales. Since SMEs are part of digital economic ecosystem, transformation and innovation in digital skills is needed so that business sustainability can take place now and in the future [6] [8].

2. INFLUENCE OF COVID-19 ON SMEs

SMEs have been the lifeblood of the European economy, accounting for more than two-thirds of the workforce and more than half of the economic value added. Yet the results of a recent McKinsey survey, conducted in August 2020, of more than 2,200 SMEs in five European countries—France, Germany, Italy, Spain, and the United Kingdom—indicate just how hard their prosperity has been hit by the COVID-19 crisis. Some 70 percent said their revenues had declined as a result of the pandemic, with severe knock-on effects. One in five was concerned they might default on loans and have to lay off employees, while 28 percent feared they would have to cancel growth projects. In aggregate, more than half felt their businesses may not survive longer than 12 months—despite the fact that 20 percent of those surveyed had already taken advantage of the various forms of government assistance aimed at easing their financial distress, such as tax breaks or payments to furlough staff. Most SMEs surveyed have seen revenues fall; although, as one might expect, the picture differs by country, reflecting the severity of measures to control the virus and their impact on business activity. Italian and Spanish SMEs have been hardest hit: 30 percent and 33 percent, respectively, said their revenues had been greatly reduced. That compares with 23 percent in Germany, Fig. 1. [7].

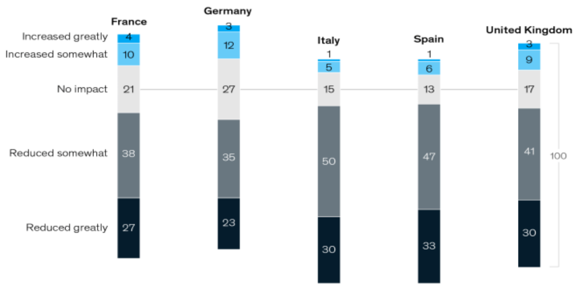

Fig. 1. Respondent's views of Covid-19 impact on their companies' revenues in % [7]

Revenues have fallen for the vast majority of SMEs in Europe since the onset of the Covid-19 crisis. Few SMEs appear optimistic about the prospects for improvement anytime soon given their views on the state of the economy ,Fig. 2.

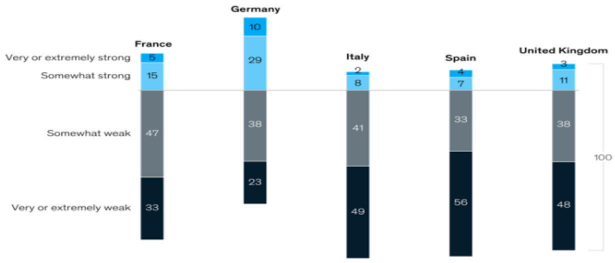

Fig. 2. Respondent's opinions about the current state of the economy in % [7]

Overall, 80 percent weighed the economy as somewhat weak to extremely weak. But here, too, we see material country variations. In Germany, where the economy is forecast to contract less than elsewhere, 39 percent of SMEs weighed the economy as somewhat strong to extremely strong. By comparison, in Italy the figure was just 10 percent. Approximately 4 out of 5 SMEs in Europe think the economy is weak [7].

3. THEORETICAL SCHEME

The sustainability scheme is designed to enhance SMEs-based digital transformation in order to facilitate knowledge for business actors during the social distancing of covid-19. This scheme is illustrated in Fig. 3.

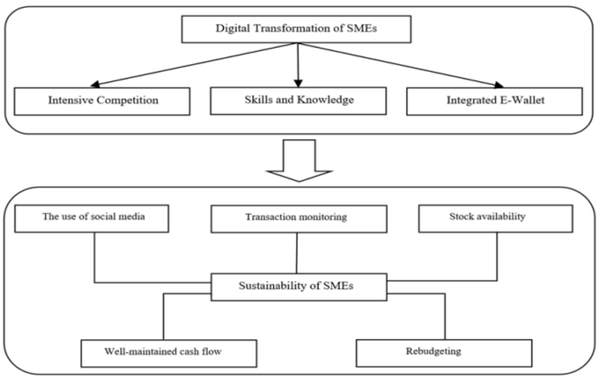

Fig. 3. Theoretical scheme of sustainability in SMEs [9]

The digital approach will work well if SMEs have digital transformation so that they can compete effectively. In the picture above, it is possible to see a scheme according to which SMEs could cope with the crisis much better by introducing digital technologies in their companies. The first part of the scheme lists the needs that are necessary for digital transformation. The second part of the scheme seems more comprehensive and describes what is important for the sustainability of SMEs in the market. Ultimately, this is a simple scheme that can help the business, especially in times of crisis caused by the Covid-19 pandemic [9].

4. CONCLUSION

Covid-19 can result in sustainability in SMEs with digital transformation. The number of SMEs that ultimately fail to survive will depend in large measure on the uncertain future course of the pandemic and the toll it takes on company revenues. Different governments will take different approaches to support their SMEs from hereon. The extent of their support will also differ, with much depending upon local market conditions. SMEs have the potential to be an economic and employment engine after the crisis, but governments' responses could prove critical. The results of this study are expected to provide recommendations to related parties, especially in an effort to increase the existence of SMEs that have an impact on the sustainability of SMEs.

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Knowledge bases, Production knowledge, Knowledge acquisition, Expert systems

Marcin MATUSZNY[1]

REVIEW OF METHODS OF ACQUIRING PRODUCTION KNOWLEDGE TO BUILD KNOWLEDGE BASES

Abstract

The aim of the article is to review the methods of acquiring production knowledge for building knowledge bases. The work lists the methods of acquiring knowledge based on the available literature and the author's professional experience. The tasks that are set for the methods of acquiring knowledge in manufacturing companies were also analyzed. Paper also presents the classification of knowledge acquisition methods and characterizes sub-processes of knowledge acquisition based on production processes.

1. INTRODUCTION

Creating a knowledge base of an expert system supporting production processes in many cases requires the development of methods of acquiring knowledge. The process of acquiring knowledge is primarily aimed at acquiring knowledge and experience in a strictly defined scope of tasks in the field of production processes with specific characteristics from identified sources of knowledge, as well as recording the acquired knowledge in a way that allows its use in the decision-making support process when solving tasks related to production processes [5].
Knowledge acquisition is the process of summarizing and extracting the professional expertise needed to solve problems from books, documents, data libraries, design specifications, national standards, company standards or expert experiences [3].
Along with the advancement of research development at the level of building expert systems, obstacles arose, mainly due to the need for increasingly extensive knowledge bases. It turned out to be necessary to develop such methods of acquiring knowledge that will be effective due to the shortening of the time of building and verifying knowledge bases in terms of their consistency, completeness and elimination of information redundancy. The most common methods of obtaining knowledge directly from an expert are:

- Direct consultations with an expert,
- Analysis and observation of the work performed by an expert,
- Recording of knowledge by an expert in an electronic or paper form specially created for this purpose.

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2. METHODS OF ACQUIRING PRODUCTION KNOWLEDGE TO BUILD KNOWLEDGE BASES

A lot of research relates to different types of knowledge [2]. Most of the available knowledge in manufacturing companies is procedural, declarative and tacit. Procedural knowledge is knowledge that is articulated in the form of algorithmic procedures. Declarative knowledge, on the other hand, is mainly a set of appropriate rules, each of which can be assigned true or false. Tacit knowledge is understood as specific skills close to the employee who acts as an expert in each field.

The process of acquiring knowledge is classified according to many criteria. One of such criteria may be the amount of information transferred to the advisory system. The following methods of acquiring knowledge can be distinguished here:

- Direct acquisition of knowledge – it does not require inference and knowledge transformation from the system subject to learning, it is implemented, for example, bydirect programming, this method is used for simple knowledge bases,
- Acquiring knowledge on the basis of instructions – requires the teacher's cooperation with the learner, implemented through the use of appropriate sources of knowledge indicated by the learner and their transformation into a language acceptable to the learner,
- Acquiring knowledge because of analogies – consists in transforming the existing information in such a way that it can be used to describe facts similar to those already included in the knowledge base, for example by modifying a computer program,
- Acquiring knowledge based on examples – a method very often used in the construction of knowledge bases, consists in generating a general description of classes based on a set of examples and counterexamples representing these classes, the general description is obtained on the basis of the principle of induction,
- Acquiring knowledge based on observation – this method requires greater participation of the learner during the learning process, the learner can make passive and active observations.

Summarizing the above, the methods of acquiring knowledge, due to the software's involvement in acquiring knowledge Fig. 1, can be divided into [4]:

- Manual methods.
- Semi-automatic methods.
- Automatic methods.

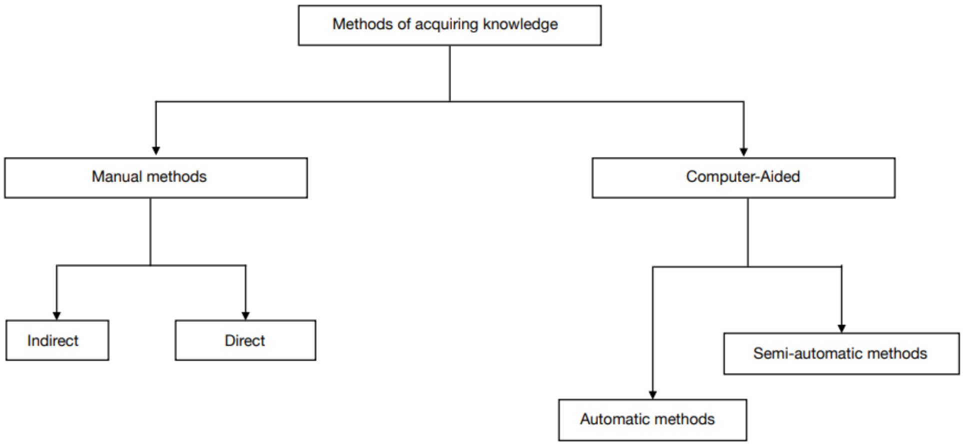

Fig. 1. Classification of knowledge acquisition methods

Knowledge obtained in an appropriate manner enables solving decision problems in the field of technical preparation of the production of finished products that may constitute components of machines. Knowledge bases and systems based on them should effectively support the design of production processes related to knowledge processing, especially in the machinery industry.
Knowledge acquisition is the first process leading to the construction of knowledge bases, which is carried out in a production company. The knowledge acquisition sub-processes are shown below in the form of a figure Fig. 2.

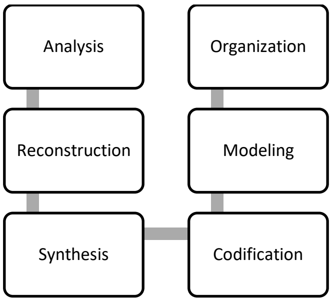

Fig. 2. Knowledge acquisition sub-processes

Acquiring knowledge is also its creation, which is possible through: knowledge creation, externalization, selection, sharing, collecting, adopting, identifying [1]. Thanks to the knowledge accumulated in the company, it is possible to introduce changes to improve production processes and adapt the product or service to the requirements of a dynamically changing market. Knowledge includes both theoretical and practical elements, as well as general and detailed rules of conduct. It is based on information and data on production processes [7]. Obtaining knowledge from experts carries a number of requirements and thus carries tasks that are intended for methods of acquiring knowledge, among which one can distinguish: creating decision rules, using analogies, formulating and defining new concepts, generalizing measurement results, gaining knowledge through conversation with the user systems, detecting regularities in data sets and generating knowledge in a human-understandable way.

3. CONCLUSION

Current research in the field of knowledge acquisition includes attempts to implement elements of artificial intelligence in knowledge management systems. This research focuses mainly on the strategy of knowledge codification [8]. However, this is too general an approach for knowledge management practitioners to proceed directly to implementations on this basis [6].
In this field of research, there is a visible shortage of strict methods of building knowledge management systems in manufacturing companies. It becomes necessary to develop such a method of acquiring knowledge that will be based on the knowledge of experts. The use of the method will enable mapping the method of solving decision-making problems in production companies. Knowledge bases can be integrated with an in-house integrated management system. Considering the specificity of the operation of the previously mentioned system, the effects of its work can be associated with many positive changes for the production company, including:

- Minimization of production costs.
- Optimization towards the improvement of production processes and products.
- Optimization towards improving the flow of information in a manufacturing company.

It can also be concluded that properly acquired knowledge will make it possible to obtain selected and condensed information related to production processes. Knowledge bases with properly acquired and implemented knowledge support the decision-making proces.

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THE CONCEPT OF INTERACTIVE TRAINING IN A MULTI-USER VIRTUAL ENVIRONMENT

Abstract

The article presents a concept of integration of multi-user virtual environment (MUVE) into immersive virtual training. Describes the difference in creation workflow and resource intensity. In addition, briefly explains the concept of multi-user immersive virtual training and its features. Lastly, the article summarizes the advantages and disadvantages of integration compared to one-player immersive virtual training.

1. INTRODUCTION

Interactive training in virtual reality (VR) allows users to experience a simulation of real places and processes. Such simulation enables a new way of safe training without negatively impacting the real world [1-2]. The user is often alone in this virtual world, relying on instruction and feedback premade by its creator. However, there is also a possibility of hosting multiple players in a single virtual environment – a multi-user virtual environment (MUVE). MUVE represents a virtual environment, where multiple users can enter and interact through their virtual avatars [3]. They often do so by using non-immersive ways, such as a PC game controlled with a mouse and keyboard. However, it is possible to combine MUVE with immersive virtual reality. A virtual training environment that allows more users in one virtual scene opens new possibilities of immersive virtual training. Communication and interaction between users enable the new of instructing trainees during immersive virtual training and their collaboration to reach the education goal.

2. METHODOLOGY OF MUVE INTEGRATION

The design and creation of immersive virtual training is no easy task. It often requires the collaboration of experts in many fields, such as 3D modelling, programming, and graphical design. Therefore, finding ways of decreasing the resources intensity is always a vital part of the process. Integrating MUVE into the process could potentially reduce the resources requirements of some stages of training design and creation while enhancing the experience.

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However, it depends on the training parameters and execution, therefore, the effect can also be negative. The upper part of Fig. 1 shows the simplified workflow of classic immersive virtual training creation [4], lower part presents the workflow of the multi-user alternative (with MUVE integration).

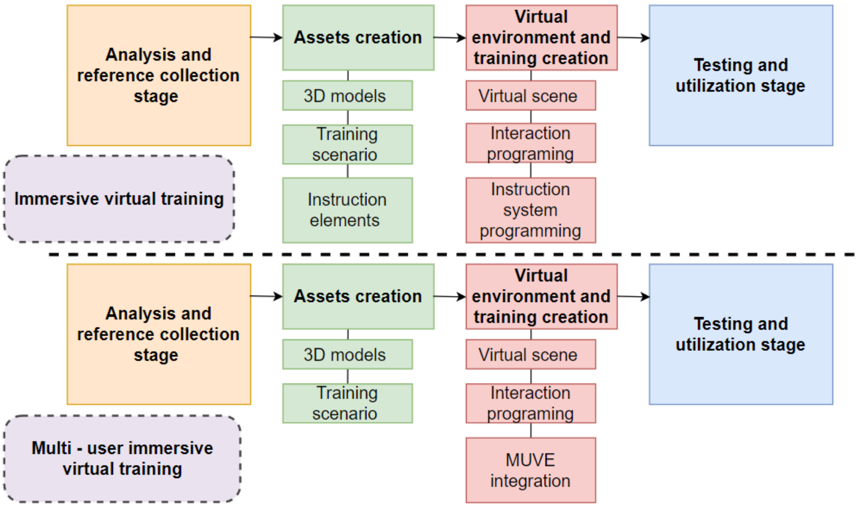

Fig.1. Creating a multi-user immersive virtual training [Authors]

Analysis and testing stages remain roughly the same, with some small changes regarding the MUVE integration. However, important changes affect the assets creation and virtual environment and training creation. In those cases, the workflow can be notably altered.

2.1 Assets creation

Creating suitable assets is a crucial part of the training creation process. This includes 3D models of objects in the real scene, the scenario of the training that sets the parameters of the taught subject or process, and all elements that will instruct the student during the training (signs, pointers, videos etc.) [4]. However, in the multi-user immersive virtual training, all the explaining can be secured by the real person. This means that the last task can be minimized or eliminated.
Integration of MUVE can potentially reduce the time needed for the completion of this stage. There will be some additions in this stage to prepare for the MUVE integration, such as the creation of the avatars so the players can see and recognize each other. However, basic avatars can be found on the internet for free.

2.2 Virtual environment and training creation

The early parts of this stage will be quite different for the multi-user immersive virtual training. Before the creation of the virtual environment (scene), it needs to be set up to support the multiplayer option. Few tasks need to be completed to achieve this, such as downloading the multiplayer SDK (software development kit), setup of server connection, players spawn and avatar setup. With a multiplayer setup, more users can join the same scene which lays the foundation of MUVE in an immersive virtual environment. The next step is the creation of the virtual environment (copy of the real place that is the subject of the training) [4]. However, since the tasks will be explained by a real person, there is no need to create a complex instruction system. Replacing premade instructions with a real instructor can potentially save a lot of time but also increases the human resources requirements.

2.3 Multi-user immersive virtual training utilization

The main idea is to replace all the premade instruction with real-time instruction by a real person. Students and instructors enter the virtual scene while interacting with the scene and themselves. The instructor can explain the subject with words or can demonstrate the task while students watch. They can be in the same room but also different towns, however, they still can meet in virtually simulated coaching sessions. There can also be more students at once with more instructors, it depends on the resources and server capacity. Fig. 2 shows the basic concept of multi-user immersive virtual training.

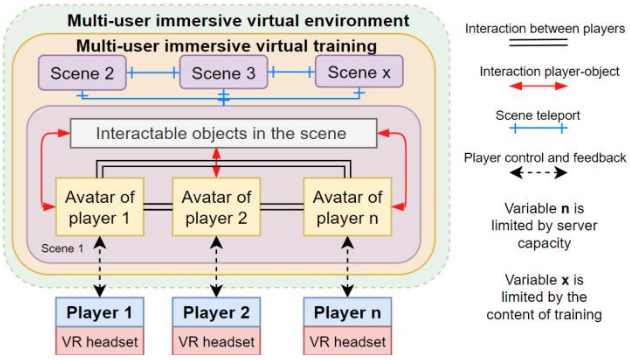

Fig. 2. Multi-user immersive virtual training concept [Authors]

Players can join the virtual environment and interact with other players (up to server capacity). Each scene can represent a different subject and with enough instructors, students can learn different things in each scene simultaneously. MUVE integration adds a lot of potential to immersive virtual training, but its utilization depends on the available resources.

2.4 Training comparison

To properly assess both approaches, it is important to know the pros and cons. It is not a matter of which is better, but which is suitable for proposed tasks. Therefore, is it vital to highlight the advantages of each approach in various parameters, as presented in the next chapter.

3. COMPARISON RESULTS

Immersive virtual training and multi-user immersive virtual training can enhance the education process in various organizations. Tab. 1 summarizes the strong points of each approach.

Tab. 1. Compassion of approaches [authors]

Immersive virtual training	Multi-user immersive virtual training
One VR headset	Multiple headsets (higher investment cost)
Instruction elements and instruction system	Real instructor (less time-consuming)
Automated instructions	Additional personnel required
Runs even offline	Network connection required
Changes in code required for instructions changes	Very flexible for instructions changes
Education of one person	Education of groups
Instruction elements may be distracting	The quality depends on the instructor
Feedback is provided by an automated system	Feedback is provided by the instructor
Does not provide social immersion	Provides social immersion
Infinite replayability for student	Requires the presence of an instructor

4. CONCLUSION AND FUTURE RESEARCH

Multi-user virtual training can provide an alternative for immersive education. It changes the way a subject is explained while simulating the social interaction of the real on the job training. It also lowers the requirements for training creation in some aspects, such as instruction system elimination. On the other hand, there are new requirements for correct execution, such as higher human resources requirements and experience with multiplayer games creation. However, this approach can be suitable in many situations. In a near future, research will be conducted to evaluate the difference between immersive virtual training and multi-user virtual training in a case study involving real participants. The article presents the concept of integration of MUVE into immersive virtual training and lays the foundation for future research.

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PLANNING AND CARRYING OUT A SIMULATION EXPERIMENT AS WELL AS MULTI-CRITERIA EVALUATION OF VARIANTS

Abstract

The paper presents an example of the use of modelling and simulation methods in improving manufacturing processes in the automotive industry. A sequential optimization plan was used to efficiently conduct the simulation tests. When selecting the best solution on the basis of several criteria, the classical method of multi-criteria evaluation was employed.

1. INTRODUCTION

The computer-based simulation model is a logical-numerical representation of the system or actions programmed to solve the issue using a computer. Modelling is an experimental or mathematical technique for analysing complex phenomena or processes. Controlling the production process with the support of simulation models has a number of advantages. Thanks to testing solutions, the probability of making mistakes as well as unnecessary costs is minimized. There is a greater chance of implementing bold and innovative improvements, the implementation of which would not be possible without simulation due to too high risk. In just a few minutes, it is possible generate results that one would have to wait for weeks or months. This tool greatly facilitates the understanding of the functioning of the production system. [1, 2, 3, 4]

Simulation studies without any plan on a trial and error basis could result in the generation of hundreds of experiments Fig. 1. Using elements of experimental research metrology, it is possible to create an action tactic that, through a small (but sufficient) number of experiments, will lead to achieving of intended goals [2]. An effective method is to plan the experiment according to a sequential dynamic optimization plan. The experiment is performed according to set sequences. The number of sequences is equal to the number of factors tested. In the "0" sequence, the importance of the tested factors and their values should be established. The most important are those that have the greatest impact on the baseline factors. Moreover, all factor values that are in the first position belong to the so-called central values. This means

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that, according to the assumptions based on experience and on the basis of the collected data, they should provide the solution that is closest to the optimal one. The "1" sequence consists in entering successively into the model the values assigned to the input factor x_1 with the central values of the remaining factors fixed. After simulating the model with the entered V_{11}, V_{12}, V_{1i} values it is necessary to decide which variant is the best. Then, the model leaves the best parameter of x_1 factor determined in the first sequence and experimenting in a similar way with x_2 to x_n factors.

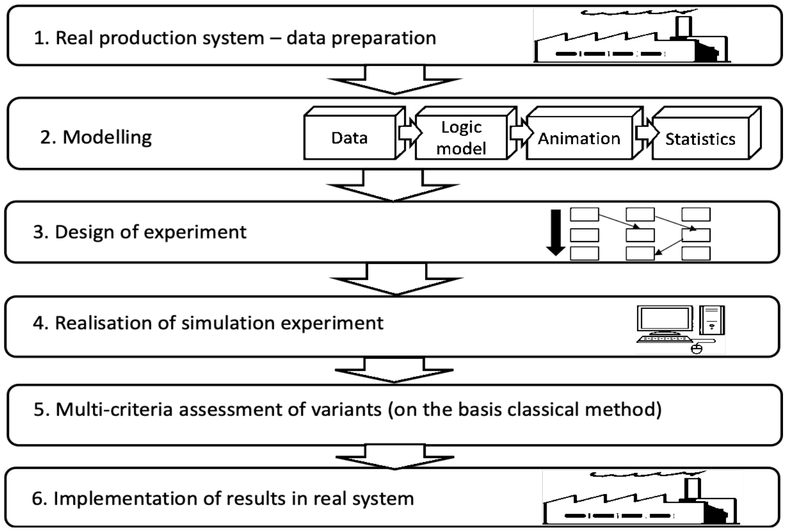

Fig. 1. Modelling and simulation of production systems [on the basis 2]

2. PRESENTATION OF RESEARCH RESULTS

The aim of the study is to present the benefits of using modelling and simulation of manufacturing systems in the improvement of production systems. Concepts such as experiment planning and multi-criteria evaluation of variants were also discussed.

The scope of the research was limited to the area of manufacturing car radiator core units. The Arena software was used to model and simulate the system, and the best solution was selected through multi-criteria evaluation - the classical method.

The production system is an operational model and constitutes a phase of the manufacturing process of a car radiator, more precisely its core unit. A total of 8 employees works on the line, including 1 team leader. Transport between workstations does not require additional equipment due to the small size and low weight of the materials. The entire system consists of operations such as: cutting a shape from a metal sheet, cutting tiles, bending, punching holes, mounting tiles in the fins of the cooler and quality control.

The project includes the analysis of the production system of car radiator core units, building its model in the Arena package, planning a simulation experiment according to a sequential optimization plan, determining the number of simulation experiments and conducting an experiment in order to:

- Producing about 570 pieces/week.
- Rational load of available machines.
- Rational workload for employees.

The factor analysis of the research object with the division of factors into input, output, constants and disturbing factors Fig. 2.

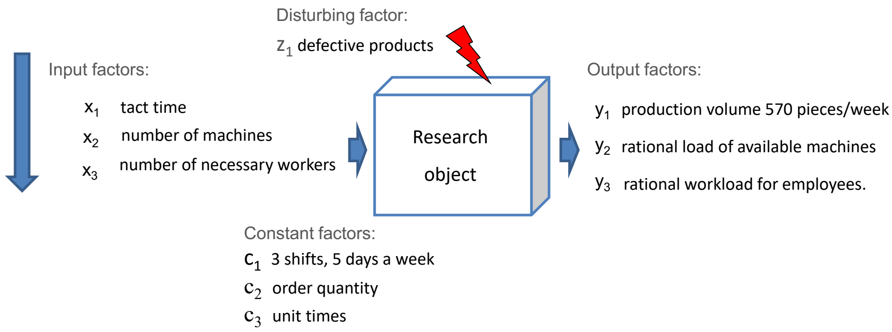

Fig. 2. Factorial analysis of the research object [Authors]

In order to visualize and analyze the processes, a simulation model was built in the Arena software Fig. 3. The simulation time was set at 6750 minutes, i.e. 7.5 hours of work/3 shifts 5 days a week.

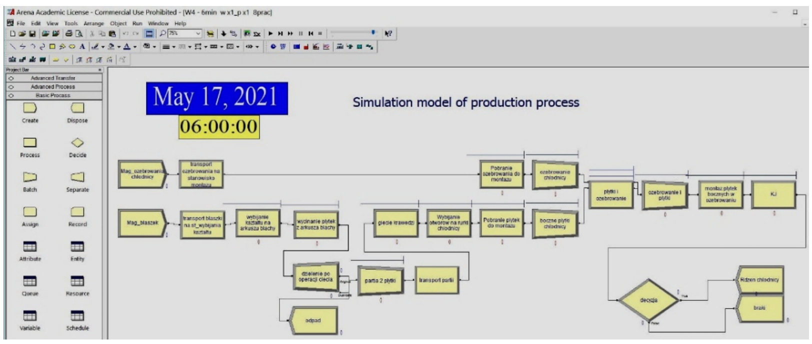

Fig. 3. A model of a production system in the Arena software [authors]

After verifying the correctness of the created system model in the Arena package, the planning of a simulation experiment was started, which will ensure success and allow to achieve the assumed design goals. During the development of the plan, the focus was on obtaining good-quality information about the system under the study with a small number of experiments. The importance of the input factors was discussed first. It was found that the factor related to determining the tact time of the line should be the highest in the hierarchy, as it has the greatest impact on the starting factors. The second factor was taken into account indicating the number of machines required in the process and their load, and as the third the number of necessary workers. In planning the experiment, a sequential optimization plan was used Fig. 4, thanks to which for the assumed factors and their values it is enough to conduct 7 simulation experiments instead of 27 if you want to check all combinations of input factor variability.

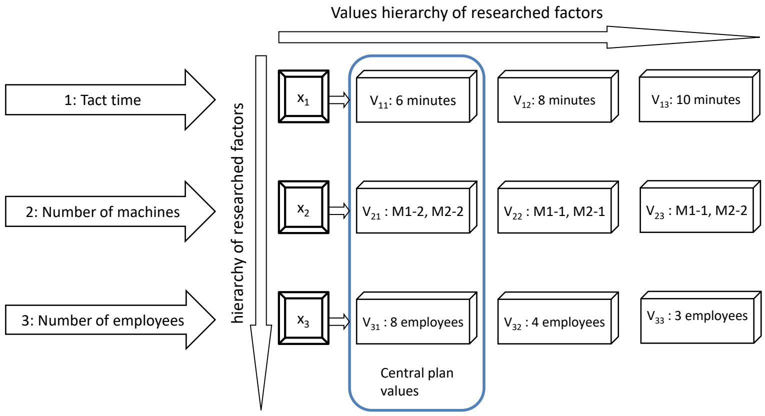

Fig. 4. Simulation experiment plan [Authors]

In the first sequence, the tact time of the line was determined according to the assumptions of the V_{11} variant. In the second sequence, the second solution was chosen as the best (V_{22}). Determining the best solution within the third sequence was based on a multicriteria evaluation using the classical method. On the basis of this analysis, the second solution turned out to be the best option (V_{32}).

3. SUMMARY

The use of modelling and simulation tools as well as experimental research methodology in improving the production process of a car radiator core brought a number of benefits. The right decision was also to plan the experiment according to the sequential optimization plan, significantly reducing the number of necessary experiments. As a result of the activities carried out, the tact time of the line and the number of machines as well as workers necessary to achieve the assumed goals of the project were established.

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RTLS SYSTEM IN INDUSTRIAL ENTERPRISES

Abstract
This paper deals with the issue of industrial localization, its use in practice and the subsequent analysis of specific examples of use. The paper explains the definition of RTLS technology as well as its topology or main parts. The use of localization RTLS systems emphasizes the importance of the Industry 4.0 concept in modern manufacturing companies, where nowadays there is an increasing emphasis on process simplification, shortening of times, savings and, last but not least, safety.

1. INTRODUCTION

Today, most large companies already use various monitoring or, in other words, localization technologies to streamline and innovate production. Many businesses are just realizing that digitization is an integral part of any "smart factory". Thanks to advances in today's technologies, managers and employees can rely on "silent workers" in the form of various localization technologies. These technologies, in conjunction with the company's software support, save money, reduce production times, ensure worker safety, and generally increase the general view of the manufacturing company's operations.

2. RTLS SYSTEM

Real Time Location Systems (RTLS) refers to any system that accurately determines the location of an item or person. RTLS is not a specific type of system or technology, but rather a goal that can be achieved with different asset localization and management systems. An important aspect of RTLS is the time at which assets are monitored, and this data can be used in different ways depending on the application [1]. For example, some applications only need timestamps as the asset traverses the area, while other RTLS applications require much more detailed visibility and require constant updating of time data. The ideal localization system can accurately locate in real time, track and manage assets, inventory or people and help companies make informed decisions based on the location data collected. Furthermore, it

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is possible to say that the RTLS system serves not only to identify the tag, but also to locate it and monitor the movement in real time. The system determines the location using small devices placed on the objects we monitor, active RFID tags. RTLS technology is designed mainly for monitoring and determining the position of objects in the interior or within the exterior (premises of the production company, etc.). RTLS is used in many industries with specific applications such as employee tracking and asset tracking. These applications can be found in the manufacturing and mining industries but are most important in healthcare [2].

Each RTLS system uses a certain infrastructure. For the system to run smoothly and properly, the monitored area must be covered by a wireless network so that each tag has a sufficient signal. Each active RFID tag in the network then independently transmits data over that network to a server, where the data is further processed. The position or trajectory of the tag movement is evaluated through the application. Tags are small electronic devices that are attached to any object or individual that needs to be tracked [2]. The marks serve as a transmitter and transmit flashes, which are received by the anchors and sent to the location server to calculate the positions of the marks Fig.1.

Fig. 1. Electronical tag

All RTLS applications will consist of several basic components: a transponder, a receiver, and software for interpreting the data from each. The complexity of the system, the technology chosen, and the scope of the application will determine the amount of hardware and software needed to create the ideal RTLS.

3. USE OF RTLS SYSTEMS IN INDUSTRIAL ENTERPRISES

The introduction of RTLS systems into industrial practice combines a well-thought-out combination of software as well as hardware support. Companies dealing with this issue also solve problems in the industrial sphere [3]. The monitoring focuses on monitoring the position of employees, which has the task of protecting employees by increasing their safety, reducing the time required for assembly and rescue operations, increasing safety and simplifying the alignment of working hours with the location Fig. 2.

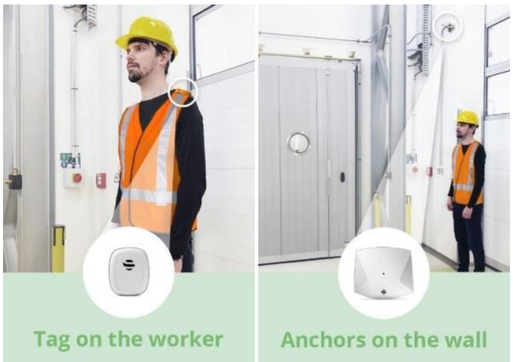

Fig. 2. Protect employees with personal tags

Another application is forklift tracking. This application helps logistics and production managers achieve greater efficiency, profitability and safety by making better use of the fleet, reducing the number of hours lost and, more importantly, accident prevention, Fig. 3. [4].

Fig. 3. Forklift and property location

Real-time asset tracking is the process of tracking physical assets in a facility to define its location. Materials or products that are monitored to monitor their flow throughout the manufacturing process can also be an asset. The goal of asset tracking is to maximize asset utilization, prevent misuse, and optimize its role in all proceses [5].
Of interest is the eKanban for material flow analysis which creates the transition from manual Kanban to eKanban (also known as Digital Kanban) for paperless production is a necessary step in the digital transformation. It allows greater control over operating profit and cash flow, increases the efficiency and productivity of existing resources, eliminates errors, and improves visibility and transparency throughout the organization [6].
In order to shorten the delivery time in the MTO production process, the current paper work orders are replaced by digital work orders that contain the same information and extend it to real-time location and other data types based on the sensors used [7].

4. CONCLUSION

The participating manufacturing companies and plants are subject to constant modernization, which is essential for success. The digitization of production data using elements of industrial localization such as RTLS systems is becoming more and more recognized. This is due to the results of these systems in protecting the health of workers, but mainly by saving production times, protecting assets and products and, last but not least, saving corporate finances. Within these applications, it is necessary to point out the importance of digital twins, which means the "mirroring" of physical classifications and processes, on the basis of which it is possible to visualize, evaluate and subsequently optimize the use of assets but also improve production. With this fact, industrial practice gains more control over everything that happens in production and thus increases the efficiency and productivity of business.

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Hard tissue, Bioprinting, Scaffold, Living cells

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BIOADDITIVE MANUFACTURING OF HARD TISSUE REPLACEMENTS

Abstract
Tissue engineering aims to maintain, improve, or replace different types of biological parts including bones. During the last two decades, a wide variety of AM technologies have been adapted to hard tissue processing. The main scope of this paper is to investigate bio additive manufacturing technologies which are used for the fabrication of hard structures. As a result of this, a comprehensive categorization of 3D printing technologies for biomaterials is provided.

1. INTRODUCTION

Conventional methods applied to bone-related diseases are not always sufficient enough for the needs of today's society with its longer life expectancy. Various studies have shown limitations and difficulties of conventional treatments of bone diseases. In recent years, with the fast development of additive manufacturing (AM) technologies, bone tissue engineering has become a promising approach for repairing bone defects. Especially, scaffolds play a crucial role in bone tissue engineering with their purpose to emulate the structure and function of the natural bone. In this regard, bio additive manufacturing techniques provide great capabilities to fabricate scaffolds and thus enable modern and more effective treatments for hard tissues.
This article aims to describe current situation of additive manufacturing techniques which are used for a production of hard structures. Furthermore, a categorization of 3D printing technologies for biomaterials is presented in order to outline wider classification framework of 3D bioprinting techniques. Finally, some important challenges associated with AM production of hard tissue scaffolds are articulated.

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2. BRIEF DESCRIPTION OF CURRENT SITUATION OF AM USED FOR HARD STRUCTURES

Hard structures which are deployed in medicine are typically manufactured from these main types of material: metals, polymers, ceramics and composites. Among typically used metal materials we can find titanium and titanium alloys, tantalum, magnesium, cobalt and stainless steel. From polymer materials are often used poly(lactic acid) (PLA), poly(lactic-co-glycolic acid) (PLGA), and poly(caprolactone) (PCL). Ceramic materials are represented by bioglass (BG) and hydroxyapatite (HA). Lastly, composites of two or more materials which are created with the aim to improve processability, printing performance, mechanical properties and bioactivity.
Hard constructions such as orthopedic implants are traditionally manufactured by techniques such as molding, casting, milling and turning. Additive manufacturing technology is nowadays very popular for a production of biomedical devices. Its unique characteristics give freedom to build complex geometry, good surface finishing and material heterogeneity [1].
While there are numerous AM techniques currently available, these four are mainly applied to produce hard structures: SLA - Stereolithography, FDM – Fused Deposition Modeling, SLS – Selective Laser Sintering, Binder Jetting. Each individual technique has its own attributes. Stereolithography, for example, uses light to solidify resin material, whereas Selective Laser Sintering applies laser beam to sinter together powder material. When comparing Binder Jetting and Selective Laser Sintering, both techniques use powder as a build material yet Binder Jetting uses binder material to create solid part and Selective Laser Sintering uses laser beam to selectively fuse powdered materials into a solid object. Many materials are relevant for production of hard tissue replacements. Polymers and composites can be processed into bioproducts through approaches such as vat photopolymerization known as stereolithography (SLA), powder bed fusion (SLS technique), material extrusion (FDM technique) or binder jetting. Ceramic material is applicable for powder bed fusion, binder jetting and directed energy deposition. Metals can be used in powder bed fusion, binder jetting and directed energy deposition. In general, a wider option of manufacturing processes is provided for a selected material group. Bone tissue engineering is a specialized field which aims to promote new tissue repairing and regeneration by the synergy of cells, signals and scaffolds. To help fix larger bone defects special support structures - scaffolds are needed. Additive manufacturing is an ideal technology to build scaffolds with highly desired properties such as: biocompatibility, good mechanical properties, customization, high porosity. In recent years, research focus in this domain has been on optimization of architecture, characterization of the effects of surface finishes and co-printing of soft, cell-laden components to promote rapid regeneration within rigid lattices [2]. As 3D printing technologies for biomaterials are rapidly developing, their application may require not only specialists in each specific area related to the given technique, but also collaborators who are experts in 3D printing innovations. In this context, the next section is devoted to outlining a number of different 3D printing technologies for biomaterials.

3. CATEGORIZATION OF 3D PRINTING TECHNOLOGIES FOR BIOMATERIALS

As mentioned above the 3D printing technologies for bone tissue fabrication are increasingly used and include a wider range of approaches. They use different types of materials including metals, polymers, ceramics, or even cells which are encapsulated within a bio-ink. The 3D printing approaches for general use or specific purposes can be classified from different points of view. Bahraminasab [3] presented categorization of additive manufacturing technologies for general purpose based on the approach used for material integration. This classification, depicted in Fig. 1, categorizes AM technologies into three basic types, which are laser based, ink based and extrusion-based AM methods.

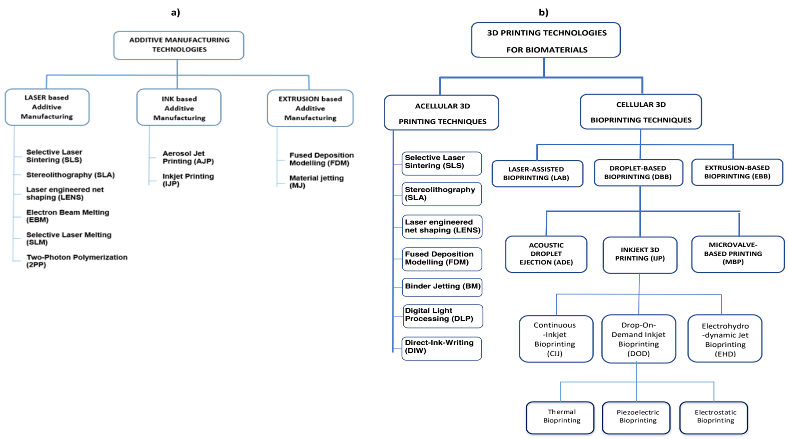

Fig.1. a) Categorization of AM technologies based on the approach used for material integration; b) Categorization of AM techniques based on the approach used for cells inclusion

As the most important one of them all is considered SLA technique that is the first rapid prototyping method developed by 3D Systems. This technique was developed by Chuck Hull in 1984 when he applied for a patent, which was granted in 1987 [4]. In addition, additive manufacturing technologies are classified into two major groups such as acellular and cellular techniques for biomaterials (see, e.g., [5]). The cellular techniques include the printing of live cells, and such methods are called 3D bioprinting technologies. The acellular ones don't include live cells during the printing process, but employ living cells in the object as a post-processing task. Accordingly, the following classification framework for these two groups of AM technologies is proposed in Figure 1b) based on existing literature (see, e.g., [6]), and our empirical investigation. As can be seen from Figure 1b), the group of bioprinting 3D technologies can be divided, similarly as AM technologies for general purposes (see Fig. 1a), into three basic types, i.e. lased based bioprinting, extrusion based bioprinting, and droplet based bioprinting. The most branched technology (on this level of classification) is droplet based bioprinting, which is extended by acoustic, and micro-valve bioprinting. Acoustic droplet ejection technique, which was developed by Xerox and IBM [7], has the advantages of improving precision and data reproducibility, reducing manufacturing costs, hands-on time, and eliminating waste. The main advantages of this bioprinting technique are the synchronized ejection of biomaterials including cells from different microvalve heads, the thin deposition layers (1–2 μm thickness), and the high throughput printing velocity (≈ 1000 droplets per second) [8]. The next and last branched inject methods of the presented classification framework are drop –on-demand techniques that eject bio ink after receiving a signal. These methods are applicable for metal, colloid, liquid resin materials, and molten polymer - polypropylene (PP6820).

4. CONCLUSIONS

Today a broad application of AM in medicine demonstrates the benefits this technology can bring to patients. There are also challenges associated with AM production of hard tissue scaffolds and these include: (1) biophysical requirements which entail mechanical properties, biodegradation properties, as well as shape and size of pores; (2) biological requirements which deal with cell attachment, growth, new tissue formation; (3) mass transport which is related to pore topology and interconnectivity is needed for nourishment of cells, exchange of nutrients and wastes, and cell migration; (4) anatomical requirements which deal with anatomical compatibility and geometric fitting; and (5) manufacturability requirements related to printability and process effects [9]. AM techniques contain many variables in their processing which have effect on final properties of the manufactured hard tissue replacements. Optimization of these processing methods is therefore important. In laser-based techniques, power of laser beams and scanning speed are the most studied specifications. In powder-based techniques, the research is oriented for the use of 3D models as templates for surgery and for in vitro and in vivo experiments, while scaffold implants in vivo are still rare. In ink-based techniques it is important to study printing speed and viscosity of ink. In spite of the limitations, increasing demand is expected for bio-additive technologies such as SLA, SLS, FDM and others, since they enable rapid fabrication of the replacements with complex geometry, good surface finishing and material heterogeneity.

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DEVELOPMENT OF DIGITAL SUPPORT TOOLS

Abstract
The exponential development of ICT technologies allows application of such solutions that make it possible to increase efficiency in enterprises. Digital technologies today serve as support tools for production and, due to their level, they are divided into technologies of digital factory, virtual factory and smart factory. In its sub-chapters, the article itself deals with the latest trends and levels in the field of digitization, such as digital factory, virtual factory and Smart Factory with their description.

1. INTRODUCTION

Process design, optimization, or validation uses tools that transfer many of the computing tasks to computing equipment. Digitalization is already a concept that has an important role to play in industrial engineering. When designing new production systems, it is envisaged to use software tools and support accessories that can achieve a certain level of digitization of processes. The development of digital technologies prompted the emergence of a digital factory (DF) at the beginning of the 21st century. Digital factory has created an environment that allows you to work with inputs to achieve optimal results. Within the application, the digital factory solved a wide range of tasks related to product, process and source. This began an era in which all the critical physical production entities were gradually represented by their digital copies, digital models, also called DMU (Digital Mock Ups). Modelling made it possible to study and analyze the efficiency and performance of production before it was put into operation [1]. The exponential development of technologies has stimulated the development of the digital factory to the next levels of virtual enterprise and smart factory.

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These support instruments will play an important role in the Factories of the Future. The article itself deals with the development and definition of these support tool.

2. DIGITAL FACTORY

It is currently a highly developed concept, based on the application of digital models, modelling and simulation, with the potential for fast, highly efficient, final product and production systems solutions [2]. A digital factory is a term used to describe the virtual image of real production and is used to plan, analyze, simulate and optimize the production of complex products. It creates conditions and directly requires teamwork in the preparation of production, while at the same time creating rapid feedback between designers, technologists, technological designers, standardators and planners [3]. The digital factory property is the ability to solve tasks related to physical objects (such as product, devices, resources) in the digital environment. It is characterized by the possibility of reusing digital models with a high degree of replication of results when setting up the correct number generator [4]. The use of DP is especially where it is necessary to respond to customer requirements in the field of product variability, short delivery times and low prices. The role of DF is to meet the requirements of manufacturers, who have to reassess their processes from the design stage to the implementation, in both directions, due to customer requirements. The possibility of detecting problems and shortcomings in production and eliminating them before production actually starts helps to reduce costs and increase profit. Support tools fall mainly from digital factory technologies. These include, for example, reverse engineering technologies, digitisation (3D laser scanning), rapid prototyping of products and production systems, and computer simulation and virtual development of products and production systems [5]. A digital factory, a real factory and a virtual factory form a new paradigm (model) and thus a new production environment that is integrated through digital data, the so-called smart factory.

3. VIRTUAL FACTORY

The production process is dynamic and generates a lot of data. In order for the model within DF to be up to date, it is necessary to carry out data upgrades. A physical factory can be understood as real ongoing processes, currently produced products and resources used. Recently, development in ICT has been particularly exponential. Currently, it is possible to apply sensors at low cost, as well as to use new means of communication and systems for virtualization of production. The idea of a virtual factory lies in the combination of model representation DF and real-time collected data Fig. 1.

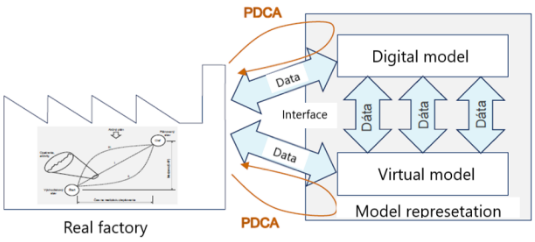

Fig. 1. Integration of the real, digital and virtual world [6]

The technological possibilities of virtual factory application are mainly due to the use of the latest ICT and sensors in the organization and management of advanced production, which has been given the designation Internet of Things (IoT). Digital data and a virtualized manufacturing environment use another new technology called Cloud Computing to realize fast computing services. These two technologies form the basis for a smart factory [7].

4. SMART FACTORY

Modern real factories, using the most advanced technologies, are referred to as Smart Factory. Smart Factory or, more broadly, smart industry is depicted on Fig. 2.

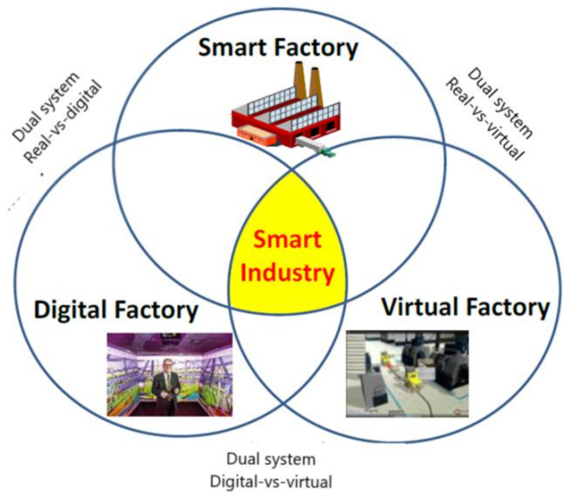

Fig. 2. Duality in the world of production [7]

According to [8] smart factory, it is necessary to ensure the integration of data collection, data and sensor printing into a single architecture so that real-time sources can be monitored and shared in the digital environment for the planning, management and support of peripheral actions. Smart Factory components according to [8] and [9] include wireless technology in factories, integration of diagnostic systems, real-time control and data collection for learning processes, location systems for mobile objects, integration of factory data management, intelligent system for transferring data upon request. Within this framework, smart factory can be considered as a system that collects real process data and creates a digital copy (Digital Twin) in the digital environment on which simulation or emulation of future states can be carried out [10]. Smart Factory, however, does not stop at the realization of the digital twin, but uses algorithms and artificial intelligence to perform data validation from historical data, analysis of relationship correlation or future status prediction, evaluates it and optimizes the real processes that take place in the company. In such an undertaking, it will be possible to find machines that can learn and carry out analyses and predictions for their own management purposes [11]. With such facilities, production will be more decentralised, equipment and resources behave autonomously, begin to interact and create complex patterns of behavior.

5. CONCLUSION

Smart Factory is still more of a dream than a reality. In the meantime, we think of it more as an ideal solution on the green field, without relation to existing production structures, existing products and today's workers. Such a generational change in production systems will certainly not be the immediate abolition of existing productions. Rather, the changes will be evolutionary and will take place gradually. Various companies are working on the development of Smart Factory, including CEIT. In their conception, Smart Factory is an extension of the Digital Factory, which extends this concept to Virtual Factory and thus creates a digital Factory Twin in a virtual environment.

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Flexible grinding, Abrasion resistant materials, Finishing

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GRINDING OF ABRASION RESISTANT LAYERS ON PRESSING TOOLS

Abstract
This paper focus is on grinding of the abrasion materials, more specifically sprayed coatings on pressing tools. These coatings are very hard and wear resistant, but also very fragile and with rough surface. For usage in pressing tools, the surface needs to be grinded to lower the roughness. But this process also needs to be technologically and economically efficient. In this paper, the main approaches for the grinding of abrasion resistant coatings are discussed.

1. INTRODUCTION

The coating on the pressing tools is applied by HFOV method, so it is in the category of thermal sprayed coatings. The layer itself is very hard, with hardness almost 60 HRC. But also, the layer is very brittle, so the base material needs to have also specific properties. The deployed layer varies in thickness and has high surface roughness. Therefore, after spraying process some of the properties of the coating are not sufficient for some application. Optimizing the tool's lifespan and easing the assembly and working process of the tool are the main reason for research and development of finishing of these surfaces.
The sprayed surface needs to be machined after the deposition, because of its properties. It is quite easy to machine flat surfaces, but more complicated tools are problem. Because the ceramic coatings are quite advanced technology, the tool manufactures does not have many tools or technologies, that can be used to manufacture this coatings. There are several methods

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that can be used to finish hard surfaces, but not all of them are suitable for the purpose. For instance, conventional grinding is too hard process that is unable to copy the shape of the surface. Rolling is unsuitable for complex components. Special methods such as laser are expensive and do not reach the required roughness.

2. APROACHES TO GRINDING OF THERMAL SPRAYED COATINGS

In this chapter are described the properties of used thermal sprayed coating and the base technologies suitable for finishing tools with the coating.

2.1 Properties of thermal sprayed layers

The thermal sprayed layer is deposited by HVOF technology (High velocity oxy fuel spraying). Advantages of HVOF sprayed coatings are mainly high density, strong adhesion to substrates, high cohesive strength and strongly limited reactions and phase transformations. Thermal sprayed coatings are excellent alternatives to hard chromium plating. The coatings provide excellent wear and corrosion resistance and can be ground and superfinished to surface finishes that are similar to chromium plating. The specific coating material applied to the tools within this paper consists of WC carbide particles in cobalt matrix. Reduction of WC particles in the coating after spraying will decrease the wear resistance of the coating. Bigger percentage of Co can increases the toughness, on the other hand it lowers the hardness and wear resistance. The addition of chromium in the metal matrix increases the corrosion resistance of this coating compared to pure WC-Co. [1]

2.2 Suitable finishing technologies

As was presented, the layer is hard to manufacture because of its properties. Also, the tools can vary in shape, but also in size. It is common, that some parts of the tool have only small thickness of underlaying material. If this material is bend during finishing, the coating can be damaged and cracked. The very high wear resistance is also the reason, why the usable technologies are limited. The main challenges when grinding thermally sprayed coatings on machining centers are the high hardness of the material, the small tool diameter, and the relatively low cutting speed. The heavy stress on the diamonds as a result of the small number of cutting grains can lead to extremely high tool wear and an insufficient surface topography.Therefore, the best suitable technologies for finishing are:

- Superfinishing/microfinishing.
- Shape adaptive grinding (SAG).
- Flexible grinding [2].

The two most suitable technologies for this operation are SAG and Flexible grinding, which will be discussed in next chapter.

3. FLEXIBLE GRINDING FOR THERMAL SPRAYED COATINGS

The main thought behind flexible grinding is, that the grinding tool has soft backing – it means, that he can copy the surface of grinded part. The coating has different thickness, so it is not flat surface. The perquisite is, that if the grinding tools would be soft, the parts of pressing tools that are higher (thicker layer) will be grinded with higher force. That also means, that technological difficult operation of CNC grinding could be left out in most parts. Such grinding tools could be special tools for milling centres (mostly must be done on demand) or sanding belts, which are one of the designs suitable for grinding flat or shaped surfaces. The belt could be placed on conventional lathe, which served well during initial tests. The workpiece can be placed on a magnetic work surface, or clamped on a work surface, which will ensure movement in the X and Y axes. The contact of the sanding belt with the workpiece will ensure a flexible contact wheel, which also serves as a drive wheel [2][3][4].

3.1 Initial experiment with grinding belt

The experiment was performed on a conventional lathe Fig. 1. Belt sander Stayer 1401EK with a flexible arm was clamped to the lathe to the tool post. Two grinding belts DA930X with 46 µm diamond grain and XK870X with 120 µm ceramic grain were tested on two shafts (No. 1 and No. 2). The cutting conditions were mostly set to speed n = 360 rpm, feed rate f = 50 mm/min and the direction of rotation of the grinder against the direction of rotation of the spindle.

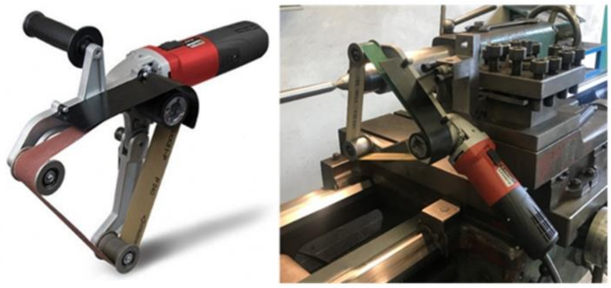

Fig. 1. Grinding belt on conventional lathe

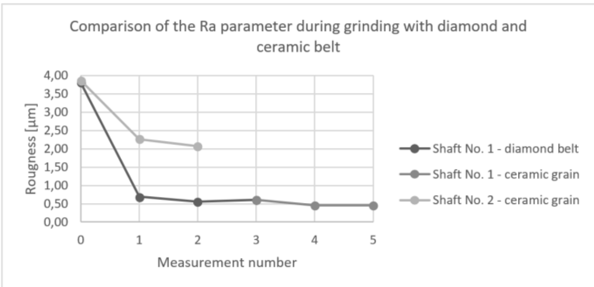

Fig. 2. Diamond and ceramic belt comparison

The graph above Fig. 2 shows roughness parameters for individual measurements. First three measurements were done after grinding with diamond belt and the rest was measured after grinding with ceramic belt. With the first diamond belt grinding on the shaft No. 1, roughness parameter significantly improved from the original value of Ra=3,80 µm to Ra=0,69 µm. It follows that very good roughness can be achieved in just one grinding with a diamond belt. Further grinding improves the roughness only slightly. The shafts have rounded shape, so it is easier to grind. In the future, other tests on more complicated parts will be held. The overall surface quality after first test was sufficient, with significantly reducing the complexity of the grinding process.

4. CONCLUSION

This paper discusses the finishing methods for thermal sprayed coatings on pressing tools. Because of the properties of the coatings, which are very wear resistant but also very brittle, conventional methods like grinding with normal tools are not sufficient, because of technical difficulties and very costly process. The key is finding such technology, that will achieve unification of surface and will reduce its roughness. Based on initial experiments, suitable technology could be flexible grinding with grinding/sanding belts or with special tools with soft backing. The results of initial test had proven, that the surface machined with this technology has good quality and parameters. In the future, more specific experiments will be held to further prove this concept.

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Gearing model, Gearbox noise, FEM, Simulation

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CREATION OF TRANSMISSION MODEL FOR FEM SIMULATION

Abstract

Effective use of simulation programs for verification of existing or required changes requires software and computer equipment, time, and experts who can adequately process the information obtained to create the model. Gear designers aim to design gears with the highest possible load capacity, but many times such design is at the expense of transmission noise. Nowadays, the aim is to reduce the noise emissions of gear mechanisms to a minimum. FEM simulations are one of the methods used for this. The first step for a successful simulation is to create a computer model of the examined gear mechanism. The paper is devoted to the problem of creating a model of gears, which serves as a basis for FEM simulations of noise and vibration in gears.

1. INTRODUCTION

Noise is one of the main problems in the automotive industry. Due to legislative pressure, the ecological aspect of car noise comes to the spotlight. This fact creates the need of identifying the sources of the noise and then to quantify them. A significant amount of noise in a car is created in the car transmissions. The most significant cause of noise is the so-called Transmission Error, which has direct relation to the kinematic accuracy and the stiffness of the gear.

Simulation is a numerical method of complex probabilistic dynamical systems by experimenting with a computer model. The rapid development of science in the field of computer technology makes it feasible to solve quite demanding engineering problems using modern methods of computation, including numerical methods of mathematics. One of the most common numerical methods is the finite element method - FEM. FEM is a method, which is used to solve a wide range of engineering problems, such as flexibility and strength problems, heat transfer topics, as well as a wide range of gear solutions. In this area, the FEM is used mainly to solve deformation and stress states in the gears of the examined gears but can also be used to solve the problem of vibrations in the gears likewise. There are many programs for solving problems using FEM, but one of the qualities for successful simulation is the most possibly accurate determination of the computer model of the studied gear.

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2. NOISE SOURCES OF GEAR TRANSMISSIONS

In a technical practice, the gearbox is defined as an acoustically closed system from which the noise is spread mainly by vibrations of the housing surface or connected units, including the basic structure. The most significant origin of noise is recognized to be the so-called Transmission Error, which is related to the kinematic accuracy of the gear and the stiffness of the gear [1].

Vibrations from gear engagement, which are then transmitted to the gearbox housing are the most significant source of noise [2, 3]. From a physical point of view, the cause of vibrations is a dynamic force that can change its amplitude, direction, or field of action. In the case of involute gearing, the most significant effect has the change of the amplitude, which causes the variable stiffness of the gearing and the stroke at the entry of the teeth into engagement due to deformations and deviations of the pitch and of the teeth profile, from the theoretical ones. By means of loading (engagement of the gears, Fig. 1), the gears roll relative to each other, and their contact is accompanied by elastic deformations. These in results in significant deviations from the theoretical profile of the tooth itself, which results in a transmission error and its subsequent excessive oscillation [4]. Another undesirable phenomenon in gearing, which negatively contributes to vibration, is pitting, or otherwise known as a fatigue of the material. It occurs by shear and pressure action on the flanks in the gearing, when various defects (pits, surface defects) appear on the surface during cyclic load. At first, the defects cause only a small vibrational component, but by gradually enlarging and growing into other parts, they contribute significantly to the increase in the amplitude of vibrations Fig.1.

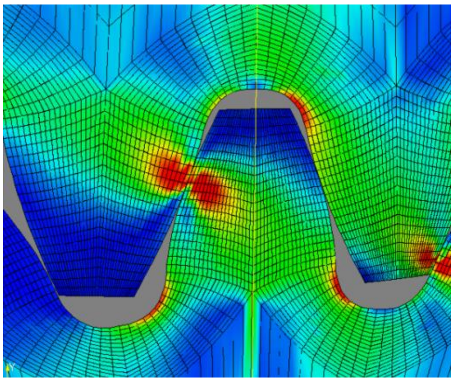

Fig. 1. FEM analysis of gear meshing of helical gearing

3. TRANSMISSION GEAR GEOMETRIC MODEL

Fastest and most accurate way for 3D gear models is to use parametric modeling. Parametric modeling is applicable to wide variety of gear models, even the ones with special shape of teeth. The main principle of this method is given by the use of parametrically defined equations, which define required curves of the soon to be model. This type of modeling creates a point cloud connected together by curves which are tangent on each other in every given

point. Result of this technique is the creation of a smooth curve or later a smooth curved surface.
Good meshing for involute shaped gearing is given by the correct involute. This involute can be created by equations (1,2) with selected parameters:

$$x = r_b \cdot (\cos(t) + t \cdot \sin(t)) \tag{1}$$

$$y = r_b \cdot (\sin(t) - t \cdot \cos(t)) \tag{2}$$

After creation of involute curve, the next step is to create a transmission curve, which creates a smooth transition from involute down to root circle. The shape of such transition curve is mostly defined by the machining process the gear wheel is put through, and this curve has also an effect on bending stress of gearing. The transition cures are either circular fillets or trochoidal fillets [5].

3.1. Face gears

For the uncommon shape of gearing such as the one in face gear wheels, modelling of the contour of face gear tooth is complicated to do directly. This is given by the special geometrical shape of the gearing. Geometry consists of two parts, work surface and transition surface [5].
For a profile of a face gear tooth, it is advised to utilize a discrete point method to produce the tooth surface. For point cloud generation, there should be used some computational software such as Matlab, because it is impossible to create a point clou in a reasonable time without it. This method can be used for any gear generation, not just face gears [6].

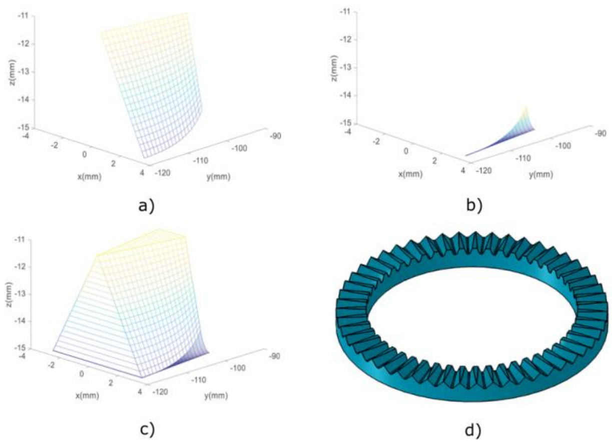

Fig. 2. Face gear creation by point cloud

Calculated point cloud is represented Fig. 2. a,b,c, where there were created two separate parts, work surface and transition surface. These two parts were then merged together which created point cloud defining and representing one tooth. Generated and represented point clouds are done in Matlab but point coordinates must be transferred to CAD software to create gear wheel. After transfer, the gear is created as a solid in CAD software, following a whole gearing and gear body.

4. Conclusion

Noise as a one of main problems studied nowadays, is also occurring to be a problem in automotive industry. In this branch, the problem is largely caused by transmission used in vehicles. But it is not only bound for automotive transmissions, but any transmission can also cause an excessive amount of noise emissions.

For successful lowering of noise and therefore ensured better design of the gears, the CAD programs are used for FEM analysis. The results of this analysis are largely influenced by the accuracy of the created 3D model. Creation of the accurate model is mostly done by parametric modeling, which ensures the accuracy of the geometry and is faster compared to other methods.

Designers have CAD programs at hand, which can also be used for better visualization and the ability to inspect a given gear, as well as the ability to modify an existing gear. Another of the advantages of accurate CAD model is that modern production machines are programed according to it.

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PLM AS A TOOL FOR DATA MANAGEMENT

Abstract
This article describes the reasons why you need to deal with data management. It also answers questions about who needs this report and especially why it needs it. Each production and management of technological units requires the creation of accompanying information that accompanies these products or equipment from the first designs to recycling. These are the production data and product information that are specified in this article. Subsequently, the tools for managing PDM product data are described, as well as their key features, as well as PLM product lifecycle management strategies with key goals and benefits.

1. INTRODUCTION

Various tools and software applications are used to create the company's business knowledge. Equally important is the fact that there is little or no interconnection between these information systems, even in areas related to product development, where information in different disciplines is processed by different applications in different formats. This fact contributes to reducing labor productivity and prolonging the time to market of products, i.e. factors that are key to the company's strategic goals. Coordinating and synchronizing information about a company's products and manufacturing processes with all related systems, assemblies, parts, and components is very challenging. It is becoming the rule that the number of workers who need access to correct, comprehensible and up-to-date information at the earliest possible stage of the product life cycle is growing. A single source of information on requirements, designs, documentation, 3D models and 2D drawings of products as parts of them would therefore allow uniform and competent decisions to be made not only by designers themselves, but also by investors and other participants in the product life cycle. Therefore, the existence and use of PDM and PLM solutions plays an increasingly important role for the existence of every company.

2. PRODUCTION DATA AND PRODUCT INFORMATION

Each production and management of technological units requires the creation of accompanying information that accompanies these products or equipment from the first designs to recycling.

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Depending on the nature and type of production, this information may be not only in paper form but also in electronic form. As communication technologies have historically developed and seep into the manufacturing and non-manufacturing spheres, the need to preserve processed paper and electronic documentation - information of a commercial, production or financial nature - has gradually developed. From this point of view, we distinguish two basic types of data, information.

2.1. Production data

By production data we mean all documentation and information necessary to produce the product and at the same time its management. These data include development, production, and technological documentation and, of course, other documents related to the introduction of products into production, on the market, about their service and the like. Using 3D design systems, digital product verification tools, simulations, we talk about hundreds to thousands of gigabytes of production data that need to be managed and backed up regularly. This is, of course, due to the size of the company, the portfolio, and the complexity of the products.

2.2. Product information

This is information that fully specifies the product. This is information that characterizes the product in detail, its parameters, price, etc. These can be various technical and data sheets, product catalogs and others. This other documentation, which is part of the product definition, is almost negligible in terms of data volume, but plays an equally important role in product lifecycle data management.

3. PRODUCT DATA MANAGEMENT (PDM)

It is a set of product data management tools that provide stand-alone or integrated tools for archiving, exchanging, and analyzing digital content. They interconnect data outputs from individual applications and enable verification of their variants, easy editing of existing documents and data in the context of the life cycle. PDM systems include tools to support the approval and assessment process. In PDM systems, data are most often analyzed and classified using user-defined attributes at the design level or the technologies used. These systems make it easier and more efficient to work with schedules, BOMs and other technical documents. PDM tools often support a variety of data formats and are directly designed to support CSCW (Computer Supported Cooperative Work) team projects.

Key features of PDM systems:

- Secure data management – address the needs and knowledge level of end-users. The PDM system should be able to understand and manage all information related to design, development and production. Users at each stage of the product lifecycle must be able to easily find and process data that is critical to their work and necessary. At the same time, the PDM system must respect the entry rights and authorization levels that protect the company's intellectual property and system security policy.
- Production process management system – enables the management of the workflow and processes that are essential for the cooperation of both internal teams and external partners throughout the product life cycle. The PDM system should ensure consistent management of

all processes through rules and best practices. Process automation then allows you to define and standardize managed workflows that can be used in many applications and product platforms.

- Configuration management system (BOMs) – allows PDM to manage product information from any source while providing it for use when needed. The PDM system should not only manage information throughout the product lifecycle, but also interconnect all its phases. The system should also allow visualization and graphical sharing of information without the need to purchase and train on specialized software. Equally important, the PDM system should provide a transparent overview of the BOMs, which includes the ability to look at the BOM before and after changes, even from different perspectives, that would be comprehensible to non-technicians.

4. PRODUCT LIFECYCLE MANAGEMENT (PLM)

The PLM (Product Data Management) solution combines both systems, procedures, and tools for solving problems directly related to the implementation of a new or innovated product, and systems, tools, and procedures for ensuring the management of its own digital content. An integral part of PLM is the direct support of economic, accounting, administrative and marketing activities. PLM solutions are significantly flexible to customer needs, which significantly affect the process. A PLM solution is not just a technology, but it is also an approach in which business processes are very important or even more important than the managed data itself. While the information is contained in all media (electronic and print), PLM is primarily about managing the digital representation of this information.

4.1. A single source of information

One of the main goals of PLM solutions is to unify the sources of information and documentation related to products into a single source and to manage this source within a unified environment. The result is then the avoidance of duplicate sources of information, the availability of the right information at the right time at a given stage of the product life cycle for all users.

4.2. Full control over company processes

One of the main reasons why companies opt for PLM solutions is that they are not able to capture and capture all the specific processes that accompany the entire product life cycle by current means so that it does not circumvent the company's defined standards and therefore does not circumvent. they can guarantee their repeated unambiguous and identical course. PLM solutions provide tools for the management of business processes, best practices within the company, in such a way that the defined company standards always coincide with the possible auditing of approval procedures for possible resolution of crisis situations, complaints, etc.

4.3. A safe and secure source of the company's know-how

PLM solution is an ideal tool for sharing corporate know-how, i.e. sharing corporate knowledge, experience within a unified environment. Thanks to this approach, companies are no longer so

dependent on the knowledge and experience of the individual and, in the event of fluctuations in top employees, they no longer take all the acquired knowledge with them. On the contrary, thanks to PLM solutions, it is still stored for other users and possibly new employees.
On the other hand, the PLM solution successfully prevents possible data theft due to its security mechanisms, such as encryption of stored data, unavailability of physical data on the data storage by ordinary users outside the PLM environment and the like. PLM solutions usually provide their own tools for backing up all data, or directly support an existing backup solution.

5. CONCLUSION

Today, more and more companies, which already have some data management, are aware that they are far from exploiting the full potential of existing solutions, and are looking for resources to implement a full-fledged solution, for example with subsidies under innovation programs, etc. Most companies suffer from a long innovation cycle, a slow response to the implementation of offers, which is of course crucial for the company's economy. Gradually, they are beginning to understand that without a change in strategy, consolidation of tools, unification of data sources into a single environment, they have no choice but to achieve these two fundamental goals, and thus increase competitiveness.

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THE FUTURE DIRECTIONS FOR CURRENT ADAPTIVE MODULAR SYSTEMS

Abstract

The article describes the future possible direction of current adaptive production systems. The basic concept presented in the article is the work of a reconfigurable production line that can be included under adaptive systems. The development of individual concepts of the reconfigurable production line is depicted using a clear time frame.

1. INTRODUCTION

The current proposal of manufacturing lines has a comprehensive structure and it is a difficult problem for many enterprises. For the design of production lines is needed to consider many options and objectives for optimal results. Therefore, there is currently an increasing need for the application of adaptive manufacturing systems, such as reconfigurable manufacturing systems. The system reconfiguration aspect can be divided based on several approaches. ElMaraghy, for example, divides this process into two types, hard (physical) and soft (logical) reconfiguration. An example of a hard reconfiguration process could be the addition/removal of a machine (module) or a change to a material handling system. The soft-reconfiguration process is achieved by reprogramming the equipment, rescheduling (or redistributing) the production, or by adding/removing manpower (or workers, work shifts). Reconfiguration can also be achieved by choosing a suitable product design, which then serves as a means to achieve it. Another approach is classification, which divides RMS into two groups: static and dynamic reconfigurable systems. Static systems are based mainly on the so-called building blocks, where another group of dynamic systems is characterized by reconfiguration using advanced robotic systems. This article focuses on the development area precisely of dynamically reconfigurable production systems, which can be generally referred to as adaptive systems or competence islands [1, 2].

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However, these reconfigurable production systems are only the initial stage of transformation. The need to develop this area will bring extensive integration of currently unrelated areas into the manufacture and thus contribute to the creation of completely currently unknown concepts of future manufacturing companies.

1. THE FIELDS OF DEVELOPMENT OF RECONFIGURABLE MANUFACTURING SYSTEMS

The description of the development of reconfigurable production systems is applied to the proposed concept of the reconfigurable production line, which was the result of the dissertation. The dissertation thesis contains a complete methodology and mathematical model for the design of a reconfigurable manufacturing system. The proposal directly describes the possibilities of using specific areas for the development of these systems. The development of the areas of the proposed concept is defined in the individual steps shown in the figure below Fig. 1.

Fig. 1. Possible routing areas for the reconfigurable manufacturing systems

2.1 Integration of reconfigurable line configuration calculations with simulation software.

The first area of research in this area could be the implementation of several advanced approaches with the software solution of the dissertation methodology. Approaches that should be implemented include a multi-agent approach. This approach would be part of the overall simulation solution, which would help to refine the values of the final line configuration design in the dissertation thesis.

2.2 Implementation of next approaches

An appropriate next step in the development of these systems would also be the implementation of a neural network approach, which, based on historical data and possible predictions of market developments, would be able to interconnect the data and make more complex decisions. The great potential of using this approach is especially in determining the suitability of the configuration in each iteration and thus extending the overall autonomy of the system. By integrating the mentioned solutions, it would be possible to create a complex system enabling the use of elements of symbiotic simulation. Such systems would be able not only to create their own configurations but also to determine the suitability of a given configuration over time based on predictions.

2.3 Connection with a real system at the level of a mirror model of production

The next step required in the next possible direction of the proposed system is therefore its connection with the real environment of the company at the level of a mirror digital model of the entire production. Current configuration design approaches cannot use an enormous amount of data, but design systems based on the platform of these approaches would be able to correctly use the necessary data for the required purposes. Another trend that will directly affect the researched area is the increasing digitization and automation of companies, with which it is possible to assume an increase in the intelligence of individual modules of the production system. A production system composed of such autonomous devices, which have their own objectives, are capable of communicating with each other, and would be controlled by a central system, will subsequently become fully autonomous.

2.4 Autonomous modular production system and future unknown systems

Research in this area can therefore reach production systems capable of predicting customer needs and making independent decisions even in the case of more complex strategic decisions. These systems can be based on copying patterns from nature and fine-grained modularity. Also, with the increasing number of modular elements of the system, an increase in its adaptability, efficiency, and also the speed of the reaction can be expected. This increasing graininess of modules and intelligence in companies is a prerequisite for the advent of nanotechnologies, but also for artificial intelligence, which will significantly change the way current production systems work. It can therefore be assumed that these future production systems will require much higher computing capacity, more specific resources, also their nature of behaviour will be the so-called. organized chaos. The production systems of the future will therefore be significantly different from the current ones.

3. CONCLUSIONS

In the past, increasing efficiency and reducing wastage times was a common practice forbusinesses today. However, companies are currently facing new challenges in the form of a turbulent market, the need to customize products as well as the growing need to robotize and digitize their production. Innovative approaches for the design, optimization, and management of new types of production, such as reconfigurable production systems, are the solution to increasing responsiveness and flexibility.
The application of new approaches, methodologies, and algorithms in the creation and management of production systems is only a partial step in creating an adaptive enterprise. An important factor is the integration of partial solutions into a complex unit enabling fast design, implementation, and prediction of the necessary changes. All these solutions should draw knowledge in almost real-time from the current course of processing and be able to make independent decisions. Therefore, it is necessary to focus on the development of new areas, such asmulti-agent systems, digital twins, symbiotic simulation, and neural networks, while only their integration can achieve the adaptive factories of the future [3, 4].

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