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Industrial Engineering, Quick Response Manufacturing, Costumer-oriented Manufacturing

Ivan ANTONIUK[1], Martin KRAJČOVIČ[2], Olha KOLESNYK[3]

PRINCIPLE OF SYSTEM DYNAMICS IN QUICK RESPONSE MANUFACTURING

Abstract
Over the past few decades, time has become a strategic factor for business competitiveness due to customers' increasing reluctance to accept long delivery time frames. At the same time, companies' flexibility and adaptability have become vital factors regarding an organization's ability to respond quickly enough to customer demands for product variety, high quality, low price and short lead times. Everything revolves around time and shortening of the lead times in the overall production process as well as in the individual processes. By focusing on the continuous production time, it is possible to influence all operating parameters. QRM is an enterprise-wide strategy that makes an organization more determined, flexible, and faster. The current QRM application requires the courage to do things differently from the ground up.

1. THE KEY PRINCIPLES OF THE QRM

Classic lean manufacturing tools have been developed to enable plants to produce more products at the required quality and price. However, Lean principles are more difficult to apply in piece and series production. Project-oriented companies often remain with only the basic tools of process stability. Where Lean doesn't work, QRM works. This philosophy can bring maximum added value and desired results in a short time. QRM perceives the variability of customer requirements as its advantage. The QRM strategy is changing the company to be able to provide excellent service and respond quickly to orders. This achieves high profitability regardless of changing demand behavior. Based on the definition of QRM, it is possible to define four main principles [1].

1.1 The power of time

Many hidden costs within a business are driven by long lead-times. Typical symptoms include excess inventories, planning difficulties, expediting costs, overtime, quality issues and so on. The result is often dissatisfied customers and a stressed workforce. By visualizing the lead-time clearly and using

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one overriding measure to drive it down, the organization will have clarity on its strategic goal and avoid confusion around conflicting objectives. The overriding measure is MCT – Manufacturing Critical path Time - the typical amount of calendar time from when a customer creates an order, through the critical path, until the first pieces of that order is delivered to the customer [2].

1.2 Correct organization structure

The traditional focus on Resource efficiency has driven a high degree of specialisation into many organizations. Lead-time can become extended as a result, due to inflexibility (e.g. specialised equipment that suffers long changeover times, or specialised personnel that can only perform a narrow range of tasks – and frequently have long queues in front of them). In fast moving production environments, the 'bottleneck' process often moves, so inflexible mass production systems are not the answer here. QRM Cells overcome this through a high degree of cross-training and autonomy, promoting flexibility for resources to move to where the workload currently is. QRM promotes Flow efficiency underpinned by additional capacity to keep the job moving, rather than holding additional inventory and applying Pull systems. [2]

Cellular organization - an organizational cell is a small and decentralized team that consists of people from different departments, who collaborate from the shared responsibility they feel for meeting the customer's demand. Instead of starting to make products because the 'boss' orders to do so, they start themselves the moment the customer's request reaches the cell. The customer's request is the key and not the orders from management. In an organizational cell the talents of employees are attuned to each other. Everybody possesses their own unique talents, and to optimally utilize them everyone in the organizational cell receives access to the available and necessary resources. They will also cross-train each other and make sure that the tasks can be performed by as many team members as possible. The role of the manager, team lead, or coordinator changes fundamentally. Ensuring that the cell can act in optimal fashion to meet the customer's request is his or her core task. Not from hierarchy, but from the shared responsibility to respond quickly and adequately to what the customer wants. [3]

1.3 System Dynamics

Lead-time is related to capacity utilization, demand variability and lot sizing. High utilization is great for Resource efficiency, but damages Flow – think about this by comparing driving along a motorway at rush hour (highly utilized), to driving along the same road in the middle of the night. The higher your utilization, the longer your queue is. Also, the higher your variation the longer your queue is. Underpinning Flow efficiency by maintaining spare capacity will help absorb variability in demand and protect lead-time reduction. System dynamics will help managers to understand the impact that utilization and variability have on lead-time, and how even a small investment in additional capacity can generate a significant lead-time improvement [3].

Imagine comparing your own organization to a motorway where all types of vehicles drive Fig. 1. If the available capacity of the road is used at 100 %, a traffic jam occurs. In that case, every piece of road is used 'optimally'. A traffic jam means delay (and annoyance). It extends the lead time of the journey. Now imagine that the available road is the available capacity of the machines in your organization. The 100 % planning of the machines has the same effect as the traffic jam on the motorway. This results in long lead times, dissatisfied customers, and stress within the organization. In short: it does not meet the customer's demand. Resolving traffic jams happens when there are fewer vehicles on the road than the available asphalt. It is no different within organizations. You do not plan to full capacity. If for example 80 % is planned, the order flow will be much better. With 20% unplanned capacity you create space to absorb setbacks [3].

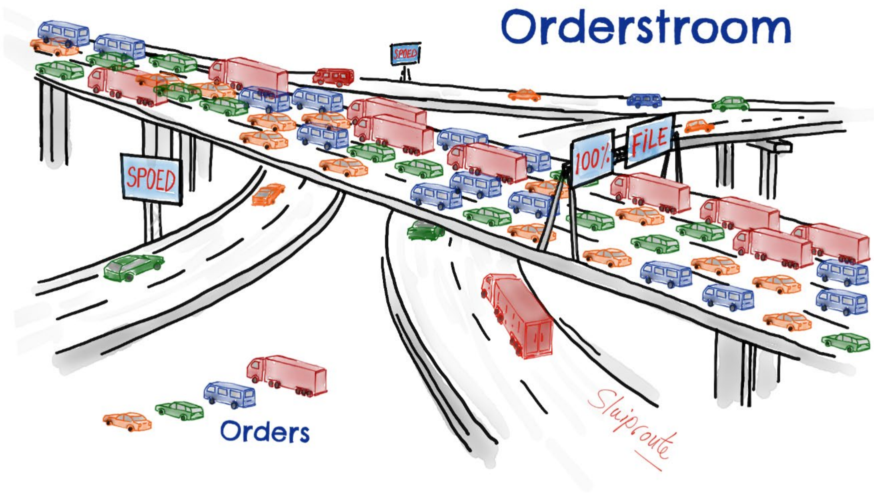

Fig. 1 Traffic as a metaphor [3]

1.4 Building a company-wide strategy

QRM is not just a shop-floor focused approach. Functions such as order processing, new product introduction, purchasing and supply chain management can all have a significant impact on the overall lead-time experienced by the customer. Office based QRM Cells can apply the same lead-time reduction philosophy to their processes to contribute to reduction in overall lead-time. As with any change management process, clarity of the goal and its benefits are essential to communicate. Remember, QRM is driven by the goal of lead-time reduction, to which all aspects of the business can contribute. Quick Response Manufacturing applies to every aspect of an organisation, is singular in its focus and simple to understand – generating competitive advantage through relentless reduction of lead-time [4].

2. EXPERIMENTAL EVALUATION OF THE SYSTEM DYNAMICS PRINCIPLE

The experiment was performed using dynamic simulation in the Tecnomatix Plant Simulation software. In the first case utilization of the line was almost 100 %. In the second case, the frequency of material input was reduced. Thus, we reduced the utilization of the line by 13 %. Table 1 shows the input data and their impact on productivity and lead time of production. So, through a simple simulation of the production line, it was found that reducing machine utilization by 15 % reduces lead time by up to 30 %.

Tab. 1 Dependence of lead time on machine utilisation

	Input frequency	Utilisation		Product	Average lead time	Production [Pcs]	Total [Pcs]
		M1	M2				
Variant 1	1:05:20	98 %	77 %	A	3:40:05	54	218
				B	3:09:39	131	
				C	4:11:55	33	
Variant 2	1:16:00	85 %	67 %	A	2:28:34	47	189
				B	2:03:48	114	
				C	3:26:04	28	

3. CONCLUSION

The cost/productivity-based mentality seems to be a major obstacle to reducing the lead time in the supply chain of the companies studied. For QRM, such a mentality may be counterproductive if a company has to compete on time and has to reduce its lead time. Market circumstances may be such that shorter lead times might make it possible to be an attractive supplier and even allow some slightly higher operational costs, as the company is more responsive to the dynamic markets of their customers. Lead time reduction is seen as a strategy that involves reduction of overhead activities, waiting time, waste, and in the end to a better market position. However, a direct focus on cost reduction and due date adherence is, according to the QRM philosophy, a root cause for problems.

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data acquisition, programmable logic controller, production line, Industry 4.0, digital twin

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REALIZING DATA COLLECTION FOR PRODUCTION LINE DIGITAL TWIN

Abstract
The aim of this paper is to present data collection from real production line for Digital Twin (DT). The research was carried out in production plant focused on automotive industry in Slovakia. Proposed production line used for creation of DT consists from CNC machines, robotic arm, conveyors, buffers, and measuring/ piercing station. The final goal of DT is to support existing production line with comprehensive data evaluation to enhance overall equipment effectiveness of machines within automotive industry.

1. INTRODUCTION

The industrial sector is transforming into a fourth stage with the growth of advanced automation, Cyber-physical systems, the Internet of Things, the Internet of Services, Cloud computing, etc. Industries are becoming more productive, flexible, versatile, safer, and more cooperative. Intelligent factories, which will be at the heart of Industry 4.0, will take on the development of information and communication technologies, bringing much higher levels of automation and digitization which is essential to create a business that can respond quickly and flexibly to market conditions to gain a competitive advantage [1,2]. Customer requirements and the impact of competition place increasing demands on businesses that are forced to constantly innovate and improve their processes. The impact of global manufacturing trends and the emergence of new supporting technologies in automation, digitization and information technology make it an ideal time to incorporate digital factory strategies into the company structures to digitally transform production processes. Using the tools of a digital factory, the company can build a virtual operation that is linked to real production in real time, with can lead to the creation of so-called digital twin. With the help of a digital twin, the company can gain operational and strategic advantage and outperform competition. DT specifically finds expression through five enabling components, sensors and actuators from the physical world, integration, data, and analytics - as well as the continuously updated digital twin application [3].

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The paper deals with creation of linkage between physical and virtual production line and data collecting for production line DT. Programmable logic controllers (PLC) and sensors were used for data collection. Data from PLC and sensors are stored in SQL database with subsequent integration and connection of simulation digital model in Tecnomatix Plant Simulation (TPS) software with SQL database.

2. MATERIALS AND METHODS

The first goal of our research was to create simulation digital model of production line. Therefore, TPS simulation software from Siemens was chosen to perform out the research. Second goal was to implement real data from real production line into digital simulation model via PLC, sensors, and SQL database.
TPS is currently leading simulation software from Siemens PLM tools that allows companies to simulate and optimize production systems and processes. With simulation, it is possible to optimize material flow, resource utilization and logistics. Simulation helps to create digital models of manufacturing systems to explore system features and optimize their performance. The digital model allows users to run experiments without disrupting the existing manufacturing system. Extensive analysis tools, and graphs allow users to evaluate different production scenarios and make quick and reliable decisions [4].
Main advantage of TPS software is possibility to simulate production systems and management strategies. Production processes in TPS are object-oriented. TPS provides simple parameterization of objects, use of application object library for fast and efficient modeling of typical scenarios and the possibility of modeling and saving partial tasks in structured and hierarchical interactive environment. The biggest benefit of TPS software is to analyze resources and bottlenecks using graphs and diagrams especially Sankey diagram and Gantt charts, which are used to analyze bottlenecks in production. 2D simulation can be transformed into 3D simulation with visualization possibility to better understand processes. Programming methods in the SimTalk programming language can be used to specify behavior of production systems with aid of debugger function for digital model enhancing by random number generator to bring model function closer to reality. Open integration with external software provides comprehensive data transfer between various software and databases [4].
The PLC receives information from connected sensors or input devices, processes the data and triggers outputs based on pre-programmed parameters. Depending on the inputs and outputs, the PLC can monitor and record operating time data [5,6]. Data collection for simulation is realized by PLC and Echocollect device which is an industrial multiprotocol gateway that provides a modern solution for further processing of process data [7]. Individual data are stored in tables in SQL database, which are then converted into tables for TPS needs.
The simulation was preceded by the analysis of the current state of production line. Production line consists from two CNC machines, robotic arm, output conveyor for OK products, output conveyor for Not OK products, input conveyor, 3 buffers for each CNC and measuring/ piercing station. The production line is fully automated and is used for machining of engine block castings. The robot operates all production machines.

3. RESULTS

The aim of our research is to create digital simulation model of real production line and data integration via SQL database. For actual data collection, it was necessary to identify the individual data collection points for the simulation. Based on production line behavior analysis, collection points listed below were selected. Index A represent input/ load of workpiece and index B represents output/ unload of workpiece.

111A	Position 1 in CNC1
111B	Position 1 in CNC1
112A	Position 2 in CNC1
112B	Position 2 in CNC1
121A	Position 1 in CNC2
121B	Position 1 in CNC2
122A	Position 2 in CNC2
122B	Position 2 in CNC2
211A	Position 1 buffer CNC1
211B	Position 1 buffer CNC1
212A	Position 2 buffer CNC1
212B	Position 2 buffer CNC1
213A	Position 3 buffer CNC1
213B	Position 3 buffer CNC1
221A	Position 1 buffer CNC2
221B	Position 1 buffer CNC2
222A	Position 2 buffer CNC2
222B	Position 2 buffer CNC2
223A	Position 3 buffer CNC2
223B	Position 3 buffer CNC2
301A	Measurement station
301B	Measurement station
401A	Piercing station
401B	Piercing station
511A	Input conveyor
511B	Input conveyor
512A	OK conveyor
513A	Not OK conveyor
514B	Inspection input

Digital simulation model was created in TPS software with logical connections of individual machines. Operations are programmed via source code written in the SimTalk programming language. To verify and validate the simulation's compliance with the real production line, the simulation was performed without real production data to test the correct logical sequence of operations. The simulation was compared with a real production line to validate and verify the simulation and to achieve 100% simulation compliance with the real production line.
The simulation model of production line for engine block castings consisting from CNC machines, robotic arm, conveyors, buffers, and measuring/ piercing station.
Data collection for simulation was realized by PLC and Echocollect device. Individual data are stored in SQL database. SQL database is implemented into simulation through ODBC interface with written source codes to link collected data signals with machines in virtual world based on real machines to copy behavior in real production line.
The total number of data implemented in the simulation is 8043 rows for one production day, recorded in the table containing the signal sequence number (Sstring), time of signal occurrence (Time String), processing time for each operation, position of robot, data collection point description, connection of each signal to its corresponding device in the simulation and total manufacturing time.

4. CONCLUSION

Digital twin is designed to receive inputs from sensors to collect data from real world machines. This allows DT to simulate a physical object in real time, while providing information on performance and potential problems. A digital twin can be both complex and simple, depending on the needs of the company. The amount of data used to create and update digital twin determines how accurately and in detail is the physical object simulated.
Our research shows that with the aid of Industry 4.0 principles and technologies it is possible to create digital simulation model with subsequent data collection and integration from real production line into virtual world which leads to creation of DT.

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Innovation, Costs, Cost calculation, Model for evaluating innovation

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EVALUATION OF INNOVATIVE PROJECTS

Abstract
Currently, there is a trend to talk a lot about innovation. There is talk of product innovation, technical solutions, usable technologies, methods and tools and how they can be improved. The article talks about monitoring and managing costs in creating an innovative product and model for determining the return on investment in a given product.

1. INTRODUCTION

The task of innovation is to create and market new products and services that meet the growing demands of customers for product functions, its variability, efficiency, economy, quality, reliability, durability, operation, design, but also environmental characteristics. However, the introduction of innovations into companies also has the opposite side, high capital is needed for implementation in production, training of employees, change of the company's layout and, last but not least, the total cost of the innovation life cycle. It is precisely for the latter reason that it is necessary to monitor and manage costs. Good cost management is a condition for a stable position of the company on the market and achieving positive economic results. The current development of the economic environment is undergoing changes that are reflected in the change in the cost structure, in particular the increase in the share of costs for the purchase of new machinery and equipment, the implementation of new software solutions and the cost of their operation. The article offers an insight into the solution of cost tracking in the creation of an innovative product and thus is a model for the valuation of an innovative product. This model is suitable for creating product innovation, whether it is a generational or tribal change. It considers all costs associated with the development of an innovative product. When purchasing machines, equipment, software or hardware, it also considers the costs for the entire lifetime of the machine. It is suitable for companies that want to expand their portfolio with new products, but also for investment companies that want to finance such expansion.

2. MODEL FOR VALUATION OF INNOVATIVE PROJECTS

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The model consists of seven steps, which aim to describe the cost structure in as much detail as possible. The result of the model will be the total cost of preparing the innovation as well as the return on investment for the project. Fig. 1 is a basic diagram of the proposed model, which represents a simplified representation.

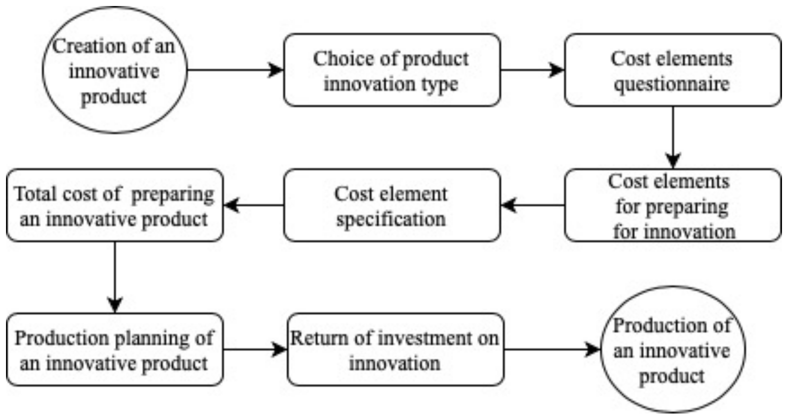

Fig.1. Basic scheme of the model (Author)

2.1 Choice of product innovation type

The first step of the model for valuing innovation projects is to correctly determine the type of innovation. For this purpose, Valent's innovation spectrum is chosen, which divides the level of technological progress according to the innovation stages. By the degree of innovation, we classify the level of change of the current state with respect to the past state or with respect to the planned state [1,2].

The innovation spectrum consists of eight stages. Only four stages will be used in a given model. This is because the model for valuing innovative projects is a suitable priority for product innovation. The employee who will work with the model will choose the right level of innovation based on the content of the innovation change and illustrative examples.

Based on the idea of an innovative product, one of the innovative stages is selected. Following the selection of the innovation stage, the system goes to the cost element questionnaire.

2.2 Cost elements questionnaire

The cost elements questionnaire is needed to correctly identify cost elements and costs when creating an innovative product. To properly monitor cost types and costs, the creation of an innovative product is divided into eight steps to prepare for innovation. Questionnaires are also compiled on the basis of these steps. Questionnaires for determining cost elements differ from each other based on the choice of innovation level. Depending on the degree of innovation, the cost groups needed to create an innovative product also change.

2.3 Cost elements for preparing for innovation

The matrix of cost elements for the preparation of product innovation is the result of a questionnaire, which was created based on the need for information on the costs incurred. The matrix contains the procedure for preparing the innovation and the cost elements for each of the steps. It graphically shows the cost types that will be present in a given step when creating an innovative product. Fig. 2 shows the filled matrix.

		Product preparation costs								
		Cost groups								
		labor costs	hardware	software	energy costs	outsourcing	machines and equipment	material costs	other costs	licensing costs
Product preparation procedure	1. Innovative idea	X				X				
	2. Product concept	X	X	X	X	X			X	
	3. Testing concept	X	X	X	X	X			X	
	4. Elaboration of the protocol	X	X		X	X				X
	5. Product prototypes	X	X	X	X	X	X	X		
	6. Prototypes testing	X	X	X	X	X	X			
	7. Pilot products	X	X	X	X		X	X		
	8. Mass production	X	X	X	X	X	X	X	X	X

Fig.2. The matrix of cost elements (Author)

2.3.1 Cost elements specification

Cost elements need to be specified for their more detailed breakdown. After the breakdown, it is determined whether these are costs incurred on the enterprise or those incurred outside the enterprise. Based on this determination, the method of calculating the given costs is also determined.

If we talk about the cost types arising in the company, the vast majority are energy costs (water, gas, electricity, ...), labor costs or the cost of various types of licenses needed to introduce a new product into production. When calculating costs, the company can use the calculation it has used so far for these cost elements. But the model also provides a suitable calculation for a given type of cost.

By cost types arising outside the company we mean mainly the costs of purchasing machines and equipment, software, hardware, materials, outsourcing and other costs. These are cost elements that are supplied by business partners. Quotations can vary considerably from one supplier to another cost element, so they need to be assessed on the basis of the TCO calculator created for this type of cost. There can be several TCO calculators in the whole models, depending on the need for purchase in individual phases of creating an innovative process.

2.3.2 Total cost of preparing an innovative product

The result of a detailed evaluation is the total cost of preparing an innovative product. Based on the specification of costs and the methodology of innovation preparation, we can find out at any time in which part of the preparation what costs arise, their specific amount as well as the cause of their occurrence.

The total costs are calculated as the sum of the costs incurred outside the enterprise and the sum of the costs incurred inside the enterprise. If the user wants, he can end up using the model in a given step, and the result is an evaluation of the costs of preparing an innovative product. Continuation is followed by production planning and calculation of return on investment.

2.3.3 Production planning of an innovative product

Planning the production of an innovative product is necessary at this stage if the company wants to determine the return on investment in innovation. For planning the production of an innovative product, forecasting is used in the models at all stages of innovation except gender. In gender innovation, forecasting cannot be used due to the absence of values. Therefore, market research will be used to obtain data when generating gender innovation. Subsequently, the production of an innovative product is planned using aggregate planning.

2.3.4 Return on investment on innovation

When calculating the return on investment of the proposed model, we decided to use the method of return on investment, as it best shows the time return (in months, years, ...) of the funds used. The result of the whole model is therefore a return on investment, which is necessary for deciding whether to create a given innovation.

3. CONCLUSION

Competitive advantage can result from many factors of the company such as its size, ownership of certain assets, investments, innovations, etc. - in practice, however, a model is increasingly being applied which favors companies capable of mobilizing their knowledge, technological knowledge and experience. Such companies can create something new in the offer of their products or services, or in the way they supply their products to the market. [3]
New products help maintain market shares and increase profitability in given markets. Given the ever-shortening life cycle of products, the ability to frequently replace products with improved versions is becoming increasingly important.
The article describes a model for valuing innovative projects and products. The result of this model can be the total cost of preparing an innovative product or the return on investment in a given innovation. The model considers the degree of innovation and the associated costs during all eight steps needed to create the innovation. The model is suitable for companies that want to invest funds in the creation of innovative products but also for investment companies.

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TWI program, on-the-job training, Job Instruction, job instruction breakdown sheet, Job Methods, Job Relations

Maria BARON-PUDA[1], Karolina MAJDAK[2]

ON-THE-JOB TRAINING FOR PRODUCTION WORKPLACES ACCORDING TO TWI METHODOLOGY

Abstract
The main functions of personnel management are: to attract the best candidates, retain them, and motivate to be innovative and more efficient. In motivation system aimed at performing these functions, it is important to provide employees with opportunities to train and develop, as well as to influence production processes and work methods. These opportunities appear already at the stage of introducing employees to jobs. The article presents the TWI program as a valuable tool in training and people development.

1. INTRODUCTION

The effectiveness of personnel management processes begins with the recruitment of "the right people to the right places". However, the choice of a candidate meeting well the job requirements does not end this stage. Next, it is very important to introduce properly new employees to work and train them continuously. The induction process, including on-the-job training is crucial for worker's future efficiency. Employee motivation, performance and commitment to improving processes, methods and products, will largely depend on how this process goes and how much time is spent on it. A well-prepared on-the-job training may bring many benefits, both for the organization and for the employee. The aim of the article is to present these benefits and show activities essential for successful on-the-job training for production workplaces.

2. TRAINING WITH INDUSTRY PROGRAM

Training Within Industry (TWI) is a program for developing key managerial skills of supervisors (e.g. foremen, leaders). It was created by the USA government during World War II to increase wartime production [2]. Its purpose was to quickly introduce to production unskilled persons (like woman and youth). After the war, USA exported the TWI methodology in Japan to rebuild industrial infrastructure. It was adopted in many Japanese companies, including Toyota. The TWI became the core of Toyota Production System. Currently, it is a part of Lean Management tools used worldwide to standardize the training of workers [8, 10].

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Effectiveness of TWI program has been proved over a number of years, in particular in Japanese industry. Companies, such as Toyota or Sanyo, have used TWI program as a foundation to develop their effective production methods, as well as management values and principles [4]. Training according to the TWI methodology is widely used in almost every sector of industry, and is recognized all over the world. In addition to production, it is also used in other areas, such as government, services, and health care [3, 10, 11].

3. COMPONENTS AND ASSUMPTIONS OF TWI

TWI program consists of three interrelated modules: Job Instruction (JI), Job Methods (JM), and Job Relations (JR). It is also called the three "J" program [8].

TWI Job Instruction

The aim of this method is to teach people to quickly remember to do a job correctly, safely and consciously [4]. TWI JI joins the job standards with the practice on the shop floor. It teaches the technique of work to ensure that people perform a task exactly the way it should be done to get consistently good results [1]. To instruct employees, it is necessary that the trainer (supervisor) follows four steps [5, 7]:

Step 1 – Prepare a trainee: The aim is to create a positive social atmosphere during the training, as well as provide the right place and the necessary resources of training.

Step 2 – Present the work: Demonstration is at least three times. With each subsequent presentation, more and more details are added – first the trainer explains what is done (major steps), then how it is done (key points), and finally why it is done this way (reasons for key points). All these elements make the training more complete and effective than using traditional training methods.

Step 3 – Try out performance: The aim is to let the learner to practise and to correct mistakes, if necessary. The trainee repeats the work at least four times – first only showing, then discussing what, how and why is doing.

Step 4 – Follow Up: The supervisor checks on the employee to make sure that he is able to do the job. The frequency of supervision decreases as employee's experience grows.

TWI Job Methods

The TWI JM is used to breakdown a job into small pieces and question everything involved in it in order to develop a new or improved working method [8]. Ideas for a better way to do work should come from employees closely involved in the work process [9]. Examples of ways to improve work are: eliminating, combining, reorganizing, and simplifying.

TWI Job Relations

The manager's role is to encourage employees to fulfil their duties leading to organization's goals achievement. During the work, specific relationships are created between the supervisor and his subordinates. The work results depend on whether these relations are good or bad. Ways to get good relationships with employees can be [9]:

- Provide employees with information about how they do their job (feedback).
- Recognition and praise for good job performance.
- Inform employees about changes that affect them, to eliminate people's concerns.
- Make the best use of employees' skills and talents.

The above three TWI modules are interrelated. Good interpersonal relations (JR) are the foundation of efficient management. They make training process easier and more effective (JI). Well-trained employees know what, how and why they are doing. This awareness enables them to improve the working methods (JM). Developed new methods (new standards) require employees to be retrained (JI) so that they can learn changes, understand them and look for further improvements (JM).

4. EXAMPLE OF JOB INSTRUCTION BREAKDOWN SHEET

There is an assembly station in a medium-sized company. The work is manual and consists in assembling guide rollers (for sliding gates. In order to prepare the training according to TWI JI assumptions, the job breakdown sheets should be developed for particular operations. Each sheet should describe the main steps, key points and reasons for key points – thus clearly presents "the best method of doing a job known today". An example JI sheet is presented in Tab. 1. Guide roller □33 with angle bracket for the sliding gate shows Fig.1.

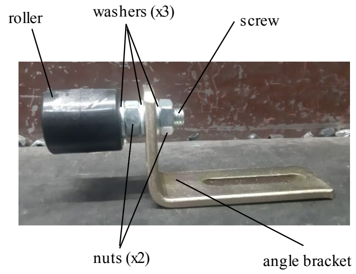

Fig.1. Guide roller ∅33 with angle bracket for the sliding gate

Tab. 1. An example of job breakdown sheet for training purpose

Job Instruction Breakdown Sheet	
Operation	Assembly of guide roller
Components	RB-33 roller, mounting screw M10, metal bracket h=90mm, three flat washers M12, two nuts M10
Tools	Combination wrench

No.	MAJOR STEPS (What?)	KEY POINTS (How?)	REASONS (Why?)
1.	Put the roller on the screw	The screw head is hidden inside the roller	Necessary to assemble properly other elements
2.	Slide the first washer	Place one washer between your thumb and the forefinger and put the hole on the screw shank	To save time and avoid wasted motions during assembly
3.	Put on the first nut	Perpendicularly to the longitudinal axis of the screw shank	To get proper connection
4.	Tighten the nut	By hand and not too tightly	The roller should turn smoothly and freely
5.	Slide the second washer	Place one washer between your thumb and the forefinger and put the hole on the screw shank	To save time and avoid wasted motions during assembly
6.	Put on the angle bracket	Match in with the hole in the shorter arm	To assembly properly
7.	Slide the third washer	Place one washer between your thumb and the forefinger and put the hole on the screw shank	To save time and avoid wasted motions during assembly
8.	Put on the second nut	Perpendicularly to the longitudinal axis of the screw shank	To get proper connection
9.	Tighten the nut	Using the wrench tighten the nut up to the stop	In this way, the guide roller will works correctly

5. CONCLUSION

Job Instruction four-step method is a basic tool for successful on-the-job training. Compared to traditional methods, it brings numerous benefits for both employees and the company. TWI training method is well perceived by employees. Work broken down into smaller sections is much easier for them to learn. Employees feel safer because they know to whom they can turn with any problem or uncertainty. When people understand working methods, it is easier for them to look for improvements in their work, and this gives them real opportunities to influence existing processes.
From viewpoint of a company, the results of the TWI JP are visible in:

- Reduced training time for new employees.
- Increased work efficiency.
- Repeatable work results.
- Fewer scraps.
- Improved quality of processes and product.
- Lower employee turnover.
- Reduced production costs.

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Ergonomics, Office workplace, Safety, and health

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ERGONOMIC ASPECTS OF OFFICE WORK

Abstract
A human was created for movement, but as work progresses, a man stops moving. Most of the work activities that are needed to operate a society are concentrated in the offices. This article deals with safety and ergonomics in office workplaces. The factors that affect a worker during office work are as specific as in any other workplace. However, their impact is often hidden, and their consequences often appear only after a long time.

1. INTRODUCTION

Ergonomics is an essential part of the process of ensuring safety and health at work and vice versa – health and safety at work is an essential part of ergonomics Fig. 1. The common denominator of these scientific areas is human. Wherever a human performs a work activity, ergonomic principles and safety of the work performed must be implemented. It is no different when looking at the office workplace [1].

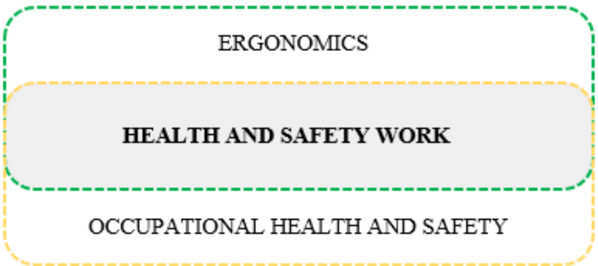

Fig.1. Relationship between Ergonomics and Occupational health and safety [authors]

At the turn of 2018 and 2019, a survey of the most frequently registered professions in Slovakia was carried out at the Department of Industrial Engineering in Žilina, focusing on the number

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of sedentary professions. In parallel with this survey, the representation of sedentary professions within the selected automotive manufacturing company was also investigated. These surveys showed that up to 60 % of the most frequently registered professions in Slovakia are sedentary; in the firm concerned sedentary profession in the office took 78 % of all the professions represented [1,2].

2. IMPACTS ON WORKER DURING OFFICE WORK

It might seem that work in the office does not pose a significant threat to safety. In an office workplace, factors affecting humans increase the risk of health problems as well as in other workplaces. Factors affecting a man at work in the office can be divided into four primary areas:

- Personal characteristics (anatomy, motivation, working habits, etc.).
- Workplace (computer, desk, work chair, computer monitor, etc.).
- Work activity (working position, duration, frequency of movements, etc.).
- Work environment (lighting, temperature, noise, etc.).

The main office activities include sitting in front of the computer and operating it by typing or moving the mouse. While these activities are not particularly dangerous for a worker who does them occasionally, the situation becomes more critical when done daily for a long time. Sitting posture has been identified as one the worst position of the body that exists, forcing the spine to assume an unnatural posture that adversely affects it. This statement is supported by the fact that, when the hips rotate, more pressure is exerted on the spine when bending the torso, which can lead to back pain in the long term [3]. On the other hand, the working position in an upright sitting position is, according to the legislation of the Slovak Republic, defined as an acceptable position. It is characterized by the following characteristics [4]:

- Less energy expenditure.
- Less fatigue.
- Less stress on the lower limbs and lower back.
- Places less strain on the circulatory system, especially the heart.
- Enables greater stability and more accurate performance of tasks with fine coordination compared to standing position.

The current problem of modern office workplaces is the visual load caused by reflections of light from windows and artificial light sources from computer screens. Another negative phenomenon is the emergence of low-level noise in offices organized by open space. Long-term work in such areas creates an accumulation of hearing load, which causes irritation and reduces the ability to concentrate and thus work performance [4].

3. THE IMPACT OF INDIVIDUAL ELEMENTS OF OFFICE WORPLACE ON THE WORKER'S HEALTH

Deficiencies in equipment, the layout of a workstation with a computer or installing the computer and its attachments, as well as organizing work, increase physical and mental stress. In addition to discomfort, there is a gradual deterioration of the health of the employee, which, in particular connection with the wrong lifestyle, can manifest itself as diseases of the musculoskeletal system (MSD) – diseases of muscles, cervical and shank parts of the spine and chronic shoulder and arm pain. The table below Tab. 1 shows the elements of the office work system shown in Figure 1, which affect office workers. Individual elements are assigned the consequences that may arise if risks are not eliminated.

Tab. 1 System elements and their impact on worker’s health at office workplace

Factor area	Factor (System element)	Impact on health	Consequences
Workplace	Computer		May cause electric shock or mechanical contact stress
	Computer mousse		Carpal tunnel syndrome, wrist tendonitis, De Quervain syndrome
	Computer monitor		Eye strain, headache, cervical spine pain
	Desk		Incorrect table height adjustment causes awkward postures → MSD
	Work chair		Lower back pain, cervical spine pain, muscle spasms, poor blood circulation in the legs, etc.
Work environment	Lightning		Eye strain, impaired metabolism
	Light reflections		Eye strain, headache
	Air conditions		Spread of allergens and diseases
	Humidity		Breathing problems
	Temperature		Lower efficiency, higher energy expenditure
	Noise		Hearing problems, nervousness, cardiovascular problems, headache, etc.
Work activity	Working position		Musculoskeletal diseases or Cumulative trauma diseases
	Frequency of movements		Cumulative trauma diseases
	Duration		Musculoskeletal diseases or Cumulative trauma diseases
	Work organization		Stress and diseases caused by it.
	Mental difficulties		Stress and diseases caused by it
	Time demands		Stress and diseases caused by it
	Recovery time		MSDs, CTD, stress and diseases caused by it.

The impact degree of individual elements on the employee´s health was determined based on the severity of the consequences and their occurrence within the registered occupational diseases. All mentioned factors or system elements and their impact on the human organism are also influenced by personal predispositions of a worker [5].
As can be seen in the table, the higher negative impact on the employee´s health has workplace elements that are directly used by worker - chair, desk, computer mouse or computer monitor. The use of this equipment is directly related to working posture and frequency of movements. During prolonged sitting in an awkward or non-physiological posture caused by a chair and a desk, the human body is exposed to a static load which causes most musculoskeletal diseases

among office workers. Another risk factor is the frequency of movements and a moderate amount of force which is applied repetitively to small muscles. These factors may result in ligament strains, swelling or fatigue. The most frequent disease, in this case, is carpal tunnel syndrome which belongs to the group of tendon diseases from long-term unilateral overload; these diseases accounted for 47.7 % of the total number of newly admitted occupational diseases in 2018 [6].

4. CONCLUSION

The risks that may arise in the manufacturing area in manual operations are now well mapped, and there are effective tools to prevent them from occurring. The area that ergonomics focuses only on secondary is the area of sedentary work. More than half of the most frequently registered professions in Slovakia are sedentary. Due to the long-term sitting and daily use of the computer, the static load accumulates, and thus the work-related diseases of the musculoskeletal system occur. The main risk factors of the office work are long term sitting, non-physiological postures, mechanical contact stress, static load, and high repetition of unilateral movements. In the long term, they cause the static load to accumulate on individual parts of the skeletal-muscular apparatus. This accumulation consequently causes pain or the onset of the diseases. The further direction of sedentary research and a new challenge for ergonomics is to develop an intelligent adaptive dynamic workplace. This workplace will adapt autonomously to its user without its intervention and ensures an active change of working position based on predefined time intervals.

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Controlling, Costs management, Profit

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DESIGN OF A COST CONTROL SYSTEM IN SELECTED ENTERPRISES

Abstract
The paper deals with the design of a cost control system and evaluation of the benefits of the proposed solution. The analysis was performed in two engineering micro-enterprises that do not currently have a cost control system in place. The proposed system is used to record, categorize and manage costs in the selected company. This cost control system brings the company clarity in cost items and the subsequent ability to control and influence the item. The established cost control system ultimately brings the company a profit.

1. INTRODUCTION

Controlling is currently an area that needs to be addressed in every manufacturing and non-manufacturing enterprise, as it is an important part of the economic information system. Knowing this topic and at the same time being able to apply it to business can be a great benefit for any company. Controlling is generally known as a result-oriented business management system. This means that this system is future-oriented and does everything to achieve the result. Currently, the business trend is very fast and controlling knows how to direct the company to the set goals. Controlling uses tools such as financial analysis, financial planning support, working capital controlling, ongoing liquidity controlling, cost controlling and financial control. The proposed cost control system should also be used in practice. The cost control system is designed as the first stage, which emphasizes the interconnection of accounting and the use of its function, which is the registration of the achieved fact. Therefore, emphasis is also placed on its quality. A business can be competitive if it handles costs effectively. The proposed system should bring clarity in costs without burdening the company with additional costs. The first of the processes within the knowledge area is called Plan Cost Management Fig. 1. It involves the production of a cost management plan, which is a component of the overall project management plan. This document describes how the project costs will be planned, structured,

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and controlled. It can feature elements such as the level of accuracy and precision, control thresholds, and rules of performance measurement for earned value management.

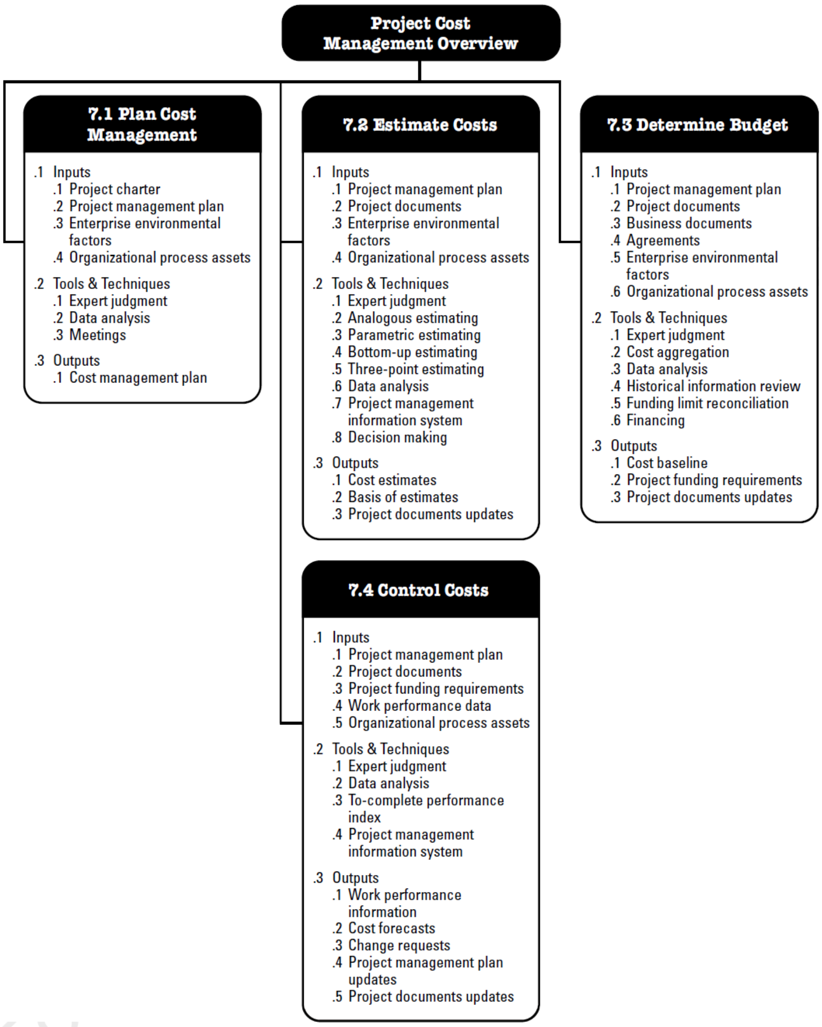

Fig. 1 Project cost management overview

2. DESIGN OF A COST CONTROL SYSTEM IN SELECTED ENTERPRISES

The first-level cost control system must be linked to financial accounting. All cost items must be clearly recorded and categorized so that they can be subsequently controlled and influenced. The system must meet these requirements and thus contribute to the efficient and effective management of costs, which will ultimately bring profit to the company.

2.1 Registration system

Evidence is an important activity for the proposed cost control system. It connects the external environment with the internal one, ie it records the external costs that enter the company. This step includes the processing of received invoices and input blocks. The costs that enter the company are in the form of cash blocks or received invoices that contain information about the subject of the cost item. Records of these documents will be used to evaluate suppliers and cost items. This cost group is external costs.

All necessary data such as date of delivery, own invoice number, supplier's name, subject of the invoice amount can be assigned to the invoices registered in this sheet. It is possible to categorize an invoice by cost type and assign it to fixed or variable costs.

2.2 Sales volume

An important indicator of in-house controlling is the volume of production, on the basis of which it is possible to quantify the importance of certain products.

2.3 Comparison and control system

The next step in a comprehensive solution of the first-level controlling system is the control and comparison of cost items and the profitability of specific products. Several sheets were compiled for this purpose.

2.4 Influencing system

The amount of external costs is also affected by a number of factors such as - location of suppliers, mode of transport, supplier-customer relations. However, to a significant extent, the purchase price has the opportunity to influence the ability of the person responsible for obtaining the best price offers from suppliers. The advantage of the order brings lower costs for the company. From the point of view of controlling, it is necessary to know future costs in time so that we can reduce them before entering the company. It is therefore necessary to set up a system for obtaining quotations appropriately.

3. CONCLUSION

Controlling is a tool through which companies gain a competitive advantage. Controlling in a micro-enterprise also takes on various competencies that shape the company's competitive advantages. These can also include information or consulting competencies. For the selected company 2, the first level of controlling was proposed, which is connected with accounting and with the use of its function of recording the achieved fact. The main task of controlling is therefore to facilitate the decision-making process on the basis of accounting outputs. Based on an analysis of the past, controlling proposes measures to achieve the set goals of the company. The proposed system includes:

- Link to financial accounting.
- Registration and categorization of costs.
- Numerical expression of unit costs.
- Influencing and controlling costs.

The system was designed so that it did not burden the company, but ultimately benefited the company. The system serves the company to help it manage costs, control them and influence them, because costs are an important indicator of the company's performance and significantly affect its operation. The more cost-effective it can be, the more competitive a business can be. Subsequently, it is ready to meet the needs of the selected micro-enterprise. Of course, the effectiveness of this system requires the training of the person responsible for performing the work with the data. Effective use of the proposed cost control system requires the cooperation of the responsible person and the accounting firm.

Quantifiable benefits cannot be estimated or assumed at this time. However, the cost control system should primarily lead to improved business management, cost reduction, ie increased profits. Costs are a significant aspect that affects this economy.

The better the company manages its costs, the more competitive the company becomes. The proposed solution, which is a cost control system for a selected company, significantly contributes to improving the record of business costs. Subsequent classification of costs according to the volume of production, allows clarity of drawing costs for individual products (products and services). The system enables the transparency of suppliers on the basis of criteria such as meeting the delivery deadline. Cost prices affect the final price of products, with the help of this system it is possible to monitor the development of costs, control them and subsequently influence.

By monitoring the cost per unit of calculation, which is the product, we can use the system to quantify the profitability and development of product prices. Using the proposed system, the company can more efficiently design price offers for potential customers. It is possible to assume that after the launch of the proposed system in the company, it will be necessary to make any changes to the system itself, but subsequently also to business processes. Due to the fact that it is built on the MS excel program, the system is variable according to the needs of the company.

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Computer Simulation, Workers, Experiments

Monika BUČKOVÁ[1,] Miroslav FUSKO[2], Milan MARTINKOVIČ[3]

COMPUTER SIMULATION AND WORKERS

Abstract

This article provides necessary information about the simulation of the work of workers in manufacturing, in the company. Then there is a description of types of data that is necessary to collect for the creation of a simulation model, advantages and disadvantages of this solution, types of decision that can managers do on the base of results after simulation. Experiments were created on the simulation model example, which results can help to make the right decisions of managers at all levels of the company.

1. INTRODUCTION TO THE SIMULATION OF WORKERS

Simulation as a word comes from the Latin word simulō - to imitate. This word describes the simulation of a certain event, process, object with the help of computer technology. Creating a real or reality-friendly simulation model is the basis of the simulation. Computer simulation allows to simulate several scenarios, evaluate them, optimize, and apply the results to the real operation. Simulation is one of the most effective tools to support training, education, and decision-making at various levels of the company [6]. An important task of computer simulation is no longer only the improvement of processes, but also the improvement of working conditions of workers, respectively the readiness of workers to perform their work in the operation, so that they can do it correctly and safely.

2. SIMULATION OF WORKERS IN THE SIMULATION SOFTWARE

An essential part of every company and production are workers. Modern technologies and the development of software solutions enable the use of a combination of software solution tools, computer simulation, and sensor technology to simulate the movement of workers in the plant. Such solutions are useful in combination with wearable sensors which allow the system, at first simulate how workers can work in a given cell and then determine the optimal location of production equipment and machinery in compliance with the optimal working conditions of the employee at the workplace. The Tecnomatix Plant Simulation software solution, which is used at the Department of Industrial Engineering, help to users create a computer simulation of the work of workers. For simulating the work of workers, it is possible to use several objects

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and settings, so that workers in the simulation model behave the same as in reality. Advantages of using simulation to simulate the work of workers, e.g.:

- Creation of a comprehensive and real environment gives the possibility to simulate a realistic way and the walking worker after work.
- The creation of a computer simulation does not interrupt the work of the worker in the real environment of the production system; it is safe, and also does not burden the mind of workers. An example could be, e.g. as a time study of work (for example snapshot of the working day), where the worker is monitored, and also it can affect the style of his work and the speed of work [6].
- Simulations for innovations - development of new trends and change of workplaces, verification of new procedures, also it can help to allows you to verify the ability of the worker to react quickly and be able to make the right decisions during the changing situations and development of production. etc.

Disadvantages of using computer simulation:

- Affordability - high hardware and software costs and it is time consuming. The creation of a complex 3D simulation model can take several months if 3D models are not available. It is also necessary to obtain additional data necessary for the proper operation of the simulation model.
- Thorough preparation is essential, the results of simulation runs affect the worker's work, and incorrect decisions can ultimately cause workers' health or mental health problems [3].

2.1 Simulation model of workers

The basic data and information that is necessary to know about workers, before starting of creation of a parametric simulation model includes, e.g. information about a number of workers in production, work shift, break time, etc. Then it is necessary to collect information about work, then about manipulated materials, what types of machines are in the production from basic to specialised equipment, consider the creation of time studies of work or detailed descriptions of work performed, etc. During the preparation of the simulation model, it is also necessary to obtain specific data on the work of employees, evaluate the efficiency of workers [%] and determine (or calculate) the speed of the workers walk [1].
For quick evaluation of a large number of experiments, it is possible to use software tools such as Experiment Manager tool in Tecnomatix Plant Simulation software, version 13 [1]. Using the results from this software, it is possible to evaluate for example an optimal number of workers in the workplace, the number of machines on the workplace, change operating times on machines, and so on. This decision of managers about a number of workers on the workplace is important with regard to considering the introduction of multi-machine operation or determining whether each machine will be operated by one worker to avoid overloading of workers [4]. In Fig. 1. it is possible to see a model example of a warehouse, which was created for the purpose of optimizing the logistics of picking goods from the warehouse by workers. When transferring products, it is necessary to set the operating time on special machines, which workers can use during picking of goods. These time values will be written by the tool Experiment Manager from Tecnomatix Plant Simulation directly to the selected machine object in the simulation model. In the given example, which is shown in Fig. 1., the range of operating time on the selected machine at the picking workplace in the range between 1 min and 5 min was determined in the ExperimentManager tool.

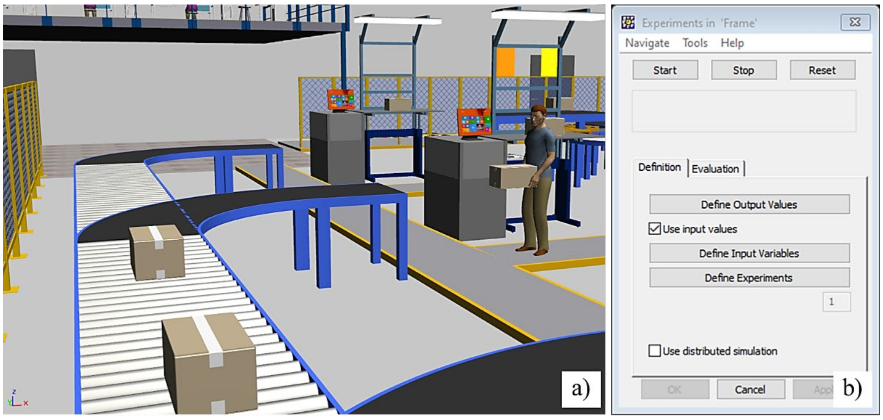
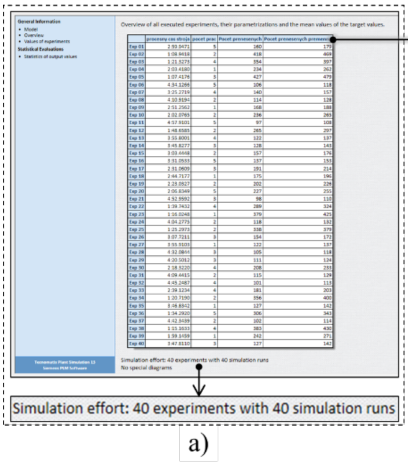


Fig. 1. View of the 3D model of picking goods (a), and ExperimentManager settings table (b) (Author: Monika Bučková)

In this example was created 40 experiments. After running 40 simulation runs, it is possible to evaluate how many workers are needed to operate the system, how many orders they are able to picking, and what would be the most advantageous setting of machines and operating times.



Number of Experiments (Exp)	Processing Time of Machine on the Workplace	Number of Workers	Number of Prepared Products by Worker
Exp 01	2:59.9471	5	160
Exp 02	1:08.9418	2	418
Exp 03	1:21.3273	4	354
Exp 04	2:03.4180	1	234
Exp 05	1:07.4176	3	427

b)

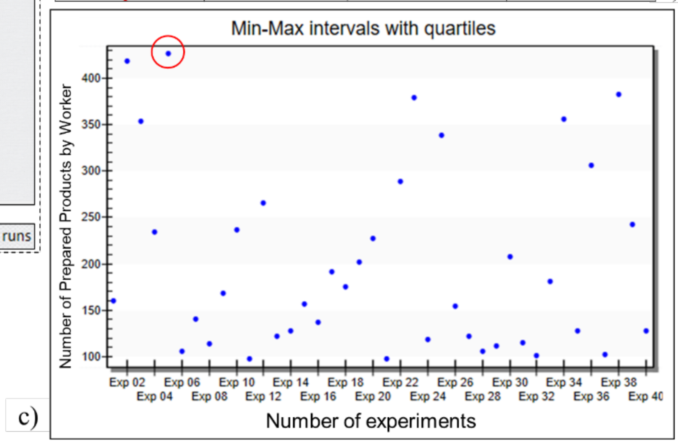


Fig. 2. Results of experiments from ExperimentManager tool (Author: Monika Bučková)

In Fig. 2. three figures are shown, and they are marked as a), b), c). On Fig. 2. a) it is possible to see the table from the output message of the Experiment Manager. All 40 experiments are described in this detailed report called "Overview", and it is created by the software. Therefore on Fig. 2. b) it is shown the first five experiments from this "Overview". On Fig. 2. c) a graph is shown, where the x-axis shows the number of picked goods and the y-axis the number of experiments. In Fig. 2 a) the number of completed 40 experiments and simulation runs is further highlighted. Red circle on Fig. 2. c) shows the highest number of transferred products, at a given time. Three employees picked up 427 orders, within 8 hours of the simulation time with 30-minute break.

3. CONCLUSION

Based on the resulting table, where the first three experiments are shown in Fig. 2. b) it is possible to precisely assign the most suitable operating time in which the highest number of orders was picked by a worker and the most suitable number of workers in the workplace. If the company has a parametric simulation model set up for several workplaces, machines, equipment, or machines that the worker uses to picking of the goods, this is a great advantage. It is an advantage because it can respond quickly to unexpectedly decreased number of workers turnover due to unexpected events such as the sudden spread of the disease or pandemic. In this way, the company can prepare in advance to respond to unexpected staff turnover and simulate several options, whether with the different number of employees in the workplace or with a change in the operating hours of the machines, if possible [5].

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Logistic, Reverse Logistic, Ecology

Monika BUČKOVÁ[1], Martin GAŠO[2], Miriam PEKARČÍKOVÁ[3]

REVERSE LOGISTIC

Abstract
This article provides necessary information about reverse logistics, which is becoming an increasing trend in the article supply chain. Reverse logistics is a strong competitive tool that can attract new customers. The article also lists its three main components, goals, advantages, and disadvantages that its effective implementation in enterprise infrastructure can bring.

1. LOGISTIC SYSTEM

The logistics system is the most important part of supply chain management. This chain is designed to meet the requirements of even the most demanding customers through detailed planning, control, information processing, access to services that help track the goods from their original location to the final customer [2]. Effective logistics management helps companies reduce various types of costs (e.g. complaints, transport, energy, fuels, etc.) and improve their services. Customers are becoming more and more demanding; it is necessary to store more and more products because customers also want to create their own combinations of product solutions, which can express their personality. The solution to the problem of moving large volumes of products is based on constant research into the logistics chain, which identifies redundant or inefficient links, after which the whole chain will be more flexible and economical to remove [3]. One of these solutions is the integrated logistics system or reverse logistics, which is described in this article.

2. REVERSE LOGISTIC

Under the term reverse logistics, it is possible to imagine all operations and activities associated with the reuse of products and materials. It is the process of planning, controlling and creating a cost-effective flow of raw materials, their ongoing inventory, and recording all related information about the goods, from the place of consumption of the goods to the place of origin, in order to recapture information about the use of the goods [6]. Logistics usually deals with

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events that bring the product towards the customer. In the case of reverse logistics, it is at least one step back in the supply chain. For example, the goods pass from the customer to back to the distributor or the manufacturer. If e.g. product is defective, the customer returns the product to him. The manufacturing company must then organize the transport of the defective product, product testing, disassembly, repair, recycling, or disposal of the product. The product would move in the opposite direction through the supply chain network to maintain any of its intended uses. The logistics for all these steps is called reverse logistics Fig. 1.

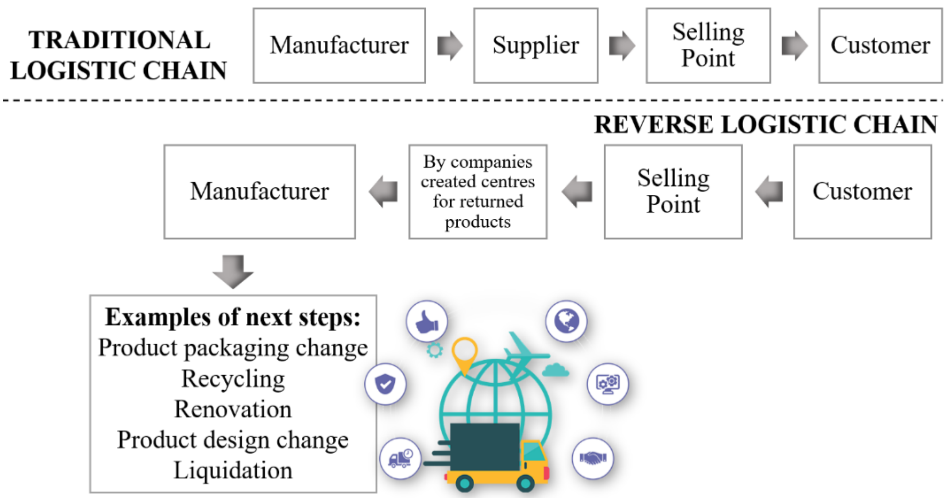

Fig. 1. The difference between traditional logistics and reverse logistics
(Author: Monika Bučková)

The reuse of products and materials is not a new phenomenon, waste paper recycling, returnable bottle storage systems, and scrap metal intermediaries are examples that have existed for a long time. However, reverse logistics as a research area is relatively new and unexplored. Despite the fact that in recent years more and more attention has been paid to reverse logistics, many companies are not fully aware of its importance and what reverse logistics is [1].

2.1 Components of reverse logistics

The three components of reverse logistics management consist of a Return Policy and Procedure (abbreviation: RPP), Renovation or Recovery (abbreviation: ROR) and Waste Disposal (abbreviation: WAD). RPP is the company's approach to product processing shared with customers and employees, which covers such aspects as, e.g. how long after the purchase is accepted the return of goods, who is responsible for transport, shipping fee, etc. The ROR covers what happens after the return of the goods, e.g. some products, from the automotive industry or production components, are refurbished and resold, some are simply put in new packaging, and so on. For some products, WAD is used for disposal because the products are not suitable or are not allowed for resale. Reverse logistics can cover any of the following activities [4]:

- Recycling.
- Goods reclaim.

- Renovations.
- Packaging management.
- Unsold goods.
- Delivery failure.
- Rental and leasing.
- Repair and maintenance of products, etc.

2.2 Objectives, advantages, and disadvantages of reverse logistics

The main objectives of reverse logistics are a well-planned and customised reverse logistics policy that can reduce warehousing and distribution costs, improve the company's reputation, meet customer needs, and create a more sustainable supply chain. Many companies use their product return policies to use the company as a competitive tool to gain new customers [7].
Advantages of reverse logistics:

- Thanks to its comprehensive strategy is it possible to reduce administrative, shipping, and other costs while increasing the speed of delivery and creation of a new product.
- A reverse logistics program can also be a key factor in customer satisfaction, leading to increased market share and improved maintenance levels.
- The supply chain will work most efficiently when optimised in both directions.

Disadvantages of reverse logistics:

- Reverse logistics management is a crucial part of supply chains; any failure can cause problems throughout the supply chain.
- The main disadvantage may be the problem with return on investment, inability to balance costs against revenues, due to, e.g. ecological packaging management or product repairs and their return to customers.

2.3 Reverse logistic in manufacturing

One of the main challenges is to monitor the profitability of reverse logistics operations. In many cases, it does not make sense to transport products from the consumer back to the distribution centre if the value of the product is lower than the transport cost. Depending on the distribution model, the company may have to manage revenue through resellers or distributors. The company will need the infrastructure to monitor the cost and ensure that any repair process is as cost-effective as possible. The reverse logistics process is the same for the manufacturing and service industries. The goal is to get the product to a point where it can be repaired or reused. In the services sector, there are opportunities for returns, warranty work, etc. The difference in reverse logistics in services and production occurs after the repair of a part or item. In the service industry, a part can be repaired and has the same value and can be used in the same way as a brand new part. During production, the renovated part may lose its value. The service industries will provide compensation, credit, warranty work and other activities to ensure excellent customer relationships [5].

3. CONCLUSION

Reverse logistics is currently one of the biggest logistics trends, which can bring many benefits to companies and create a better market position, better competitiveness, and attract new customers with its ecological approach. Like any activity in the supply chain, it also has its disadvantages, which are mainly related to the questionable return on investment. In reverse logistics, it is necessary to invest in new technologies, quality software solutions, monitoring equipment, the use of new sensor technologies, the greening of the packaging industry, etc. Incentives to launch reverse logistics in companies can also come from customers who want to recycle old products, renovate products or simply be environmentally friendly.

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A3 Report, PDCA cycle, production processes

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A3 REPORT AS A TOOL TO SIMPLIFY PRODUCTION IMPROVEMENTS

Abstract
The paper describes selected issues related to production process improvement. In general, requirements regarding production processes and final products have been characterized. Next, some assumptions in relation to products quality, including the PDCA analysis and A3 Reports, were presented and illustrated by a practical example. The main goal of this paper is to present the concept of Lean Production and to show how to use the A3 report in practice.

1. INTRODUCTION

Continuous development of the market and customer requirements, shortening innovation cycles, globalization and rising competition bring about increased requirements for companies in terms of dynamics and flexibility [4, 6].
Modern business philosophies, like, among others, Just-in-Time, Lean Manufacturing, Supply Chain Management, assume a maximum leaning, which means that a company has to eliminate all the waste associated with the transformation process [2, 3, 5]. As part of the above-mentioned concepts, many different methods and tools have been developed, the most important of which are Kaizen, 5S, work standardization, SMED, and various ways of visualizing activities, an example of which is the A3 Report that is increasingly used in production companies [1, 7].

2. THE IDEA OF THE A3 REPORT

Creating the A3 report is a specific process, or rather a structured method of problem solving. While the A3 report is a visible centrepiece of the process, it is actually rather a result of the process than the actual process itself. The A3 report is simply a concise communication tool. Because of its recognizable format (the A3 sheet format: 97mm x 420mm), individuals can instantly share ideas and make sure what is being discussed or considered [9].
The A3 report has been mainly developed by Toyota. It was created to take into account employees' needs. It has a great importance in solving problems, facilitates management of improvement projects, including planning activities, assigning people responsible for their implementation and controlling progress. It is also focused on group cooperation, by jointly

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correcting errors and introducing common corrections and ideas, as well as working out good habits and practices.
A team should consist of at least 5-7 people who are proficient at a particular process. It is important to prepare this report where the problem occurs, so that an error can be corrected and verified at any time in a continuous way.

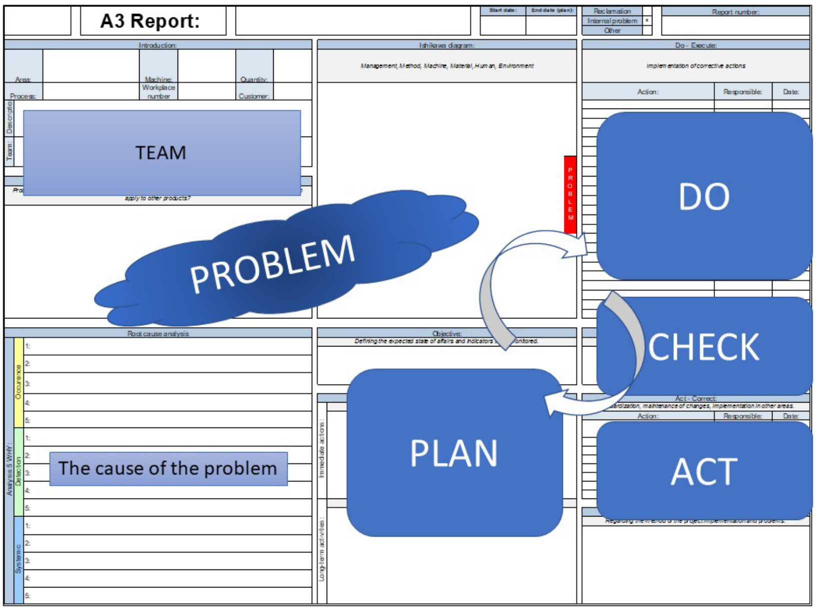

Fig.1. A3 Thinking Relies on the Use of PDCA [https://www.velaction.com/a3-thinking/ - [20.07.2020]

The most effective problem-solving methodologies is the PDCA Cycle (the Deming Cycle), which constitute a basis for completing the A3 report Fig.1. This cycle consists of the following four steps that are carried out cyclically. Those are:

- Plan: Create a plan for solving the problem, which should include a description of the problem, identification of its cause, and setting goals.
- Do: The presented plan must be realized.
- Check: Problem solvers should check to see if the solution they had adopted really worked.
- Act: When solvers identify an area where the "Do" step fell short; they need to fix it [8].

The main benefits of The A3 Report with PDCA are:

- A systematic approach and recognizable format promote collaboration among employees.
- It acts as classroom teaching, promoting learning and growth.
- Because of methodical approach, solutions are more likely to have permanent effects.
- Assigning a problem-solving owner increases the likelihood for completing a successful project.

- The way of presenting both the problem and its solution in the a3 report engages people more effectively [10].

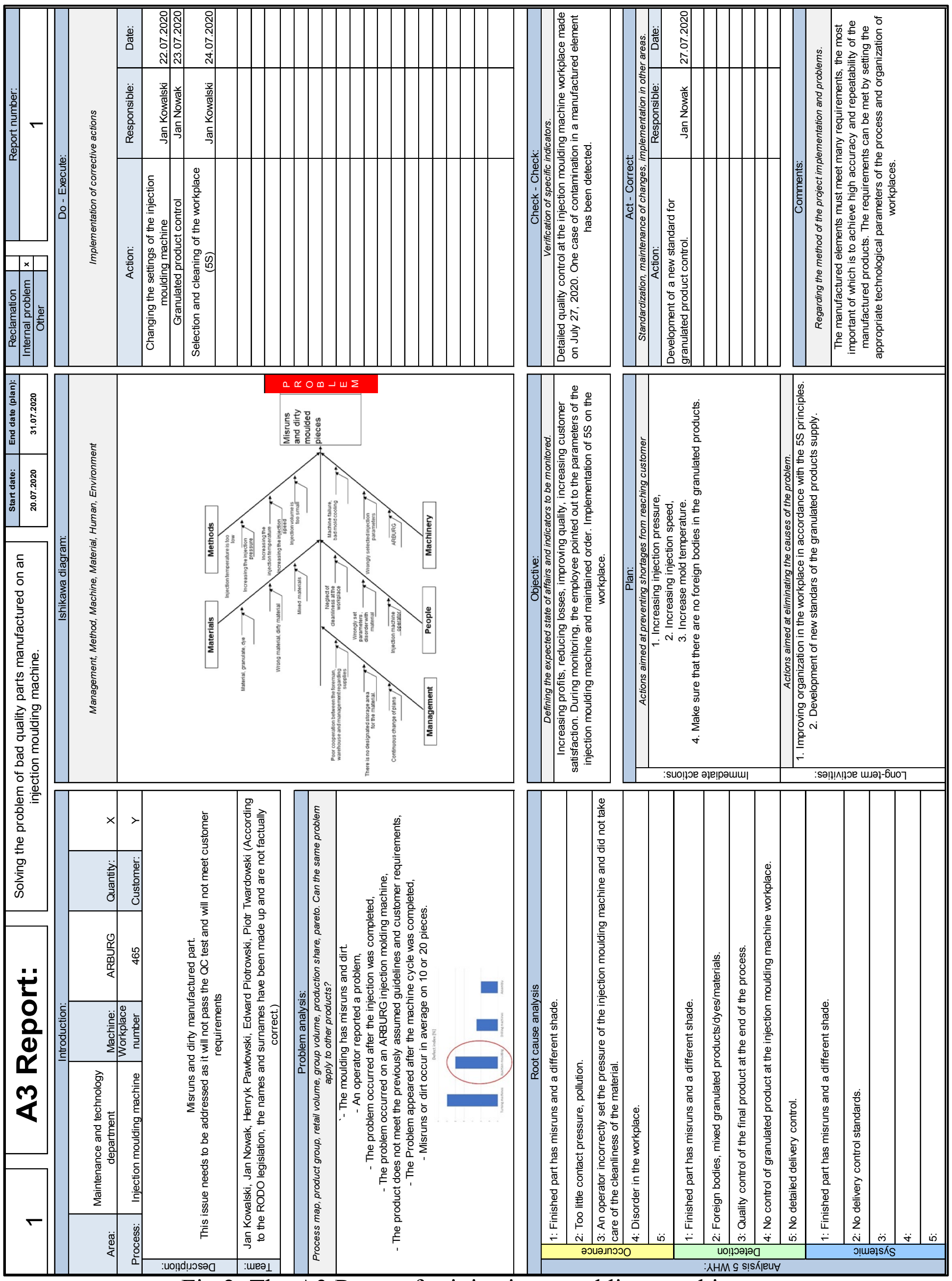

Fig.2. The A3 Report for injection moulding machine

3. A PRACTICAL EXAMPLE

The A3 report described above was used in a machine manufacturing company. This company has quality problems at several machines. Based on an analysis related to deficiencies locations, it turned out that most deficiencies arise at the turning machine. However, due to the improvements which had already been implemented there and current impossibility of modernizing this machine, the second workplace, i.e. the injection moulding machine, was taken up for consideration. The solution of the quality problem was presented using the A3 Report, which shows the effect of work of a five-person team.

The project team performed a preliminary detailed analysis of the problem, identified its source causes based on the 5WHY method and the Ishikawa diagram, and defined the purpose of improvements. Then, according to the PDCA cycle, improvement actions were planned, their implementation was realized according to the plan, the obtained results were checked and further actions improving the process were planned. All these activities are presented in the A3 report in Fig 2.

4. CONCLUSION

The Lean Manufacturing concept based on the A3 report is a very good solution for solving problems occurring in production workplace. The presented example shows the effectiveness of A3 reports in finding the causes of the identified problems and in determining possible solutions. In addition, presenting them in a visible place, not only for team members, makes it easier to control improvements in production workplace, and, above all, good ideas can be transferred to other workplaces easier and faster.

As a result of preparing A3 reports, losses are reduced, workstation organization is improved, and machines' setup times are shortened (e.g. an employee does not have to look for tools due to disorder).

In many companies, the A3 report can become a basic tool of the production process improvement system and can significantly enhance cooperation among employees.

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Lean office, Industry 4.0, Industrial Engineering, Waste

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LEAN OFFICE IN INDUSTRY 4.0 ERA

Abstract

The original idea of lean management of the factories originated in the production sphere. At present, it is necessary to implement and enforce the idea of lean management in non-production departments and in the non-production sphere. Lean factory and their administration have a much higher potential to increase efficiency compared to production areas. This article describes the implementation of lean principles in administrative. One of the least demanding, yet very effective ways for greater work efficiency is the 5S methodology.

1. INTRODUCTION

At present, factories are trying to use the principles of lean management, which are focused on activities that add value, continuous improvement, eliminating all forms of waste from production and administrative processes. The Industry 4.0 paradigm is currently accessible in manufacturing. It is not based on methods; it focuses on connecting the physical and cyber worlds using the latest technologies. The field of lean administration gains on the realities of lean manufacturing. The most common methods used in the implementation process are 5S principles, quality management, process standardization, continuous waste elimination, visual management, VSM and others. How is Lean Administration different from Lean Manufacturing? In the environment. When we think about the changes in business processes over the last hundred years, in the field of production, improvement and constant change, have settled permanently, and we can say that production workers are used to changing. On the contrary, changes in the administration have been much slower. The most significant change in the administration was brought about by the implementation of IT resources and the Internet. The administration is a much more conservative environment than manufacturing, and change is much harder to push through here. Due to, it is necessary to solve many problems in the implementation of lean thinking in the field of administration, which we are not used to from production. It is required to communicate much more. Workers need to understand the methods used well and see real improvement. Despite these obstructions, the administration is nevertheless a little paradise for an industrial engineer - the possibility of achieving a 90 % improvement in the process, whether

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in fields of productivity, efficiency, or quality. That is why it is necessary to talk intensively about this area and pay attention to it [1-4].

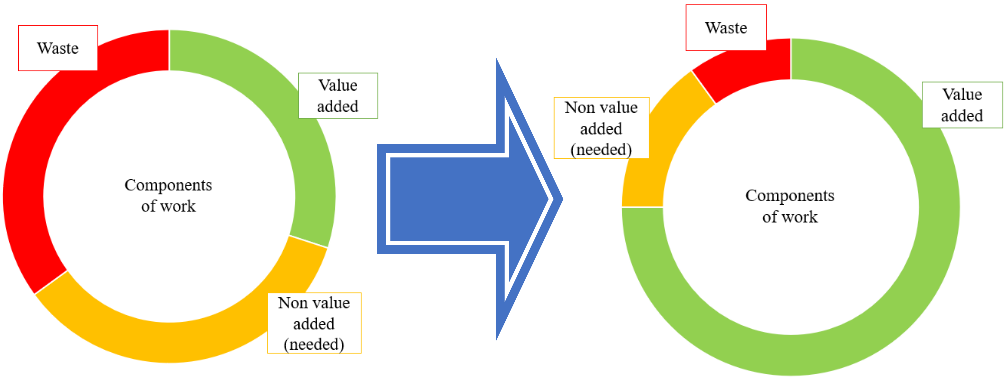

Fig.1. Components of work – basic and optimised

A value-adding activity is an activity that directly adds value to products. It belongs to the work component Fig. 1. This addition of value can be seen by the customer, e.g., communication with the customer. The goal of every factory should be to eliminate waste and increase the share of added value while reducing costs Fig. 1.

2. LEAN OFFICE 4.0

A lean and rational value flow requires support processes that follow the same logic and methodology are managed, and that is just as efficient and waste a minimum of resources. The potentials are often not evident at first glance. They need to be improved through process analysis and optimisation, as well as effective communication and leadership. The value stream-oriented factories eliminate unwanted division, improves communication, and achieves significantly shorter lead times with better quality. Better job organisation, innovative technologies, standardisation and teamwork will facilitate the transition to Lean office 4.0. It is first necessary to carry out an administrative audit and eliminate the waste of tools such as VSM, snapshot observation, working day image, spaghetti diagram, ABC analysis, etc [5, 6].

2.1 Snapshot of the working day

This method is one of the methods of direct measurement of time consumption using a timer. Continuous-time studies are based on data that are found by continuous measurement. The data obtained from the analysis of time consumption form a working snapshot. It is necessary to prepare before performing the time frame itself. Doing a snapshot of the workers is ideal to do on a PC in Excell. These data can then be used immediately for their analysis, statistics and making graphs. In the first step, it is necessary to prepare an overall table for the snapshot of the workers. Note, it is possible to take the snapshot of two workers at once. Fig. 2 shows the output of the workers' snapshot. The measurement was carried out due to the implementation of the Lean office 4.0 concept in a factory focused on the production of hydraulic valves. Based on these steps, it is possible to see how workers work effectively, and it is possible to increase the level of value-added activities through various arrangements.

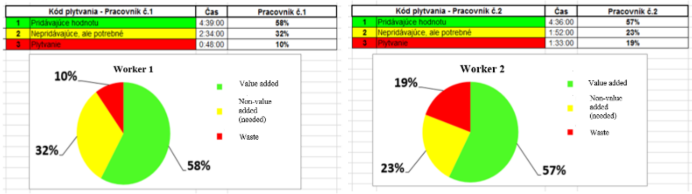

Fig.2. Worker evaluation

2.1 5S methodology in the Lean office 4.0

This method aims to make order in the workplace. It is concept emphasises maintaining only the necessary things in the workplace, and only in places that are designed for that. Many people believe that 5S means cleaning. Furthermore, it is often including some managers who introduce methods into factories. However, 5S means much more - it is one of the cornerstones of lean manufacturing or Lean office. 5S should also be implemented in the office. Improperly applied 5S ends in a negative perception by employees and the non-use of essential procedures in practice. Therefore, it is necessary to learn to interpret the various methods and tools of Lean management correctly. With the right implementation, cost savings of up to 20%, clarity and improvement of the working environment can be achieved Fig.3., and various advantages can also be achieved with it, e.g.:

- A clean and organised space through which the factory attracts the customer.
- Spaces are freed.
- Removal of unnecessary items eliminates obstacles at work and thus prevents excessive search for documentation and office supplies.
- The factory culture is improved, the productivity and quality of employees' work are increased, and the security of work with information is achieved.
- Use in marketing due to the possibility of use in sales argumentation and to gain the trust of customers.

Fig.3. Lean office 4.0 in practice [4]

Figure 3 shows Lean office 4.0 in a modern factory. Paper documentation has been removed, and all factory processes and their status can be shown on two large screens in the director office.

3. CONCLUSION

The goal of Lean office 4.0 is to create digital efficient and stable processes that allow achieving high productivity, required quality and maximum performance of administrative activities at a fixed time. The main goal and effort are to detect and eliminate waste. Learning to search, see and eliminate waste is crucial for the future of each factory. Starting to implement the principles of Lean office 4.0 often means a significant change for the factories. The change mainly concerns the change in people's thinking.

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New trends, Society 5.0, Industry 4.0, Advanced Industrial Engineering, Digitisation

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TOWARDS SOCIETY 5.0

Abstract
The article deals with mega-trends in society and the new concept of Society 5.0. This concept comes from Japan and is an initiative of the Japanese government. The basis of this idea was laid in Industry 4.0. A prerequisite for the successful development of the Society 5.0 concept is the characteristics of the innovative technologies and the creation of a roadmap for the implementation of innovative and disruptive technologies into people's lives. It started in Industry 4.0.

1. INTRODUCTION

In the smart society, innovation and globalisation have become the dominant elements of socio-economic development, posing new challenges for governments, businesses, and citizens. It is essential to understand the unique challenges to increase the chances of success and to define the most appropriate responses. The answers to the new challenges cannot be found in yesterday's solutions, even those that succeeded in the past [1].

Today, Europe is interconnected to the world through various economic and social binding that allow the flow of materials, financial resources, innovation, ideas, but also waste and emissions. Global competition for resources is increasing, as are the effects of global phenomena such as biodiversity loss and climate change. This development means that the ecological, economic, and social situation in Europe and within it in Slovakia is and will be significantly affected by various global changes in the coming decades [2].

We are now in a new era in which innovation is driven by technologies like the Internet of Things, Artificial Intelligence, robotics, exponential technologies and so on. These technologies bring significant changes to the economy and society. Megatrends represent the direction of long-term political, economic, and cultural changes in society that occur during the transformation of the industrial period to the post-industrial period. Fig. 1 shows current megatrends, their key drivers, and their innovation potential [3].

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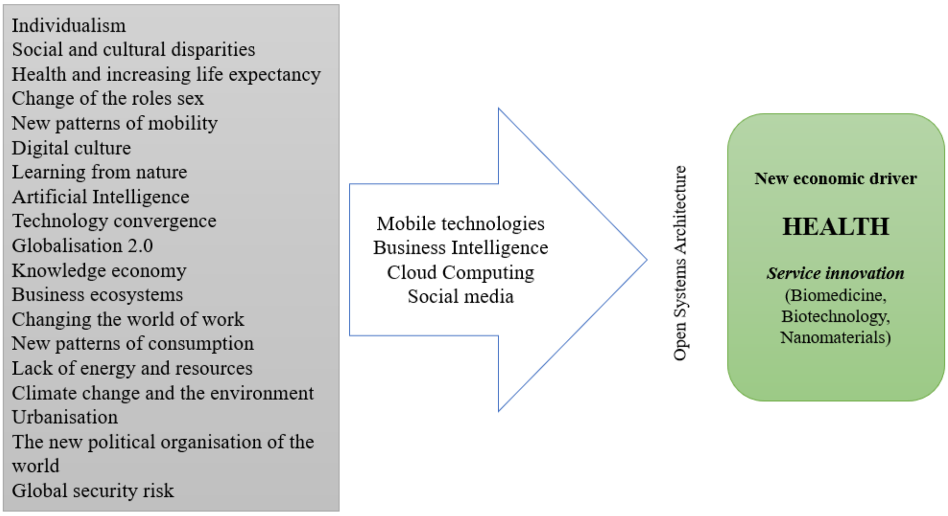

Fig.1. Megatrends and new driver [4]

As can be seen from Fig. 1, the concept and one of the megatrends of today were characterised by our colleagues in the year 2014. This megatrend significantly touche the already current concept of Society 5.0, which the Japanese government has decided to implement in Japan fully and thus raise the country to a new level.

2. ACHIEVING SOCIETY 5.0

Advanced Industrial Engineering (AIE) has always considered the forecasts of further technological development and development strategies not only of Slovak society and research but also of society. Today, more than ever, the AIE needs to focus more on new trends and megatrends that are emerging in the world and disrupting existing things. AIE must also respond to these disrupting trends and take them into account when designing Factories of the Future are, due to Society 5.0 will be a crucial element in the future. Fig. 2 shows the progress of the society concept that is currently happening in our society: [5]

- Society 1.0 – humans hunted game to survive.
- Society 2.0 – the source of productivity became land and human labor.
- Society 3.0 – the fields were replaced by factories.
- Society 4.0 – muscle activity was replaced by brain.
- Society 5.0 – highly intelligent work.

According to [5], it was described in the year 2014 that the fourth revolution from society would be the intelligence revolution, and people will perform highly intelligent work. This revolution will lead to considerable developments in three areas: genetics, artificial intelligence (AI), and nanotechnology. When we transfer this idea into Society 5.0 concept, we can find many common ideas in it.

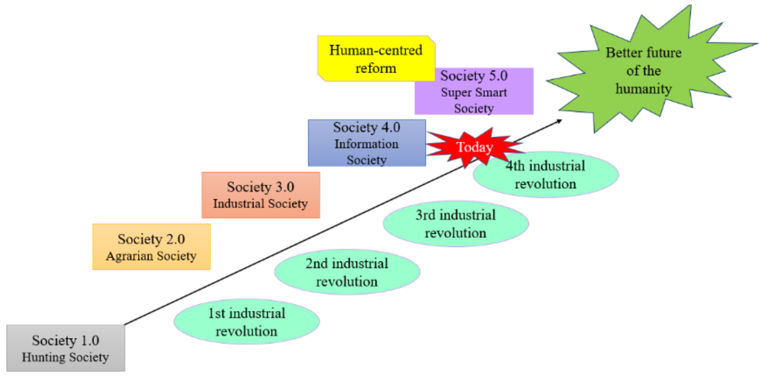

Fig.2. Progress of Society [6]

This concept was presented at the CeBIT conference in Hannover in the year 2017. Chancellor Merkel expressed her strong support for the Society 5.0 concept. Based on this, it can be argued that the concept of Society 5.0 will diffuse worldwide, as has Industry 4.0. Japan has created an economy where robots and artificial intelligence can coexist with humans and perform critical functions together. With the concept Society 5.0, Japan wants to create an environment in which social problems can be solved by integrating technologies into the areas of healthcare, mobility, infrastructure, and society. Japan believes that it is leadership in data collection, and technology will give it a lead in creating this new society [7].

If we look at the current information society (Society 4.0), there are several shortcomings in it, e.g. people's collaboration is still challenging, and knowledge sharing is insufficient. There are also limits to what a person can do, and the demographic curve is deteriorating, the depopulation of some areas of the country due to lack of work, finding the right information is difficult and so on. Social reform (innovation) in Society 5.0 will achieve a forward-looking society that breaks down the real sense of stagnation, a society whose members have mutual respect for each other, transcending the generations, and a society in which each and every person can lead an active and enjoyable life [8]. Big Data gathering by IoT sensors will be converted into a new type of intelligence by artificial intelligence and will reach every corner of society. As we move into Society 5.0, all people's lives will be more comfortable and sustainable with nature as people are provided with only the products and services in the real amounts and at the time needed. Society 5.0 has essential in two facts in Japan: [9]

- **First fact - Gathering Big Data in real-time**. Based in health and medical data from a universal health care system and a wealth of operating data from numerous manufacturing facilities, Japan has an environment rich in real and usable raw data for use in the current market economy and industry.
- **Second fact - Technology cultivated from “monozukuri”.** Japan’s advanced technology developed from “monozukuri” (Japan’s excellence in the manufacturing of things) and years of basic research, will work as advantages toward creating products using information technologies like Big Data and AI, which can then be released into society.

By taking advantage of these unique factors, Japan will overcome social challenges such as a decrease in the productive-age population, ageing of local communities and energy and environmental issues ahead of other nations. Japan realize a vibrant economic society by improving productivity and creating new markets (since the Toyota Production Systems concept - TPS). With the latest technologies which are currently available, this rate of transformation is increasing. By doing this, Japan will play a key role in expanding the new Society 5.0 concept to the world (as was the case with TPS).

3. CONCLUSION

Many of the changes in Japan's Society 5.0 are driven by the need to address the nation's shrinking workforce, which poses a severe economic threat that could cause massive strain on public spending and industry productivity. We think that we have the same problem in our country, and it is necessary to solve the issues immediately. Ideally the same approach as they do in Japan.

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automotive industry, Statistical Process Control, Measurement System Analysis, Gage R&R

Ewa GOLIŃSKA[1]

PROCESS RACIONALIZATION WITH THE USE OF MSA AND SPC METHODS

Abstract
The article presents an efficient way of introducing and maintaining statistical process control in an organization. It points out/to reliable literature references featuring theoretical background of quality management methods such as MSA and SPC. The paper elaborates on some common mistakes committed by organizations in relation to applying SPC, as well as presents a practical example for headrest assembly process in a production company, which is a 1-st-Tier-Supplier.

1. INTRODUCTION

System quality management according to normalized standards has been used in organizations for over 30 years. During this time, these standards, primarily ISO 9000 series standards, have gained tremendous popularity and have also standardized business language around the world. System requirements in the automotive industry are constantly evolving and being improved. Currently, the entire supply chain related to the automotive industry is subject to the fourth amendment to the technical automotive standard IATF 16949 from 2016 - IATF 16949: 2016 Quality management systems - Detailed requirements for the use of ISO 9001: 2015 in serial production and production of spare parts in the automotive industry. Under this standard, there function the so-called manuals that provide important guidance on the quality system in the industry. A manufacturer can use the manuals as part of the IATF 16949 standard [1]. The requirements included in the reference manuals – MSA and SPC have been analysed for this purpose. Conducting analyses according to SPC and MSA manuals is obligatory is the automotive industry – both for OEMs (Original Equipment Manufacturers) as well as suppliers in the logistic chain. Requirements for the automotive industry apart from the technical specification are also referred to by specific industry requirements - individual customer needs (CSR - Customer Specific Requirements). The undisputed leader which attaches great importance to enforcing specific requirements is the German market. The sector-specific requirements of this market in form of VDA manuals are particularly important for the VW group, with which the company discussed in the article has been cooperating for years as a sub-supplier.
The automotive industry, looking both from the point of view of the requirements of the IATF 16949 technical specification and from the point of view of individual requirements (including VDA), attaches great importance both to the assessment of measurement systems and the use o statistical methods to reduce the variability of production processes. Therefore, companies should validate not only their processes, but also the measurement methods related to these processes.

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2. LITERATURE REVIEW

Literature sources [eg 2,3,10] have widely elaborated on the issues related to some of the most popular quality control methods – MSA and SPC. The Polish terminology standard PN-ISO 3534-2:2010 [9] defines statistical process control as *activities aimed at using statistical methods in order to reduce changeability, increase knowledge about a process and manage the process in a desired way* [9]. Bearing in mind that, *changeability of conditions, properties, way of executing work etc. is the most serious enemy of an enterprise in meeting customer requirements* [2], organizations are forced to take actions that enable them to control and limit volatility. Such actions include both the analysis of the qualitative ability of the processes and the use of control charts (under SPC), as well as the analysis of measurement systems suitability (according to MSA). Another group of activities in this area is statistical acceptance control - however, the issues in this area go beyond the scope of this article and were not discussed in the paper. The aim of this study is not to present the theoretical basis of MSA and SPC, but only to indicate comprehensive sources of information on these issues that are used in the automotive industry. During the tests, the authors referred to the requirements of the IATF 16949 [11] technical specification, AIAG - SPC and MSA [4,5] manual manuals, as well as to the requirements of the German automotive market – VDA [6,7]. These are the only credible requirements that the entire industry is based on.

3. DATA AND METHODOLOGY

The project related to production process rationalization was carried out in one of the automotive industry companies in Bielsko-Biała. One of the analyses concerned special characteristics related to safety (SC/s, High Action Priority in FMEA analysis) - testing the hardness of the headrest foam according to the SPC methodology following the requirements of SPC 2nd Edition AIAG and VDA 4 [7]. The required hardness amounts to 6.0 +/- 0.030 (foam hardness expressed in possible deflection in millimeters). According to the PN-EN ISO 2439: 2000 [8] standard, the methods adopted for determining the hardness of flexible porous materials are different and include three basic methods with the use of an indenter, whereas only one of them is used during product quality control [8].

The implementation of SPC in measuring the discussed characteristics in the initial phase did not include system verification using MSA R&R. The inference about the process was made only on the basis of the analysis of the values of Cp and Cpk indicators, with an assumption that the process is capable and stable when Cp is approximately equal to Cpk and amounts to at least 1.67 (the minimum required level of Cp for the safety characteristics for the VW group - it means that there is no acceptable property value outside the tolerance range, i.e. 0 ppm). Control cards were used, but the circulation of this documentation (paper, generated at the production stand) was ineffective and was not analysed on an ongoing basis. This approach resulted in the client's complaint, and finally an audit of the other party, during which a non-compliance in this respect was formally found. After issuing a non-compliance card in the area of qualitative analysis of measurement systems during an external customer audit for compliance with VDA, the company analyzed the approach and decided to take corrective actions aimed at minimizing the risk of the non-compliant fraction in components delivered to the customer (OEM).

4. RESULTS AND DISCUSSION

After analysing the causes of non-compliance, the corrective actions were narrowed down to the need to analyse measurement systems capability wherever there is measurement processes repeatability. The activities were extended to the entire system, but the paper presents a fragment concerning only the described inconsistency. The MSA for measurable features was analysed according to procedure 2 (taking into account operator's influence on the measurement system). Three operators performed tests for 10 headrests, taking three measurements on each. The headrests were selected taking into consideration the entire range of tolerance. They were also numbered in a way that is invisible to operators. The persons conducting the study do not contact each other and do not know the results of their measurements. After collecting the data, R&R calculations were prepared according to procedure 2. Tab. 1 shows a report on the conducted activities.

Tab 1. A report from measurement process capability assessment – MSA R&R, the ARM method – an excerpt.

	operator A			operator B			operator C		
obiect no.	series 1	series 2	series 3	series 1	series 2	series 3	series 1	series 2	series 3
1	6,029	6,03	6,03	6,025	6,029	6,033	5,999	6,015	5,984
2	6,019	6,02	6,007	5,986	6,003	6,02	5,999	6,014	5,984
3	6,004	6,004	6,003	6,015	6,011	6,007	5,99	5,974	6,006
4	5,982	5,982	5,982	5,996	5,991	5,985	5,992	5,975	6,01
5	6,009	6,009	6,009	5,972	5,993	6,014	6,008	5,995	6,02
6	5,971	6,028	5,999	6,014	5,994	5,973	6,007	5,994	6,02
7	5,995	5,991	5,987	5,986	5,991	5,997	6,023	6,016	6,03
8	6,014	5,993	5,972	6,007	6,013	6,019	6,023	6,015	6,031
9	5,985	6,002	6,018	6,019	6,003	5,987	6,016	5,997	6,026
10	6,024	6,001	5,977	6,032	6,031	6,029	6,006	5,986	6,025
	Xavg A	Ravg A		Xavg B	Ravg B		Xavg C	Ravg C	
	6,004	0,002		6,006	0,001		6,005	0,001	

EVALUATION OF THE CAPACITY OF THE MEASUREMENT PROCESS:

Mean range R=(Ravg A + Ravg B + Ravg C)/3=0,0013

Range of operator means Ravg=0,002

Equipment Variation (EV) EV=R*K1, gdzie K1=0,8862 EV=0,0115

Appraiser Variation (AV) AV=((Ravg*K2)²-EV²/(n*r))½; K2=0,5231, n=10, r=3 AV=0,001

R&R (GRR) GRR=(EV²+AV)½ GRR=0,0015

Part Variation (PV) PV=Rp*K3; Rp=0,058, K3=0,3146 PV=0,0182

Number of distinct categories ncd ncd>=5? ncd=1,41*(PV/GRR) ncd=16,67

%GRR %GRR=6*100*(GRR/T); T=0,060 %GRR=15%

The performed analysis indicated that the factor with the most significant influence on process disturbances is the human factor. The analysed measurement system is conditionally capable (the obtained %GRR result from the range 10 %-30 %), so corrective actions should be taken. The work of the surveyed operators, their skills and completeness as well as the effectiveness of their training were analyzed - in this area it was not possible to identify the cause of the problem. Although operators possess the required expertise and skills, they are not able to manually set the zero point for performing subsequent measurement series. In connection with the above, a decision was made to automate the control process, which would eliminate errors resulting from

manual measurements carried out by operators in a unique and non-reproducible manner. The final solution to the problem was the use of an automatic hardness measurement system that is able to perform all the required operations for Shore hardness tests. High measurement precision is possible thanks to the use of special image analysis techniques. The system needs only 0.3 seconds to measure the dimensions of the cavity, which significantly affects its efficiency, and in the long run allows to reduce the costs of controlling the tested characteristics. What's more, all data - starting from setting the measurement conditions and ending with the analysis results, can be performed in an Excel spreadsheet, which allows easy and quick access to current information on the applied measurement systems.
After introducing the changes to the measurement system, another assessment of the MSA measurement system was carried out for numerical (measurable) features - R&R analysis using the ARM (Average Range Method), and the % GRR was obtained at the level of 6 %, which proves that the measurement system is capable. The next step was to conduct an SPC for the tested characteristic. Satisfactory results were obtained: Cp = 2.32 while Cpk = 2.12. The process meets all the requirements, although it still requires improvement.

5. CONCLUSIONS

The tests performed and presented in the paper were necessary to verify the rationality of using a given measurement method in the control process. The implementation of the SPC method without first examining the influence of repeatability and reproducibility (R&R) of measurement systems on the actual values of the process capability coefficients Cp and Cpk leads to wrong decisions based on false input data. It often occurs that Cp and Cpk indicators are at a satisfactory level, yet the number of inconsistencies in the process is unacceptable. The reason behind this appears to be a disrespectful approach to the analysis of measurement systems imposed in the control plan. Only achieving an acceptable level of the R&R measurement system capability index allows to determine its suitability in the process with the use of SPC control. If the indicator level is below the acceptable range, it is required to take actions to improve the measurement system.

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employee performance, business performance, performance indicators

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BUSINESS PERFORMANCE INDICATORS AND EMPLOYEE PERFORMANCE EVALUATION

Abstract
Business performance assessment is an important part of business management. The choice of indicators based on which the assessment process is conducted plays an important role in the business performance assessment process. The aim of the paper is to analyze the structure of the used enterprise performance indicators and the approaches of management of industrial enterprises to employee performance evaluation. The results of the research showed that management of industrial enterprises focus mainly on financial performance in enterprise performance assessment. Furthermore, research has shown that the management of industrial enterprises does not consider the age structure of employees when evaluating employee performance.

1. INTRODUCTION AND LITERATURE REVIEW

When managing the business performance, it is important to choose indicators or criteria for measuring and assessment of the enterprise performance. Choosing the right indicators is a critical aspect in translating an organization's mission, or strategy into reality. Indicators and strategies are tightly and inevitably linked to each other. A strategy without indicators is useless; indicators without a strategy are meaningless [1]. It is possible to distinguish the so-called primary performance criteria, the values of which will enable an overall, final interpretation and evaluation of performance to be made and which will not become apparent in a descriptive and interpretable form until the activity has been completed. In order to be able to describe the enterprise performance during the activity, it is necessary to derive from the primary criteria such causal secondary performance criteria, which will be continuously comparable and interpretable [2].

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However, an isolated assessment of the indicators values does not make sense. It is necessary to assess the figured values in relation to a certain base (values of the indicator in the past, values of the indicators for another enterprise, comparison of actually achieved results with the plan or with the so-called ideal value of the indicator [3]. When measuring performance, therefore, some emphasis is placed on quantification in order to provide an objective, uniform and consistent picture of reality. Although, this is only possible in some areas. It is easy to quantify areas such as profits, return on assets or cycle times, and we can count incoming orders, service visits or rejected deliveries. However, some things are not easy to calculate or quantify. Areas such as organizational culture, know-how, customer relationship strengths or brand reputation are all difficult to measure, if not impossible. At the same time, it is these less specific resources that drive future performance [4]. What is more, there was proved a positive link existing between non-fi nancial performance and financial performance [5]. The value of an enterprise is not primarily the probable price of the enterprise on the market, but the sum of the benefits of a particular participant in the transaction. The evaluation of the enterprise can therefore take place by the enterprise itself or by its management for the needs of management or owners. The second group of users of information are external entities cooperating with the evaluated entity – suppliers, customers, banks, insurance companies, cooperating partners, employees, trade unions, etc. In general, this group, which in various forms influences the evaluated enterprise and, at the same time, is influenced by this enterprise, called "stakeholders" [6]. Important stakeholders within the organization are employees. On the one hand, they contribute to the enterprise performance through their partial performance, on the other hand, they are interested in the enterprise performance and its prosperity, because it provides them with remuneration for work, the ability to apply their knowledge, skills and experience, and their work position to some extent defines their social status.

2. RESEARCH METHODOLOGY AND RESEARCH RESULTS

The main aim is to analyze the structure of the used business performance indicators and the approach of the management of industrial enterprises to the evaluation of employee performance.
Research Question 1: Which performance indicators are used most often in industrial enterprises in Slovakia?
Research Question 2: Do managers of industrial enterprises consider the age of employees when evaluating employee performance?
The research sample consisted of employees of various ages working in Slovak industrial enterprises. In Tab. 1, the distribution of employees based on their job classification can be seen.

Tab. 1: Employees by job classification (own elaboration, 2020)

Job classification	Absolute frequency	Relative frequency [%]
Production employee	51	09.6
Administrative employee	216	40.4
Employee - specialist	126	23.6
Manager	99	18.5
Other	42	07.9
Total	534	100.0

Tab. 1 shows that the majority of respondents hold administrative (technical-economics) job positions – 40.4 %. Only respondents at managerial positions in the industrial enterprises were considered for further analysis. The distribution of the research questionnaire was carried out physically in paper form and electronically from May 2018 to January 2019. The authors of the paper selected a sample of respondents based on an improbable quota selection. A total of 534 respondents took part in the research.

Evaluation of Research Question 1: Which performance indicators are used most often in industrial enterprises in Slovakia?
Only respondents at a managerial position could answer these questions. In total, 93 from 99 respondents at managerial position answered this question. Respondents were able to choose several possible answers.

Tab. 2: The most used performance indicators in Slovak industrial enterprises (own elaboration, 2020)

Performance indicator	**Absolute frequency**	**Relative frequency [%]**
Profitability indicators	52	26.3
Liquidity indicators	17	08.6
EVA – economic value added	18	09.1
BSC – balanced score card	7	03.5
KPI – key performance indicators	36	18.2
Employee fluctuation	20	10.1
Employee stabilisation	33	16.7
Number of employees coming up with innovative ideas	15	07.6
Sum	198	100.00

Tab. 2 shows that, the most often, management of industrial enterprises uses profitability indicators (26.3 %) for performance assessment, followed by KPI indicators (18.2 %) and employee stabilization indicators (16.7 %).

Evaluation of Research Question 2: Do managers of industrial enterprises consider the age of employees when evaluating employee performance?
The question was answered by 97 from 99 respondents at managerial positions. Tab. 3 shows the evaluation of the first research question.

Tab. 3: Age diversification of employee performance evaluation (own elaboration, 2020)

Answer	**Absolute frequency**	**Relative frequency [%]**
YES	**11**	**11.11**
NO	**86**	**86.87**
Without Answer	**2**	**2.02**
Sum	**97**	**100.00**

Tab. 3 shows that up to 86.87 % managers of industrial enterprises do not diversify the evaluation of employee performance based on the age of the employee.

3. CONCLUSION

The analysis showed that most industrial enterprises do not take the age into account when evaluating employee performance. Thus, the management of the organization cannot objectively assess whether belonging to a certain age category affects the employee's performance. In the absence of objective performance measures taking into account the age of employees, the management of an industrial enterprise cannot even assess whether or not the coexistence of employees of different age groups contributes to improving the performance of work groups or the enterprise itself. Due to unfavorable demographic developments and an aging population, it is necessary for industrial management to diversify performance assessments based on the age of employees. Another important finding is the fact that industrial enterprises in Slovakia use rather quantitative economic indicators in the enterprise performance evaluation. As mentioned in the theoretical part of the paper, focusing on people in the form of non-financial indicators can bring the organization an undeniable advantage in human resource management. In a turbulent period of operation of industrial enterprises, it is necessary not only to look at the performance of employees and organizations through financial performance indicators, but also to take into account non-financial and qualitative indicators that help shape new challenges for organizations.

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Emulation, Optimization, Logistic system

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EMULATION AS A TOOL FOR OPTIMIZING LOGISTICS PROCESSES

Abstract
Software solutions are an essential part of the further development of logistics systems. Therefore, combining existing logistics systems with computer simulation will enable the development of complex solutions that can meet the requirements of enterprises in the construction of intelligent logistics systems. Such a comprehensive system will enable us to adapt real logistic systems into the virtual environment.

1. INTRODUCTION

The flexible response of the company to customer requirements and the change in the production program nowadays is decided by successful and unsuccessful enterprises. The system for testing logistics processes in real terms in the expansion of production provides a competitive advantage and the possibility to be included among successful enterprises on the market. While competing with industry organizations in global markets, any new solution to optimize costs and speed up production is a tool to gain a competitive advantage and become a market leader. The proposed system in this work is the concept of how process verification in enterprises can take action once certain areas have been worked out. Current logistics systems use huge amounts of data that result from sensor use. Software solutions and their development have become an essential part of the further development of logistics systems. By combining computer simulation with real logistics systems, it is possible to create complex solutions to meet the requirements of enterprises in building intelligent logistics systems. The proposed solution of the emulation system provides the foundations for the creation of emulation systems for a wide range of elements in production. In addition to the test application on automatic logistics scramble, the proposed system can be used for robots, robotic lines, and other artificial intelligence systems. I believe that the proposed system will be a sought-after tool for businesses and will help them find the right decisions.

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2. DESIGN OF A SYSTEM FOR VERIFICATION OF LOGISTICS PROCESSES USING COMPUTER EMULATION

The proposed system for verifying logistics processes using computer simulation and emulation represents a system where certain system elements, control programs and applications for production management are not available in the production system and the system operates on the principle of mixing and synchronising the production system emulator, real devices and control applications. The proposed system is based on the interconnection of three subsystems of the enterprise and represents the interconnection of the real and virtual worldthrough the communication-management interface. The structural scheme of the proposed system is illustrated in Fig. 1.

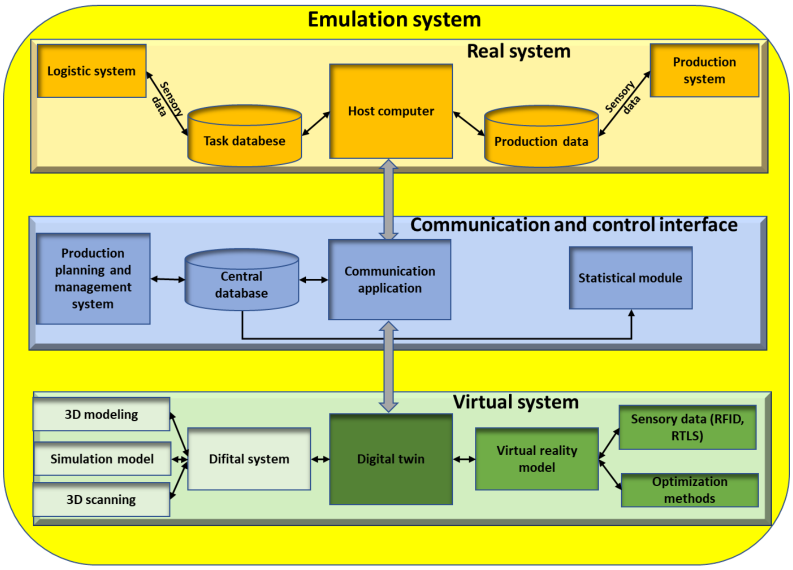

Fig.1. Design of the structure of the system for verifying logistics processes using emulation

The basis of the proposal is the physical dimension representing the real system. This system is composed of elements performing logistical tasks and elements of the production system. Real-world data and cues are collected into a data base through sensory data. On the one hand, information on logistical tasks is stored on the data base, on the other hand, it is data obtained from the production system. To perform specific tasks, control activities and mediate the exchange of information between peripherals (databases), the host computer is installed. On the other hand, there is a subsystem that represents the digital twin of the system being examined. The digital twin is composed of two partial parts. It's part of the digital world used to design the system. This part realistically represents the test system through 3D models of individual objects. By folding individual objects, we obtain a digital image of the real world of the test system. In addition to digital image, it is necessary to inch a virtual reality model into the system. The virtual reality model allows us to dynamically track the course of events through sensory data from the real world. The quantities are obtained from the real system through RFID and RTLS tags. Based on the information obtained from sensory systems, we have available real data that serves as input data for optimization methods. Optimisation methods will look for variations of measures that we will verify through experimental tests. The tests are carried out through dynamic simulation. To create the most realistic virtual form of the test system, the digital and virtual world is merged into one whole, thus gaining the digital twin of the real system. The creation of a communication-management environment is necessary to connect and manage the real and virtual world. Mutual communication between the host computer and the digital twin is ensured through a communication application. The application ensures the transformation of data into an acceptable form for individual subsystems. Data transfer between the host computer and the digital twin through the application is secured over the local eternet network. Through the communication-control module, the different subsystems will communicate, process and evaluate the information received, as well as provide feedback. All subsystems will be transformed into a comprehensive integrated emulation system. Through the emulation system, we can test the running of the system under different system load conditions in real time, thus more accurately reflecting the behavior of the real system. Emulation system is a system for rapid verification of the impact of management principles in advanced production and logistics systems. Those subsystems will form a functional whole, representing the basic principles of the concept of a digital enterprise [1].

2.1 Integration of all modules into a single solution

The individual modules of the proposed system need to be integrated into a comprehensive solution that will ensure the integrity of the entire system. The principle of operation of the system is based on incentives from the system of planning and management of production processes. The system sends a logistical request based on the production plan. The logistics system shall accept the information through the proposed eternet network. Once the request has been received, the logistics element is put into operation. During the task, the equipment's status information, information on the task performed, capacity capacity of the equipment, information and location are collected in the logistics facility, with the possibility of supplementing the information necessary for further analysis and optimisation of the process. After performing a logistical task, the information collected is sent to the communication interface module. This interface assesses the status information obtained from the internal logistics element database. The communication interface also contains a production database in which information from the internal ERP production system is collected. According to the system settings of a particular production company, information such as technological parameters of production and key technological parameters such as OEE, MTTR, MTBF, reliability and availability of equipment and others are collected. At the same time, data from the production system is also sent to the virtual model of the monitored system. This information can be transformed into a model by using an xml file. The values thus obtained will convert the simulation software to data types, but you must define the data type for each column of data collected. This data obtained needs to be filtered out for data that is not necessary for the simulation model. By receiving information from the logistics system and on the basis of the production plan from the system for planning and production management, we are created new requirements with tasks for logistics. These tasks need to be checked on the basis of capacity capabilities and a production plan through a virtual model that is created by simulation software. In the simulation model, we can verify the suitability of the current logistical settings. If the production requirements obtained from the TSO system would not be met, an alternative solution is being found through the optimisation methods and experiments used in the simulation model, which may consist in rescheduling logistics routes, changing individual supply lines, modifying and adjusting the production system. The system virtual model module is connected to the interface module between man and hmi machine. The HMI module is an interface that is connected by the operator to the system and allows it to interact with the process. The task of the HMI module is to make the functionality of the monitored technology for the operator simple and understandable so that, on the basis of the received message, it can react quickly. The solution to the problem is sent back to the communication interface from the virtual model, which sends modified commands to logistics elements based on the information we receive. This process is cyclically repetitive based on incentives, from the production planning and management system [3].

3. CONCLUSION

The article discusses the need to design a system for testing logistics processes in real conditions before installing devices. As production and delivery of production and assembly equipment is a time-consuming process, the possibility of testing the logistical system provides a competitive advantage in a dynamically evolving market. Testing of logistics systems within an enterprise with a link to emulation is possible in two different ways. In the case of production which does not possess real production facilities or new equipment will be added to existing production, it is possible to test the behavior of real logistics by means of virtual production facilities which will be replaced by simulation software. The second case is if the enterprise has real production facilities and plans a change in the functioning of the logistic system or the deployment of automated logistics. Here, using emulation can be proposed in the simulation software virtual logistics, which will then be tested and optimized for real production requirements [4]. Further research will be needed to develop dynamic, object-oriented models that will represent examples of real-world resources as well as semantic representation for modelling of intangible assets at the operating level. In the future, the goal is to create a link between logistics devices and a model that interact with each other and work with data in real time.

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Digitalization, Work instruction, Industry 4.0

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DIGITIZATION OF STANDARDIZED WORK INSTRUCTIONS IN CONTEXT WITH INDUSTRY 4.0

Abstract
The article is focused on the possibilities of applying digitization within industrial organizations. Digitization is one of the essential phases in the implementation of the fourth industrial revolution. The main goal is to analyse the process of creating instructions, identify wastes within this process, and design solutions to eliminate them using digitization. The secondary objective takes into account and contributes to minimizing the environmental impact of organizations.

1. INTRODUCTION

Standardization allows companies to reduce costs, eliminate waste, reduce process time without increasing the load on people, increase product quality, and strengthen and maintain organizational know-how. Standardization also enables the benefit of employees such as easier to identify specific problems, to contribute with ideas to improve, and also to learn new procedures or activities sooner [1].
Digitization is an innovative part of the industry. Manufacturing companies are therefore heavily focused and consistent about digitization technologies. Digitization can take place and improve based on the key technological concepts of Industry 4.0 (The Internet of Things, Big Data, Virtual Reality, etc.). Their cooperation creates intelligent and flexible systems that simplify operations, cooperate in the value chain, and improve production processes [2].
If companies decide to digitize their business, they can choose from a variety of strategies. One of them is the process of the gradual transformation of production and individual production processes. Using the mentioned strategy of gradual digitization of society, every single device, production line, or workplace is digitized just one by one. There is no risk against the instability of a whole production. Digitization is focused only on certain parts of the company and it is much easier to set up successful change into an already chosen established system [3].

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2. CURRENT APPROACH TO STANDARD WORK INSTRUCTIONS

The Standardized Working Instruction (SWI) is a document for more detailed information on how the product is manufactured and what employees are to perform exactly in what position. According to standard instructions, operators work in production. The standard work instruction should include information on the entire assembly process, step-by-step production, information on the safety instructions for each operation, and the required checks and warnings on important steps that operators must be careful of. SWI has the format shown in Fig. 1.

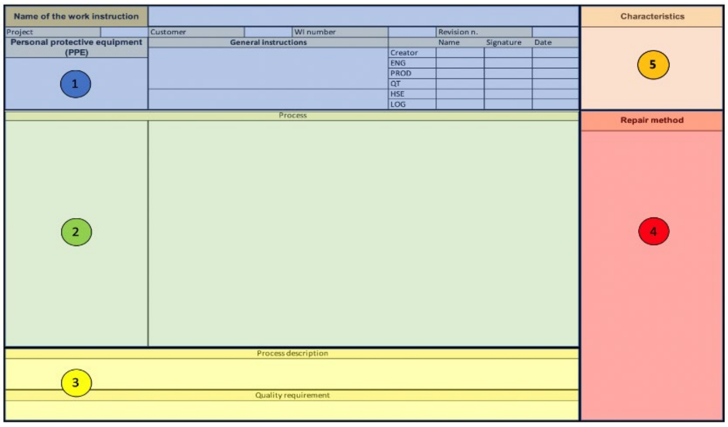

Fig.1. SWI - Standardized work instruction

The standard work instruction contains the following sections:

- The first part of SWI contains the header of the work instruction, the name of the instruction, the project, the process customer, the SWI number, and the revision number.
- In the second part, the left column of the SWI contains a process, which expresses the technological process of the operation in the instruction - the order in which the individual operations in the instruction must be performed. The column shows the location on the product or the location on the parts or machines where the operation is performed. The column also lists the tool or part that is used in the process step. In the middle part, there is a place for displaying the operation in the form of pictures, shapes, and pictograms. The operation should be displayed so that it could be understood even without a text description of the operation.
- The third part contains a specific description of the operations and a quality criterion.
- The fourth part on the SWI shows the correction method, which determines the method of correction at a given process step of the operation.
- The last, fifth part of SWI is characteristics. This is a feature of the product or a parameter of the production process that may affect safety or compliance with legislation, functionality, performance, or subsequent processing of the product.

A standard work instruction is prepared in Excel and stored on the server for further editing with all revisions in one document.

2.1 Procedure for creating SWI

A predefined person is responsible for creating and updating SWI which means that other people are not allowed to create and update SWI. To create or update a SWI, a detailed knowledge of the process by the responsible person is a must so that the instruction meets all the specified criteria. The relevant representatives of the individual departments are responsible for approving the SWI. The creation process and time duration are shown in Fig. 2.

Fig.2. SWI implementation process

It is clear that the longest step in terms of time is the approval process, but at the same time, there is also the potential to shorten and streamline the release (publication) time in production and archiving. During the approval process, the printed SWI is validated by the responsible persons and after successful approval, it is reprinted and published, replaced with the old one at the appropriate workplace.

3. PROPOSAL FOR STREAMLINING THE PROCESSES ASSOCIATED WITH STANDARDIZED WORK INSTRUCTIONS THROUGH DIGITIZATION

Digitize the SWI process. Such a solution will contribute to speeding up and streamlining the process, but also to cost savings and, above all, employee time. As part of the procedure, it is necessary to digitize the approval, signing, which is the third step in the diagram. At the same time streamlining the fifth step, namely archiving. To shorten the time and streamline the process after the creation or updates take advantage of the electronic signature option in PDF format in Adobe Reader. The SWI need to be stored in a folder on the shared server Fig 3. In the fifth step, employees used to archive the signed instruction to the stackers. As an electronic signature is designed, these signed SWI on the servers also perform the function of digital archiving. This eliminates the need for SWI printing, personal signing, and, also archiving to stackers.

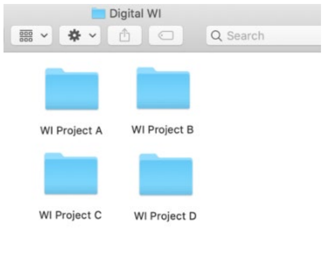

Fig.3 WI located on company's servers

Fig. 4 Kiosk for digital WI

Fig. 5 NEW SWI implementation process

The fourth step of the diagram included updating the work instructions directly in production. By providing a central PC, Kiosk Fig. 4, employees will have access to up-to-date SWI from the company SWI folders (Digital WI) in a dedicated location within the organization. Such a solution would eliminate the waste caused by movement and streamline the whole process of publishing new/updated SWI Fig. 5.

4. CONCLUSION

By digitizing SWI, organizations are able to reduce waste caused by waiting, moving, and thus streamline the processes associated with SWI. Digitization brings, among other things, positive outputs towards the EMS of organizations, it contributes to minimizing the impact on the environment. This article focused on one of the possible ways how to take advantage of the opportunities offered to organizations and bring them closer to the Fourth Industrial Revolution. Not all changes need to be radical, even small changes can reduce the organization's costs and increase their competitiveness. In a situation that organizations currently find themselves associated with the COVID-19 virus, it is essential to constantly seek and implement improvements.

The paper is a part of project VEGA No. 1/0721/20 „Identification of priorities for sustainable human resources management with respect to disadvantaged employees in the context of Industry 4.0"

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Industry 4.0, Readiness Assessment, Refractory

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INDUSTRY 4.0 IMPLEMENTATION IN REFRACTORY

Abstract

This article focuses on the topic of Industry 4.0 principles implementation to the existing environment of manufacturing enterprises more precisely in Refractory. Due to different levels of IT infrastructure and production processes in Refractory industry, it is hard to use common methods of Industry 4.0 implementation. This article describes the need of special model for company's Readiness assessment for future elements and structures implementation and describes the framework of such Readiness model.

1. INTRODUCTION

Industry 4.0 as a concept has strong background mainly in traditional segments of industry in Czech Republic, such as automotive and aviation. In automotive, processes for implementation of production elements within Industry 4.0 concept are widely used and fairly complex. In terms of readiness to implementation of the new elements of Industry 4.0, companies in the automotive and aviation are therefore much better prepared.

Refractory industry is a traditional industry in the Czech Republic, but the ideas of the Industry 4.0 concept are not yet well established. Given the wide range of products in this industry, this is a complex issue. Due to the complexity and uniqueness of the Refractory industry, the general models for Industry 4.0 Readiness assessment can't be used properly, without extensive modifications to the model. In this article, current readiness models will be discussed and outline of the new Industry 4.0 Readiness model for Refractory will be presented [1].

2. RESEARCH OF EXISTING INDUSTRY 4.0 READINESS MODELS

Currently, there are few models and methodologies to assess the state of digitization, automation and use of Industry 4.0 elements, but mostly, they only assess the current situation and does not propose a solution to the situation. Most comonly, methodologies to assess and implement Industry 4.0 elements are created by large companies for their own use or serve as a commercial activity for large consulting companies, therefore, they tend to be very general. Majority of the aproaches focuses more on the energy, automotive and aviation industries. Some

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companies and their assessment methodologies deal with this issue solely on the basics of advice and consultation, others provide more complete solution with the implementation of Industry 4.0 elements directly to their customers. Main models for assesing Readinnes (maturity) for Industry 4.0 implementation are shown in Fig.1.

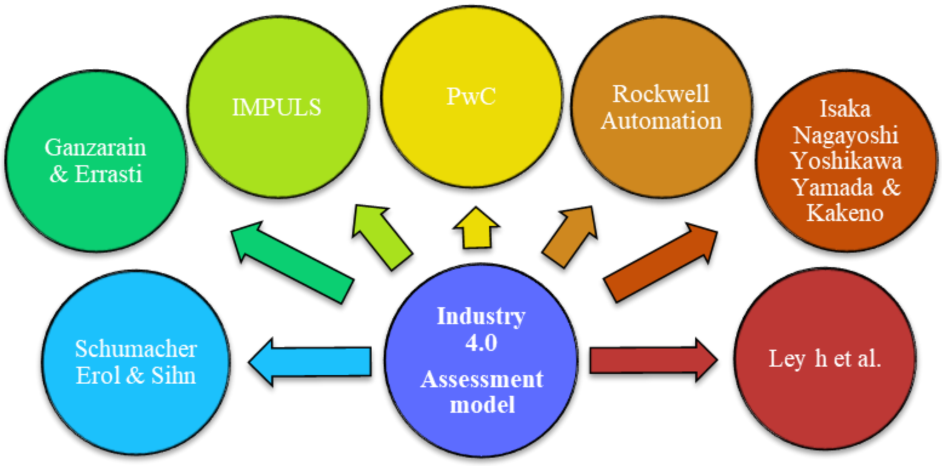

Fig.1. Models to assess Industry 4.0 maturity

None of these models is easily transferable to be used to assess company within Refractory industry. The main reasons those models can't be used in Refractory are: significant difference in the product portfolio, the material of the products, the method of production, the quantity of products produced, the size of the component base, the material storage, but also the current state (differences in infrastructure and production processes) of both industries [3,4,6].

2.1 Main research and implementation projects within Industry 4.0 in Refractory

In recent years, few projects and models had already been created to help companies implement other elements of Industry 4.0. In general practices, only small areas of Industry 4.0 are being implemented in Refractory, so it is problematic to find best-practice in this area of expertise.

There is small number of bigger projects in Refractory or ceramic industry, that can fit into Industry 4.0 implementation category, the most significant are these: Mobile Manufacturing Execution system (MMES), Cloud Laboratory Information Management System (CLIMS), The Meld Digitalization, Big Data for marketing and internationalization, Scanning of ceramics, Monitoring system. The most similar project to presented topic is: Ceramics Industry 4.0 – maturity model. This projects was held in Portugal and the aim of the project was to create a model according to which it will be possible to create solutions for each subsector of the ceramic industry. The downside is, that this model is strictly oriented to certain ceramic companies in Portugal, so it can't be used in general. [2,5]

3. GENERAL CONCEPT OF INDUSTRY 4.0 READINESS MODEL FOR REFRACTORY

Based on the literature research, there is no acceptable model for readiness assessment in Refractory. All the models are too general, or can't be used without excessive changes in the model. Therefore, new model is proposed. The aim of the model is to enable various companies involved in the refractory industry to be able to assess their current readiness and identify bottlenecks or shortcomings in the production, and also in non-production processes.

If the bottlenecks and shortcomings in process or infrastructure can be assess correctly and fully, that opens the opportunity for future Industry 4.0 elements implementation and lower the uncertainty of choosing the wrong implementation approach or wrong feature to be implemented and optimized. Therefore, the Readiness model could serve as perfect management tool for planning the future of the company within Industry 4.0 boundaries without taking too much risk in company's profitability or production effectivity.

The proposed model is divided into 6 separate categories, which are evaluated separately. The first two categories see Fig. 2 are there to serve as classification of the current company in the segment. The other 4 categories of "IT and Infrastructure", "Input Materials", "Production Processes" and "Information and Data flows" will be essential to assess the overall readiness for implementation of Industry 4.0 features.

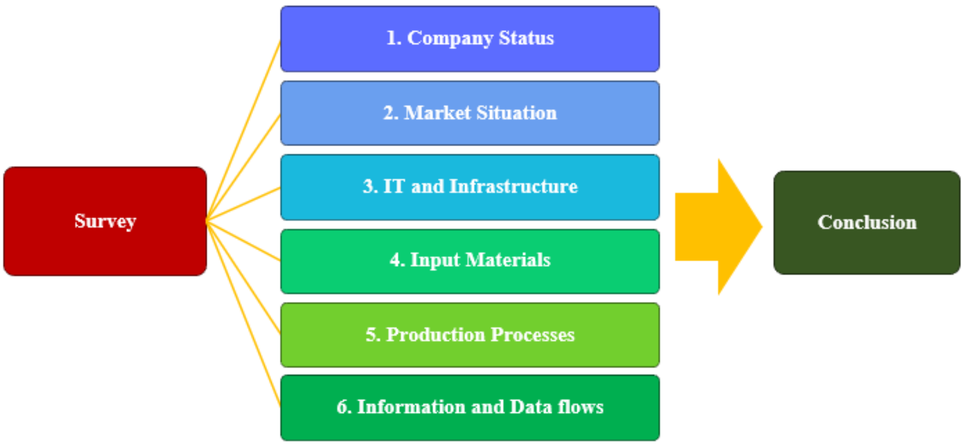

Fig.2. Design of the Industry 4.0 Readiness Model for the refractory industry

Within these categories, surveys will be made to address more specific parameters of the company, from technical and economical margins. Each question will have its weight, represented by points. There will also be logical branches of questions, depending on the previous answers. The main difference between proposed model and existing models is, that the results will be linked directly to possible future implementation scenarios, which will be part of other model, in this case Industry 4.0 Implementation model for Refractory.

4. CONCLUSION

The main goal of this article was to present the framework of the Industry 4.0 Readiness model for Refractory industry and to discuss the need of such a model. Based on literature research, there are few Industry 4.0. readiness models, nevertheless, they are way too general or made for automotive or aviation industry. Refractory industry is unique due to its production processes and infrastructure and for that reason, the existing models cannot be used properly in Refractory without extensive changes. As Industry 4.0 concept finds its way to more and more industries, it is vital, that Refractory industry will be ready to assess the readiness for Industry 4.0 implementation, mainly because of great differences in different company's processes and infrastructure. The readiness model could be vital for decision making in companies, giving them tool to assess the future implementation with more precision based on their current state of business, processes and infrastructure.

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Simulation, layout, project, production process

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USE OF SIMULATION TOOLS IN SOLVING THE LAYOUT OF A NEW PRODUCTION HALL

Abstract
The paper is oriented to the design. In addition to the usual design techniques, the simulation was used to determine the appropriate location of the machines in the production hall. The selected company plans to build this production hall in the near future. With the help of the software module Tecnomatix Plant Simulation, 2 possibilities of machine layout were processed, and based on the simulation results, the final layout of the production hall was determined. From this layout, subsequently, in the technical part of the project of construction of a new hall, it is possible to follow up on the appropriate layout of outlets from the engineering networks, which are necessary for the proper operation of production equipment.

1. INTRODUCTION

The aim of the paper is to get acquainted with the process of designing a layout for the production process of a selected company, which plans to build a new production hall to unify the existing production process, which took place in several places that were several hundred meters apart. With this investment, the company plans to optimize transport costs as well as improve the flow of the production process. The simulation, which makes it possible to quickly and relatively easily compare several variants of the arrangement of the devices, taking into account the offered assortment of production, helped with the efficient deployment of the equipment. The production process consists of equipment and operations for the preparation of the material, such as cutting and sanding of the material. Subsequently, from machining equipment, several CNC lathes ,and milling centers. If the nature of the manufactured components so requires, or the customer

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requires, a surface treatment follows, either by dyeing by conventional paint application, or by thermochemical reactions, alkaline blackening, or phosphating of zinc.

2. PROCESSING OF THE PRODUCTION HALL PROJECT

We first used the MS Project software to process the production hall project. With the help of him, we worked out the procedure by which we will implement the project. The implementation schedule is in Tab.1

Tab. 1 Project implementation schedule

Job	Job name	Previous activity	Estimated duration of activities
1.	Project initiation phase	-	-
1.1	Develop a project proposal	-	1 month
1.2	Determining the scope of the project	1.1	1 week
1.3	Prepare a preliminary budget	1.2	2 weeks
1.4	Plot preparation	1.3	1 month
1.5	Handling of administrative matters	1.4	2 months
1.6	Ensuring construction company	1.5	3 weeks
2.	Investment phase	-	-
2.1	The project construction organization	1.6	4 months
2.2	Purchase of materials	2.1	2 weeks
2.3	Acquisition of fixed assets	2.2	2 weeks
2.4	Acquisition of current assets	2.3	3weeks
2.5	Layout creation	2,1,2.2,2.3	1 month
3.	Implementation phase	-	-
3.1	Creating new jobs	2.5	1 week
3.2	Selection and acceptance of new employees	3.1	2 weeks
3.3	Employee training	3.2	2 weeks
3.4	Installation of machinery	2.5	1 week
3.5	Starting machines	3.4	1week
3.6	Testing	3.5	5 days
3.7	Checking	3.6	6 days
4.	Project completion phase	-	-
4.1	Start of operation	3.7	1,2 weeks
4.2	Project evaluation	4.1	2,2 weeks
4.3	Evaluation analysis	4.2	1,2 weeks
4.4	Completion of the project	4.3	6 days

Subsequently, we began to deal with the implementation of variants of the layout of machinery and equipment directly in the production hall.
We processed 2 variants of the layout and in the final evaluation, we evaluate the more advantageous variant on the basis of statistics from the simulation.

2.1 Design of variants for the layout of the production hall

We have placed the necessary devices that will be used in the production process in the floor plan of the production hall and we have started to develop variants to determine the efficiency of this process. We evaluated these variants using the simulation software Tecnomatix Plant Simulation. When setting up the simulation, it was necessary to enter the parameters of the production process, such as the times of individual operations, the need for the human factor at individual workplaces, the energy load at a given machine power, and the like. We took over these parameters from the existing production process in the previous production halls, where the machines were located until now. From these points of view, the production process cannot be influenced in any significant way, the advantage of unifying production into one hall will be the elimination of unnecessary transports of material between the two existing workplaces.

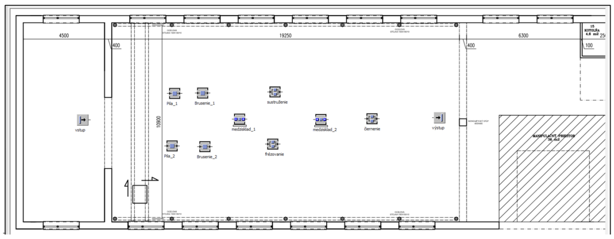

Fig. 1 Location of workplaces in the floor plan of the production hall

2.1.1 Variant 1

The production process takes place in two working shifts. On the statistical evaluation, we see that the total production of this product variant is at a value of 17.03 %, which is a relatively low value. Therefore, we decided to develop another variant of the placement of the same devices in the same space.

2.1.2 Variant 2

When processing variant no. 2, the workplaces were arranged in a different way than in the first proposal. In this proposal, we also considered the possibility of applying trolleys for inter-object transport, which would facilitate the movement of material between some workplaces. In order to develop proposals for the deployment of equipment, we have taken into account the products that have been most repetitive in the production process in the last 5 years and their production process is very similar. In this respect, too, the workplaces were arranged in such a way as to eliminate, as far as possible, unnecessary transport of material between the individual production stations.

3. SUMMARY AND SELECTION OF A SUITABLE VARIANT FOR THE LAYOUT OF THE PRODUCTION HALL

Looking at the statistical evaluation of Variant no. 2 we see an improvement in the efficiency of the production process. We also individually evaluated all machines and equipment that work in the production process and compared them with each other, so that it is clearly visible in which workplaces the efficiency was increased and where parameters deteriorated Tab. 2.

Tab. 2 Efficiency of machine

Efficiency of machines			
	Simulation 1	**Simulation 2**	
Saw 1	2,38 %	58, 33 %	55, 95 %
Saw 2	1,47 %	75, 52 %	74, 05 %
Sanding 1	1,57%	85, 94 %	84, 37 %
Sanding 2	2,90 %	98, 44 %	95, 54 %
Turning	92,12 %	13, 54 %	78, 58 %
Milling	92, 12 %	11,46 %	80, 66 %
Blackening	24, 27 %	34, 38 %	10, 11 %

Total production in variant 2 improved from 17.03 % to 63.81 %. however, in turning and milling operations, production decreased in this variant. However, if we also take into account the fluidity of the production process, we see that variant 2 appears to be more advantageous. It can be seen from the given example that the application of simulation can be found in various areas of the product life cycle.

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Biomaterial, biocompatibility, biodegradability, magnesium alloys

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USAGE OF MAGNESIUM ALLOYS FOR IMPLANTATION PURPOSES

Abstract

Magnesium (Mg) as a metal with low weight, mechanical properties similar to bone tissue, importance in biological processes of the human body and degradation in the living organism is suitable for the production of biocompatible, biodegradable and osteoconductive implants in orthopedic or cardiovascular applications. In contrast to the titanium alloys used so far, the application of magnesium alloys is much more suitable. The work summarizes the properties of Mg alloys, their biological impact and also the possible production of Mg implants in the future.

1. INTRODUCTION

Biodegradable implants have been the focus of attention in the field and have faced increasing interest in recent years. The main reason for the development of biodegradable implants is precisely their degradability in the physiological environment (the words "degradability" and "corrosion" have similar meanings but are used in the context of in vivo or in vitro). The advantage provided by this class of material is that the clinical function of the permanent implant is achievable and if successfully completed, the implant will disintegrate if it is no longer needed. Another of the main advantages of biodegradable implants is the elimination of the subsequent operation to remove the implant after sufficient healing of the tissue as with permanent implants. Thus, this means reducing or eliminating lifelong problems caused by permanent implants such as long-lasting endothelial dysfunction, permanent physical irritation, and chronic local inflammatory reactions. Nevertheless, polymeric materials have a dominant position in current medical applications, but magnesium, iron and zinc based alloys have been introduced as more advantageous biodegradable materials for load-bearing and loaded implants due to their first-class combination of strength and toughness over polymers.

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2. CURRENT STATE OF DEVELOPMENT AND USE OF MAGNESIUM AS A BIOMATERIAL

Technological development and new possibilities for the production of high-purity Mg and material modifications have provided us with improved mechanical and corrosion-resistant properties, which have renewed interest in the medical use of Mg alloys, which began studies in 2000-2003 when Heublein et al. took advantage of the degradable characteristics of Mg alloys for the development of cardiovascular stents. Since then, BIOTRONIK has developed and manufactured three generations of absorbable metal stents (AMS for short) from WE43 alloy and modified Mg alloys, an example in Fig. 1. Clinical trials have shown no symptoms of allergic or toxic reactions to Mg stents and at the same time achieve almost immediate angiographic test results, which are similar to other but permanent metal stents and decompose completely and safely within 4 months. Currently, the first commercial product made of Mg alloy is also available. A screw with the commercial name Magnezix® Fig. 1. Animal tests have already been performed on other potential Mg alloy implants such as laryngeal microclip, platelets, pins, and wound closure devices [1-3].

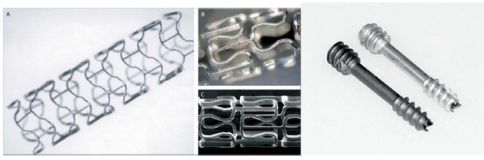

Fig. 1 BIOTRONIC AMS left, titanium and magnesium screw right

Despite exceptional progress in the development of biodegradable implants made of Mg alloys over the last 15 years, several significant problems remain unresolved. The wide range of uses of Mg alloys is still limited mainly due to the rapid degradation and the associated loss of mechanical stability at pH levels of 7.4 to 7.6 and also in environments with a high concentration of chloride anions. In addition, high hydrogen production and the formation of subcutaneous bubbles during the first week after surgery can have a negative effect on the surrounding tissue. Research into potential ways to overcome the corrosion rate problem began with coatings, which was the fastest way to improve material properties [4].

3. PROPERTIES OF MAGNESIUM AND ITS ALLOYS

Magnesium and its alloys are commonly used as materials for lightweight structures in the transportation industry due to their low weight, high specific strength and fast machinability. But at the same time, Mg is considered a suitable material for biodegradable implants associated with osteosynthesis or other temporary medical application because it is physiologically compatible, biodegradable in the human body and stimulates the growth of new bone tissue. Compared to applications in the transport industry, where corrosion is undesirable, this is a major specific advantage in medicine. But one important fact must be considered, and that is the generally rapid rate of corrosion of Mg alloys, which can be modified by the selection of suitable alloying elements or by surface treatment. Alloying elements must be selected with care and supervision and only those that are not harmful to the human body should be selected [5].

Mg is an essential element for the human body. The body of an adult contains approximately 21-28g Mg and most is stored in bones, muscles and soft tissue. Excess Mg is excreted in the urine quite effectively, so the risk of toxicity is low. Although Mg is required for the body in relatively large amounts, the degradation of the Mg implant should not take place too quickly and especially not immediately after implantation. First of all, the implant must provide adequate strength and stability after implantation so that the tissue heals sufficiently and can carry the load. Vice versa too rapid degradation could cause premature loss of implant stability. Second, hydrogen gas is produced during the corrosion of Mg in aqueous solutions, and also the increase in pH associated with corrosion can cause irritation to the injured tissue. However, the accumulated hydrogen around the implant Fig. 2c disappears over time or can be removed by aspiration with a syringe. Despite the relatively rapid corrosion, Mg has a positive effect on the formation and growth of new bone tissue. This was confirmed by an in vivo study where they compared the amount of bone tissue around two implants, one of Mg and the other of PLA polymer Fig. 2 [7].

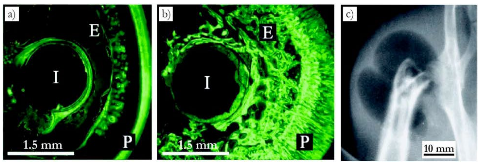

Fig. 2 Fluorescopic imaging in section a) PLA implant b) Mg implant in guinea pig femur after 18 weeks. "I" represents the implant, "P" the formation of the periosteal bone and "E" the formation of the endosteal bone. Figure c) Subcutaneous hydrogen bubble around Mg implant. [6] [8]

In general, degradable implants have many advantages, in addition to which they can also be used in pediatrics, i.e. the patient's body is still developing and growing, and thus permanent implants would have to be replaced in size more appropriately. Compared to other metallic materials in implantology, the use of a Mg implant does not result in stress shielding, which is due to the large difference in stiffness / Young's modulus of elasticity between the implant and the bone [4].

4. DESIGN OF MATERIAL PROPERTIES FOR VARIOUS APPLICATIONS

Biomaterials are now available for the third generation in terms of clinical requirements. In the first generation, the biomaterial was to be inert and harmless in every way. Later, doctors investigated more complex coatings that would allow tissue bonding. Mg biomaterials are part of the third generation of biomaterials with a focus on a new way of constructing and regenerating tissue. These materials are degradable and allow the original tissue to integrate with the implant and gradually replace it. According to these new functions, the criteria for designing a biodegradable implant are largely different from the criteria for inert permanent implants. The concept of degradable biomaterials is based on three main functions: 1. Temporary support and fixation; 2. promotion of healing and 3. degradation [5].

5. CONCLUSION

In this work, a general overview in the field of Mg alloys as a biomaterial was summarized from the current state of use of magnesium to the assumption of production using additive technology. Magnesium implants offer new possibilities in regenerative medicine.

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Virtual reality, augmented reality, working ergonomics

Karolina KŁAPTOCZ[1]

IMPLEMENTING VIRTUAL AND AUGMENTED REALITY IN THE PROCESS OF DETERMINING WORKING ERGONOMICS

The main subject of this article is examining virtual technology and augmented reality. Their applications were mainly introduced within the framework of production engineering. The key part of this study is an attempt to combine both technologies in order to conduct preliminary evaluation of working ergonomics. Using both virtual and augmented reality allows for a quick assessment of a work station as well as to introduce changes in the model instantly.

1. INTRODUCTION

Designing new work stations and improving the already existing ones is confronted with great amount of requirements, therefore new solutions and advanced technologies allowing to improve, shorten and, which is crucial, make the process more affordable are being researched. Due to adopting techniques of reverse reality (laser scanning) there is a possibility to recreate production systems using 3D modelling and, subsequently, assess them in terms of working ergonomics by adopting virtual and augmented reality. Both technologies can be implemented when designing new working stations which can be validated and tailored during the designing stage to anthropometrical size of a human during. Parametrical 3D model allows for introducing immediate alterations in key aspects of geometrics therefore it can be repeatedly altered and improved.

2. VIRTUAL REALITY

Vitrual reality was flourishing in the 90's [1]. This term means projecting entirely artificial environment before the eyes of a user. The user can, without restraint, look and move around and interact with the environment [2].
Virtual reality is becoming widely introduced in plenty of fields, e.g. medical science, military, aviation, production engineering, education, marketing and entertainment [3].
When it comes to production engineering, virtual reality can be used to:
- Design new and reorganize already existing production systems.
- Staff training.

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- When combined with augmented reality, virtual reality can be applied to conduct an ergonomics assessment of existing and newly designed production systems, which will be examined in the further pat of the article.

3. AUGMENTED REALITY

Augmented reality is a combination of real objects (e.g. work station) and artificially generated items. It is a state where on top of sensory perception of real world, virtual objects are placed. Augmented reality, unlike virtual reality, does not create "new", three-dimensional world but only complements the existing object and places with new information, e.g. in a form of 3D models, subtitles, pictures, diagrams, sound information or movies [4].
Pilot training systems were among the first applications of this technology as it allowed to reduce expenses and, most importantly, minimalized the risk connected to conducting such training in real conditions [5]. Within production engineering, augmented reality can be applied [2]:

- In systems supporting warehouses and orders completion – because of augmented reality such processes are easier and faster.
- In designing production and logistics systems – to markers, placed in productional space, virtual objects are assigned, which can be visible via stereoscopic 3D glasses. With a properly prepared base of elements of production system various versions of system layout can be established and verified, without having to disrupt the operation of actual system.
- Designing assembly work stations and visualization of assembly procedures – implementing 3D environment allows for a better understanding of how particular elements of a workstation interact and constrain one another. Accurately prepared models can be as well a valuable source of information for the worker during assembling process.
- Complicated service actions presented as visualization will make it easier to perform the task.

4. ERGONOMIC EVALUATION BY IMPLEMENTING AUGMENTED AND VIRTUAL REALITY

CERAA is a mobile device used for a quick identification and analysis of any risk possibly occurring at a particular workstation, regarding the ergonomics. The main purpose is verification whether a given space poses a threat to a worker from the ergonomics point of view and whether a detailed analysis should be performed. An application allows to investigate four matters: ergonomic workspace, height of working level, reaching zones and working positions [6]. Performing an ergonomic evaluation or workspace regards:

- Existing production systems in big companies which are unable to identify them using its own tools and resources. In such case actions are undertaken in actual operating conditions on real work stations. Marker, which is essential for the application (installed on a tablet) to work properly, is placed in the right position and therefore it is possible to project a virtual model of a worker constituting a pattern or a graphic picturing reaching zones Fig.1. Patterns and graphics are adapted to worker's gender and anthropometrical size which are established in the application before commencing the analysis.

Fig.1. CERAA – Ceit Ergonomics Analysis Application
(Source: Gabajová, Furmannová, Rolinčinová, 2020)

- Existing production systems, which by using methods of reverse engineering (laser scanning) have been recreated as 3D models and via virtual reality can be analyzed without having to interfering into worker's actions performed at a workspace. A model of a workspace, software and equipment are necessary to implement this method. Therefore, the worker, after putting glasses on, will be a part of virtual working environment which can be analyzed correspondingly as in the first case, however without the need to acquire an actual work stations. What needs to be highlighted, is an existing limitation when it comes to positioning the marker. In cases where the marker is not placed on the floor, it has to be laid on the same height as the corresponding virtual model. It does generate inconvenience, on the other hand, it is still easier to perform than in case of having a real work station. Subsequent restriction are the analysis of sitting position – in that instance virtual reality cannot represent working conditions and it is necessary to use an actual object.
- Production systems at the designing stage also requires additional usage of virtual reality. 3D model of a workstation incorporated into the right software designed for VR can replace a physical workstation therefore it can be evaluated in terms of ergonomics. In case of designing the stations it is advised to create parametric models as it allows for introducing changes and adjusting it to the worker's needs in a very short time. Limitations similar to the ones mentioned above can be found in the mentioned case.

Advantages of the introduced method of evaluating workspaces in terms of ergonomic are:

- Possibility to detect nuisance work actions and a chance dynamic implementation of changes and improvements to already existing drafts of working stations.
- No need to possess an actual workstation in order to execute an initial analysis.
- Ability to conduct analysis of large stations within a limited space.
- Saving time because of handling analysis for different workstations in a short time and in one place (as they are picked from models available in a database).

A disadvantage of such method is that the person operating the tablet does not see the workstation model, as only the person wearing VR glasses can see it. However, such matter can be solved by excellent communication with the worker.

5. CONCLUSIONS

Development of virtual technologies is extremely dynamic. Virtual technologies and augmented reality are being applied to recent matters. Production engineering is a field where they can be encountered on plenty of areas, e.g. storage, designing and reorganizing production systems, installation, staff training and actions related to work ergonomics. Their advantage within the context of presented idea is cost-effectiveness achieved due to the possibility of performing a given analysis multiple times with various parameters of a workstation. Implementing changes in such short time would not be achievable in case of physical objects.

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Technology SLM, Support structure, Printing time

Miroslav KOHAN[1], Viktória RAJŤÚKOVÁ[2], Radovan HUDÁK[3]

THE INFLUENCE OF THE SUPPORT STRUCTURE ON THE PRINT PROCES FOR DENTAL APPLICATION USING SLM TECHNOLOGY

Abstract
The aim of this study was to compare the individual support structures used in terms of printing time as well as the ability to remove the support system from the printed dental model. The machine MLAB Cusing R was used who one of tool SLM technology. Support structures were created in CAMbridge software. The material was used Starbond Easy Powder 30 metal powder. The results show, that the production of a dental bridge is more suitable to use a support structure in the form of a "Cross" with a spacing of 1 mm and 1.5 mm.

1. INTRODUCTION

Additive production, specifically selective laser melting (SLM) technology, is widely used in industrial engineering as well as in biomedical engineering. SLM technology is used in biomedical engineering in the production of dental implants and scaffold [1]. There are many studies described support structure of 3D printing. A study by Paul and Anand [2] focused on the production of parts with a minimum amount of support structure used the appropriate orientation of the printed parts. Yang et al. [3] describe a method of multidimensional deposition to make less use of support structures in stereolithography. There are also studies that describe "oblique printing" as in the study by Zhao et al. [4]. The aim of this study was to determine a suitable support system in terms of time and remove the support system.

2. MATERIAL AND METHOD

2.1 Material

This material can be used for production in selective laser sintering (SLS) as well as SLM. The properties of this material are suitable for further processing as well as excellent flexibility in the subsequent choice of metal or ceramic. The material also has good properties for creating veneers which makes it a good candidate for dental bridge (DB) application. The weight percentage composition of the powder was Co (61 %), Cr (27.5 %), W (8.5 %), Si (1.6 %), C, Fe, Mn (1 %).

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2.2 Method

The total number of printed samples was n = 25. The printed samples were DB, with different types of support systems used on each model. Designed printing support systems were: Cross, Cylinder, Bar, Cone, and Pyramid. The spacing of the support pillars of the support system was determined at distances of 0.6 mm, 0.8 mm, 1 mm, 1.5 mm, and 2 mm. The thickness of one pillar in the support was set at 0.6 mm. The positioning of the stl model DB on the base plate was performed in software CAMbridge (3Shape, UK) as well as the setting of the required support structure. Another procedure was to print DB using additive SLM technology with an MLab Cusing R (Concept Laser, USA). The device settings were given by the manufacturer without the possibility of resetting the print (maximum power of laser - 100 W, support height - 2.5 mm, print speed - 300 mm/s). The printing process was followed by the disassembly of the support system from the base plate as well as from the printed model. This procedure was performed using a cutting wire or a band saw.

2.3 Evaluation of results

Based on the established methodology, support structures will be evaluated according to the following parameters:

- Printing time
- Removal of the support system at the interface "base plate - support structure" and "support structure - printed dental model"

When evaluating the printing time, we divided it into three categories: 1 - short print (up to 3 hours), 2 - medium print (up to 6 hours), long print (more than 6 hours). When evaluating the removal of the support system in the division "base plate - support structure" as well as "support structure - dental model" into the following categories: 1 - easily removable (using pliers), 2 - difficult to remove (using a saw)

3. RESULTS AND DISCUSSION

Fig. 1. shows the print length for the use of different support structures as well as the arrangement of the support pillars in the spacing of 0.6 mm, 0.8 mm, 1 mm, 1.5 mm and 2 mm. The graph shows, when was using the “Cross” support structure at a support structure spacing of 1 mm and 1.5 mm, DB printing lasted up to 3 hours. Using the “Pyramid” support structure with the same setting, the printing time was more than 6 hours. As shown in Fig 1, the spacing of the support structure at distance of 1 mm and 1.5 mm at the “Cross” and “Cone” supports is a print time of up to 3 hours, however the spacing of support 0.6 and 0,8 on DB had length printing time 6 hours.

This fact is also confirmed by a study by Jiang et al. [5] where they describe the effect of support on printed properties in modeling processes. They argue that some support systems consume less material, saving more time to extrude other support structures. Another solution to speed up printing is to optimize the movement of the extruder as described by the study by Jin et al. [6].

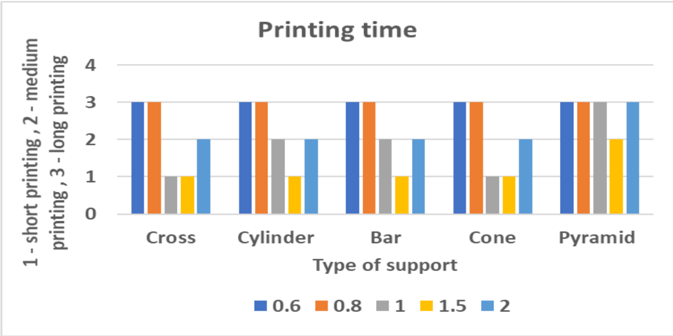

Fig. 1 Printing time with used different type of support structure

Fig 2 shows the evaluation of the removal of support from the base plate. It has been shown that the removal of the support was easy when using the support structure at 1 mm and 1.5 mm support pillar distances. However, in other cases such as "Pyramid" support was difficult to remove support. Fig. 3 shows the evaluation of support removal from the dental model. Using a distance of 1 mm and 1.5 mm with the support of Cross, Cylinder, Bar, Cone, the removal was easy.

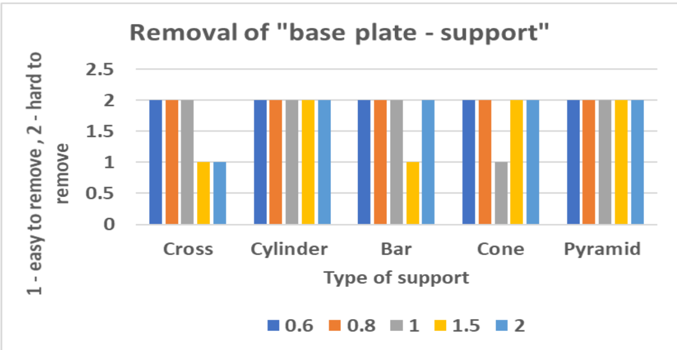

Fig. 2 Results of the removal created support structure (base place – support)

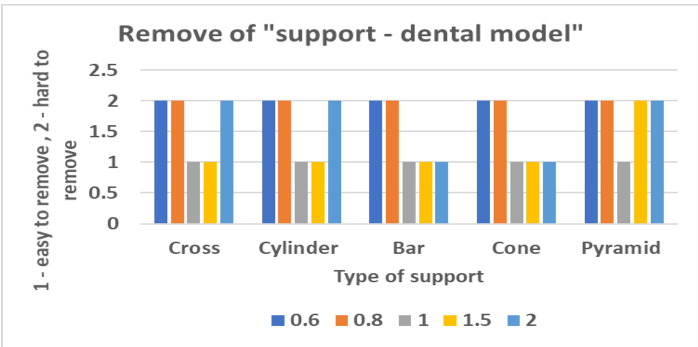

Fig. 3 Results of the removal created support structure (support – dental model)

4. CONCLUSION

The aim of the study was to compare the influence of the used support structure at different distance of the support pillars in terms of printing time and the ability to remove the support. The Cross support structure at 1 mm and 1.5 mm intervals appear to be a suitable candidate for the application of dental bridge printing in terms of printing time and removing support.

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Keywords Learning Factory; Digital Factory

Olha KOLESNYK[1], Peter BUBENÍK [2], Ivan ANTONIUK [3]

MULTILAYER, RESEARCH, AND EDUCATIONAL FACTORY FOR INDUSTRIAL PRODUCTION

Abstract

The concept of the educational factory has become popular among industries and universities for education, practical training, and research. There are specialized factories around the world that address a variety of industry issues, such as Industry 4.0, lean manufacturing, and sustainability. Educational factories are used to educate students and employees of industrial partners. Each factory has its scenarios and courses focused on a wide range of topics related to Industry 4.0. Besides, such factories make it possible to develop new or validate methods and technologies for digital manufacturing, cloud manufacturing, data analysis, IT and OT security or digital twins. This article introduces the concept of a digital factory and describes the functionality of the factory.

1. INTRODUCTION

In recent years, educational competitions have been the subject of great interest. Because these plants represent a promising environment for education, training, and research, especially in production-related areas, which are a major driver of wealth creation in any country. The use of training plants can be very beneficial for preparing employees for Industry 4.0 processes. They show that training plants have proven to be effective in developing theoretical and practical knowledge for both new and experienced employees. There are currently various training modules with specific learning objectives and scenarios for the Smart Factory in Industry 4.0. These modules can be used, for example, to prepare students for a new employee employment profile in Industry 4.0. In Denmark, they presented an educational factory at the University of Aalborg, where they implemented a platform for developing technologies to meet production requirements and demonstrate their value in the production environment.

It is difficult to master several new technologies in the digitization of production processes. Therefore, they use scenarios to teach future production engineering focused on problems. Tisch et al. [1] represent a systematic approach to the development of skills training factories. They integrate the conceptual design levels "learning race", "learning module" and "learning situation". However, training plants can also deal with specific aspects of production processes.

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2. IMPLEMENTATION OF A DIGITAL FACTORY

Digital Factory is a factory for demonstrations of digitization in the manufacturing industry. Its implementation focuses on various topics related to industry 4.0 with a strong emphasis on piece production.
The production plant of the digital factory is designed to produce simple products in an automated, digitally controlled device for mass production of customized piece items. The factory contains only the minimal core of logistics and production processes needed to develop and demonstrate digital production. Processes and stations are selected and designed to be exemplary and simple, with an exclusive focus on the development of digital systems and processes [2].
However, to enable the training and development of digital processes at the industrial level, all machines, systems, and controllers must be professional products commonly used in the relevant sectors [2].

3. DIGITAL CONTROL SYSTEM

The central industrial system SCADA (Zenon) is the basic data and control center of the plant. All machines, stations, and controllers are connected via this system (Figure 1). Machine controllers are connected via controllers via standard protocols (eg OPC / UA) or customized controllers (eg DNC) have been developed. The data is homogeneously collected by the SCADA system and stored in an external database (crate.io), to which a dedicated server for data analysis has access. Touch panels and HMI control panels are accessible via Zenon and can be easily customized. A simple MES (Manufacturing Execution System), MES_VL, and web store have been developed to manage product configurations, production plans, and order execution. In this online store, the customer can customize the product, and the design review tests the specifications and geometry for manufacturability. If the design is submitted for production, a CAD file and the required production plan are generated. The resulting CAD file is sent to the CAM system to generate the required part programs. In the case of simple objects, this can be done completely automatically. For more complex geometries, manual input may be required. After all, CAM files have been generated and the production sequence has been sent, the production order is sent to the MES for automatic processing [3].

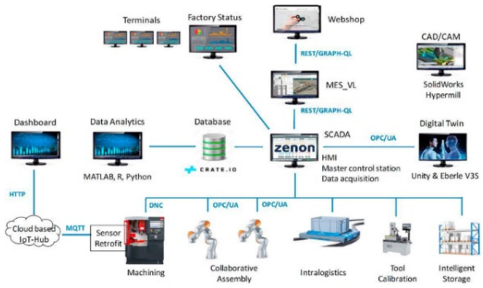

Fig.1. Digital system of a digital factory. [3]

4. MANUFACTURING MULTILAYER PLATFORM

At present, production processes are no longer limited to a single physical plant, but rather involve production steps performed in distributed facilities. Providing the means for surveillance systems and the standardized exchange of information between plants is a key task of modern production.
Internet computing paradigms and their technologies are factors enabling the interconnection of distributed services and form the basis for the combination of distributed factories in cloud manufacturing platforms. Compared to traditional production, this is a new model with specific characteristics and requirements. Also, new applications and business opportunities are emerging. A multilayer production platform based on these paradigms has been developed and implemented at the University of Dornbirn. The platform uses a microprocessor architecture with services implemented in Java using Docker and Kubernetes. This platform not only enables the acquisition of expertise in related research areas but also connects with local manufacturing companies [3].
The platform includes the entire production facility, including low-level machinery in the production hall and higher-level enterprise information systems. The web application serves as an interface for consumers and providers to interact with the cloud platform. Providers, e.g. Factories providing services can register here or get customers, t. J. Customers can order products. To compile the range of available products, we use techniques that were first introduced into the product lines of software products. The information collected, such as orders, is processed by services at the core of the platform, and stakeholders are informed, e.g. Upstairs machines. With this approach, we can provide complete customizable, piece production. An overview of the platform is given in Figure 2 (a) [4].
A gateway with an interface definition (API) and a communication-oriented service was used to connect external services to the platform core. Complex systems such as SCADA or MES can be connected. One of the key features of the gateway concept is that it includes a plug-in system. This allows the integration of different protocols by providing a wrapper implementation using the gateway API. For example, Kuka iiwa robots that communicate via OPC-UA are connected to a multilayer platform using Eclipse Milo. Figure 2 (b) illustrates the concept of gateway access [4].

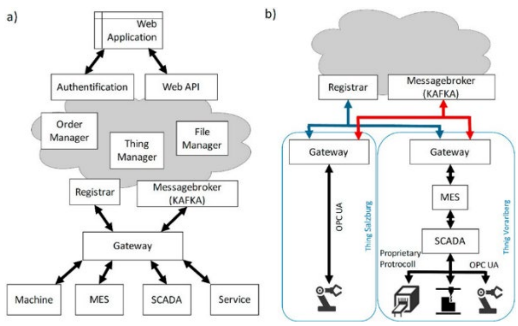

Fig. 2. a) Overview of the production multilayer platform; b) Multilayer platform connecting two production sites [4].

The core of the platform contains a semantic knowledge base that contains all the information needed for production processes. These include related services and their capabilities, such as product information and life cycles, making them a hub for factories and customers [5].
Thus, based on the platform, an Order Manager has been developed, which collects orders, and an intermediary service that optimizes work plans and dynamically distributes orders from the Order Manager to registered services, i. J. Solves the problem of satisfying constraints. The resulting process plan may include production steps in distributed factories, but it is the only operation for the customer.

5. CONCLUSION

The use of such platforms can lead to new business opportunities that are not yet possible with traditional production paradigms. In general, the automatic transformation from design to production is not possible in all cases. If such a case occurs, this transformation must be performed by experts manually.
The platform allows you to register a service that does exactly that. The subscriber providing such a manual service is informed e.g. in the web application and a task is assigned. After completing the task, the result is sent to the cloud platform and the production process continues to the next step.
The use of the digital factory implementation allows teaching students and employees of industrial partners in a wide range of topics. To achieve this, we have formulated educational scenarios that address the current latest issues in Industry 4.0 and use a digital factory to implement them. It is possible to train the development of digital production systems at different levels and demonstrate various state-of-the-art showcases. Also, the plant is used to develop new paradigms and systems, such as cloud production systems, service-oriented production, data analytical methods, or security, and IT procedures.

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Business performance, Knowledge, Productivity, Skills

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GAINING KNOWLEDGE TO INCREASE BUSINESS PERFORMANCE

Abstract

The prosperity of a company depends on the impact of external and internal factors of the environment in which it is located. External environment and external environment factors in most cases the company is unable to influence. However, he can anticipate them and try to prepare for it. Therefore, sufficient attention should be paid to their monitoring. Internal factors affecting the performance of the company and are in principle in the hands of the owners, respectively. business management. Businesses are increasingly looking for knowledge that will help them increase performance. Managers require managers to acquire, manage and use knowledge.

1. INTRODUCTION

Business performance is affected by several factors that interact with each other. Industrial engineering uses a range of techniques to increase the efficiency and quality of production processes, choosing the process itself. The choice of individual techniques in increasing the efficiency of operational processes is determined by the current situation in which the company finds itself and requires a certain level of readiness of the company's employees. The individual techniques are already known as standard and are elaborated in several publications. The most well-known techniques Tab.1. for increasing operational processes include [1].

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2. PRODUCTIVITY TECHNIQUES

The individual tools for increasing productivity, work organization and management, the causes of undesirable phenomena, in essence, use the knowledge of employees, managers, consultants and knowledge shared within the group of companies.

Tab.1 The most well-known techniques for increasing operational processes.

5S	Visual management
3Mu	Tools of Thinking proces
A3 report (Toyota A3 sheet)	EWO analysis
Kaizen	Value analysis
FMEA	8D report
PM analysis	Workshop
Mind map	SMED
Value stream mapping	TPM
Benchmarking	RCFA

To manage and increase performance, it is necessary to understand and respect the interrelationships between stakeholders, the relationships between data and information resources, the company's knowledge system and ongoing improvement processes are important [2-5]. An example of such a connection is shown in Fig. 1.

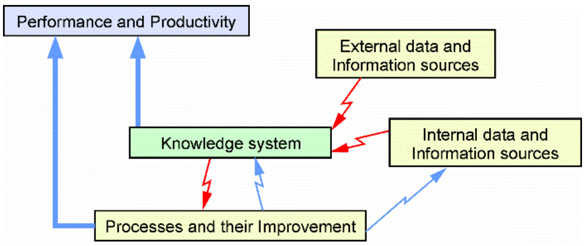

Fig. 1 – Framework relationship between the company's knowledge system and its performance [6].

Every company can be described as a "living" organism, which, in addition to the people who work in it, also creates the processes and technologies by which it realizes its production. It also includes information and knowledge provided by government employees, which is embodied in its internal documents of various forms and natures. He is influenced by the environment in which he carries out his business activities, from which he can draw information and knowledge. *Potential sources of knowledge can be identified as:*

• analytically processed data and information sources,
• results from the implementation of standard processes,
• results obtained by process improvement,
• built knowledge system of the company.

3. KNOWLEDGE AND TYPES OF KNOWLEDGE

From the point of view of research in the field of artificial intelligence, it is very important to divide knowledge into declarative ("what") and procedural ("how"). From the point of view of general management, we distinguish knowledge individually and collectively (eg company culture). Or knowledge of type: know-what, know-how, know-where, know-why, know-who.

From the point of view of knowledge management, the most important aspect is the division of knowledge into implicit, tacit and explicit. Implicit and tacit knowledge are a kind of opposition to explicit knowledge. Implicit knowledge is not yet expressed knowledge acquired through education or training. In the case of tacit knowledge, the situation is more complicated. The first mention of tacit knowledge can be found in the work of the philosopher M. Polanyi from 1966. Polanyi writes: "We can know more than we are able to pronounce" [7]. So tacit knowledge is a hidden kind of knowledge that we commonly acquire by socializing with our surroundings and about the existence of which we often do not even know. In general, in KM publications, we often find that implicit and tacit knowledge is used as synonyms, which can be useful at a certain level of problem solving. Of the two types of knowledge, the decisive force of the company is tacit knowledge, which, according to the authors, is the key to knowledge management. Their strength lies in the application of human expertise in specific areas and in the ability to "communicate" this expertise, to share it with other employees.

Explicit knowledge is relatively uniformly defined as knowledge that is codified, resp. structured, and can be easily expressed in letters, words, characters. They are equally simple to communicate and share in formal language, as well as to capture and display them in documents, databases or information systems. [8] state that explicit knowledge can be expressed in formal language, including grammatical or mathematical expressions, specifications, and manuals. They can therefore be stored in document management systems, library systems, marketing information systems, etc.

Knowledge based on their place of existence can be divided into:

embodied - are only partially explicit, related to activities; they represent knowledge related to perception, sensory information, stimuli and human presence. Many authors describe it as "practical thinking" - it is a solution to problems based on their own experience;

embedded - represent knowledge is rooted on the basis of a strong theory of the researched area (eg rules of technology, formal procedures, ...), the concept is understood as knowledge based on routine,

embrained - represents knowledge acquired on the basis of knowledge, which depends on cognitive abilities conceptual skills

encultured - knowledge related to the process of reaching a common understanding, meaning culturally meaningful systems that are related to the processes of socialization, where comprehension strongly depends on the language built for open social negotiation,

encoded - represents knowledge transferred to characters and symbols, either in the traditional form as books, manuals or transferred to electronic form. James Brian Quinn (1998) distinguishes knowledge according to its content into:

know-how - ("book learning"), knowledge gained from books, the ability to apply knowledge to solve a real problem then represents knowledge that creates added value,

care-why - knowledge consisting of motivation, will and adaptability to success, group motivated workers can perform tasks better than a mentally or financially motivated group.,

know-what - knowledge acquired on the basis of a certificate or more extensive training, this knowledge is necessary, yet it is often not enough to achieve greater success,

nowknow-why - they represent a deep knowledge of the relationship between the cause and effect of the problem, their professionals who solve more complex problems, their solutions create extraordinary value, where they can detect and predict subtle interactions and consequences based on experience.

4. CREATING AND STORING KNOWLEDGE

The process of creating organizational knowledge is conditioned by several factors. Among the most important are the willingness of individuals to learn, the willingness to share information and knowledge with other members of the organization, the organization's ability to create an environment for knowledge sharing, creating an environment for knowledge sharing and the organization's ability to create an environment for mutual learning.

5. CONCLUSION

The aim of the paper was to point out that there is a framework relationship between a company's knowledge system and its performance. Therefore, sufficient attention should be paid to the acquisition, transformation and storage of knowledge that affects business performance. At present, companies do not suffer from a lack of data and information, quite the contrary. Information can be found in several sources and in various forms waiting to be processed.

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Extruder, printhead, 3D printing

Samuel LANCOŠ[1], Jozef ŽIVČÁK[2], Radovan HUDÁK[3]

DESIGN OF THE PRINTHEAD FOR 3D PRINTING USING THE ABB IRB 140 ROBOT

Abstract
Additive technology in conjunction with robotics can bring significant process efficiencies in various manufacturing industries. The aim of the article is the design of the printhead as an element that is increasingly used for 3D printing. All components were created and then assembled in PTC Creo 3.0 software. The work also contains current trends in 3D printing using a robotic arm, which is used mainly in specific activities. The model of the proposed head is properly adapted for the ABB IRB 140 robot.

1. INTRODUCTION

By 3D printing we mean an innovative technology for which it is currently difficult to find limits. The main idea is to create a physical spatial object using a pre-prepared digital model. Today, this technology has found its way into many industries, such as: architecture, aerospace and the automotive industry. However, for some specific spatial printing tasks, the application of a robotic arm is more suitable. Using the suitable printhead mounted on the robot, items that a conventional 3D printer has problems can be produced. The aim of the work is to point out the possibilities of printing with a robotic arm using a designed printhead.

2. APPLICATION OF 3D PRINTING BY ROBOTIC ARM IN AN INDUSTRIAL ENVIROMENT

The inclusion of 3D printing in production and its production processes achieves significant results. It is possible to print prototypes and concepts in a very short time, sometimes within a few hours. This option is implemented quickly and with minimal funds [1].

2.1 3D printing in the aviation industry

The aerospace industry is currently an industry that fully supports this technology and its investment in 3D printing is enormous. Spatial printing is attractive for aviation because there is the possibility of producing lighter parts of aircraft. With traditional production methods, there are limitations that are eliminated by the using of this technology, which makes it

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possible to design parts with optimized geometry and thus make full use of the efficiency of the material. By optimizing the material of metal parts, it is possible to reduce the total weight of the aircraft by up to 7%, which results in significant savings in fuel and CO2 emissions [1].

2.2 3D printing in the automotive industry

Another huge industry that has begun to fully explore the possibilities of spatial printing is automotive manufacturing. It leads to the expansion and adjustment of the processes and technologies needed to meet the unique needs of this fast-moving sector. By eliminating the need for machining and assembly, such printing brings significant time and money savings in the prototyping and production of solid durable parts. Rapid concept production is key for any company that wants to continue rapid product development [2].

2.3 3D printing in architecture

Architecture and its models have long been a part and main application of printing processes at the production of precise buildings and visions of architects. 3D printing creates space for relatively fast, simple and vital implementation in the construction industry directly from CAD digital data used by architects. Many architectural firms now generally use this viable printing option as their core part of the manufacturing process, to increase productivity [3].

3 DESIGN OF THE PRINTHEAD

Element modeling was performed in PTC Creo 3.0 software. The stepper motor type SSA-TR-56-D3 was chosen as the basic driving element of the head. This type of motor has found application in cases where high torque transmission is not required. The advantage of this motor is the possibility of precise angular positioning even at low speeds. The motor is then followed by a component that serves to properly connect other pieces of the structure. The connection is formed by nuts and bolts.

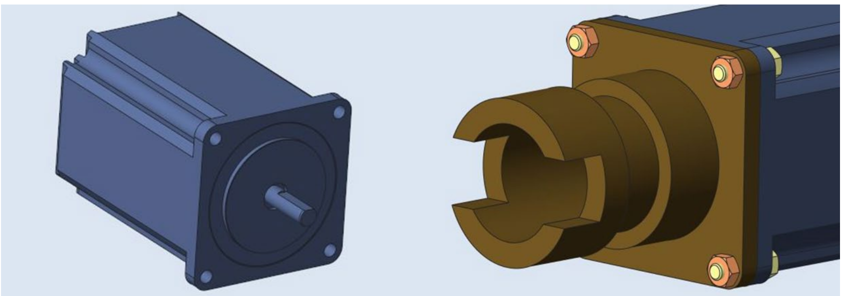

Fig.1. Drive type SSA-TR-56-D3 (left), intermediate piece connected to the motor (right)

The magazine, which is divided into two parts, is slid onto the intermediate piece. By fitting the protrusions exactly into the gaps of the intermediate piece, we limit any radial and axial movement. A hopper is inserted into the square hole between the divided hoppers, which serves to fill it. This type of extruder uses granules to print the object.

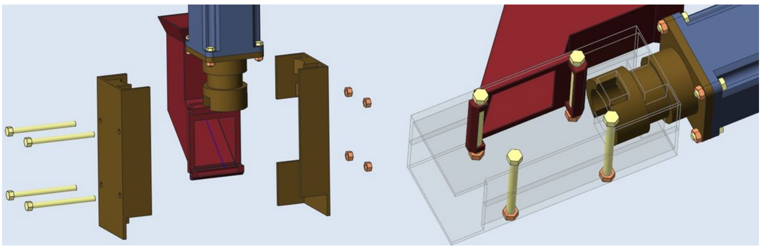

Fig.2. Expanded magatine view (left), folded view (right)

Place a screw on the output flat shaft from the motor, which pushes the granulate towards the hotend. The shape of the blade on the shaft is adapted to allow this displacement of the granules.

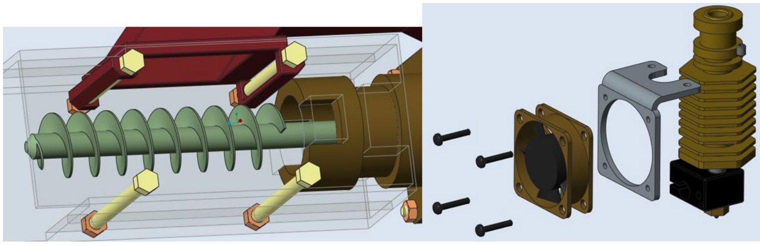

Fig.3. Sliding screw assembly (left), radiator to hotend connection (right)

The hotend of the print head together with its cooler is assembled. Molten fiber with a suitable temperature, which is regulated by the cooler, must come out of the hotend. The radiator holder is inserted between the hoops, and the radiator is attached to it. Everything holds together thanks to screw connections. The hotend is then fastened to the hotend holder using two pieces of sheet metal and screws. We can also see a hole for the supply of granulate. The hole has the same diameter as the screw blade. The patches together encircle the hotend in the cutout between the two circular protrusions and prevent any movement.

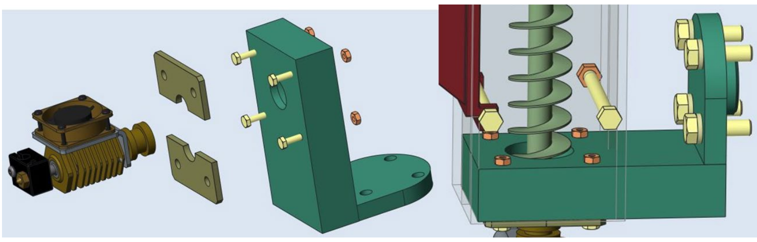

Fig.4. Connection of holder and hotend

The purpose of the holder is also to attach the head to the robot.

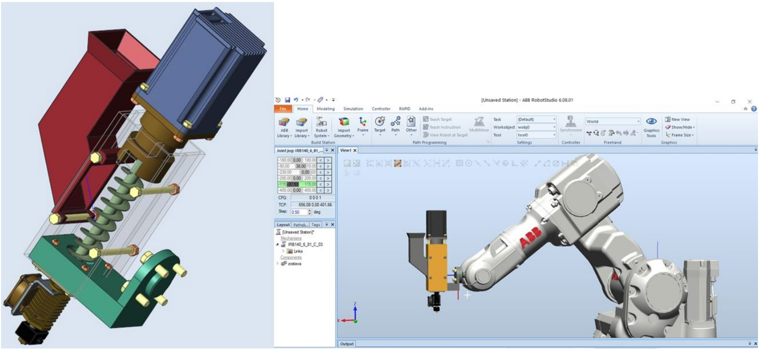

Fig.5. Completed design of the head (left), attachment to ARB IRB 140 robot (right)

3. CONCLUSION

When designing the print head, be sure to pay attention to which material will be used for printing. We also pay attention to the form of the material. For printing with the help of granulate, we need other mechanisms for moving the material than it is with fiber printing. It is important to properly dimension the cooling, choose the drive, the attachment to the robot and the size of the hotend. In this case, all dimensions depended on the type of robot used. Nevertheless, we managed to create a print head that fit exactly on a particular robot. The print head contains all the elements necessary for proper operation. This concept is suitable for the subsequent simulation of 3D printing of a robotic arm.

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genetic algorithm, crossover probability, Kruskal-Wallis, experiment repetition

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THE INFLUENCE OF THE NUMBER OF REPETITION ON THE STATISTICAL EVALUATION DURING GENETIC ALGORITHM TUNNING

Abstract
Genetic algorithms are suitable to solve a large field of problems. During development, it is necessary to be able to compare the quality of different algorithms. The main motivation of this article is to discuss the necessary number of repetitions of the experiment to find a statistical representative quality comparison of different algorithms. The Kruskal-Wallis method was used for statistical comparison of VSP using the makespan. The change of optimization algorithm behaviour was done using different values of crossover probability.

1. INTRODUCTION AND LITERATURE REVIEW

When developing genetic algorithms, it is necessary to be able to compare their quality, for example, the objective function. We can perform for example 10 repetitions, such as an article [1], or 20 such as an article [2], or 30 such as an article [3], and compare the mean or median of the objective function. However, there are methods for such a comparison.
The first step during statistical testing it is necessary to set a proper testing method beginning with the type of data (continues, attributive etc.) together with its distribution (e.g. normality). When testing the normality of the resulting data, an abnormality of the data was found. Therefore, the nonparametric Kruskal-Wallis is used for comparison [4, 5]. *"The Kruskal-Wallis test is a popular non-parametric statistical test"* [6].
One of the possible number calculations indicating the required number of repetitions of the experiment is this [5]:

$$n = \left(\frac{1{,}96}{\Delta}\right)^2 * P * (1 - P) \tag{1}$$

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Where:

n	number of repetitions of the experiment
P	10 %, an estimate of the proportion of defects in the population or process
Δ	5%, the level of required selection accuracy in units of share
1,96	constant representing the 95% confidence interval

When substituted into the equation 1:

$$n = \left(\frac{1{,}96}{0{,}05}\right)^2 * 0{,}10 * (1 - 0{,}10) = 138 \tag{2}$$

However, this source does not specify the application for which the calculation is intended. This is therefore only an initial quick design of the required number of experiments. It does not deal with the issue of multiple comparisons using the Kruskal-Wallis method.
The aim of the paper to discuss the number of experiments needed to obtain statistical certainty using the Kruskal-Wallis comparison method.

2. THE HYPOTHESIS

The number of repetitions of experiments from 10 to 30 is commonly used [1–3]. This article discusses whether this number of experiments is sufficient for a reliable comparison. The evaluation is by the Kruskal-Wallis method at the limit of reliability α= 5%.

H0: 30 repetitions of the experiment is sufficient for a reliable and correct comparison of algorithms using the Kruskal-Wallis method.
H1: More than 30 repetitions of the experiment are required.

3. EXPERIMENT SETTING

The following parameters were used in the experiment: Problem specification is Vehicle scheduling problem (VSP) based on Job shop scheduling problem FT10 with transport times between stations. The first population was created randomly with random key representation [7]. The population size of 100 individuals. The number of computational generations is selected 200. Selection method uses a roulette wheel principle for minimisation problem:

$$P(x_i) = \frac{O_{bw}(x_i)}{\sum_{j=1}^{N} O_{bw}(x_j)} \qquad \text{where } O_{bw}(x_i) = \frac{f(x_i)}{f_{min}} \tag{3}$$

Reproduction method is using 2 parents to create 2 offspring by the uniform crossover with constant probability to exchange genes. The best individuals survived the elimination.
The effect of a 50% change in crossing was compared with other probabilities. Other probabilities of crossing were chosen 55 %, 60 %, 65 % and 70 %.

4. RESULTS AND DISCUSSION

We created a total of e = 10,000 experiments for each algorithm setup. Each set of tests contains n repetition. The number of sets s are given by both experiments and repetition s=e/n. It means

that experiment with e.g. group of 500 repetitions was done 20 times and a group of 2000 was done 5 times. The experiment starts at n=10 repetitions and increases by 10 each experiment (n=10, 20, ... 530, 540,…, 3000).
From this set of results, sets of the required size for Kruskal-Wallis comparison were taken. Each p-value of the Kruskal-Wallis comparison was saved for further processing. For all results of p-values for a given number of experiments in one set, the mean, quartile 25 %, quartile 75 % and min, max value were calculated. These values are entered in the following Fig. 1.

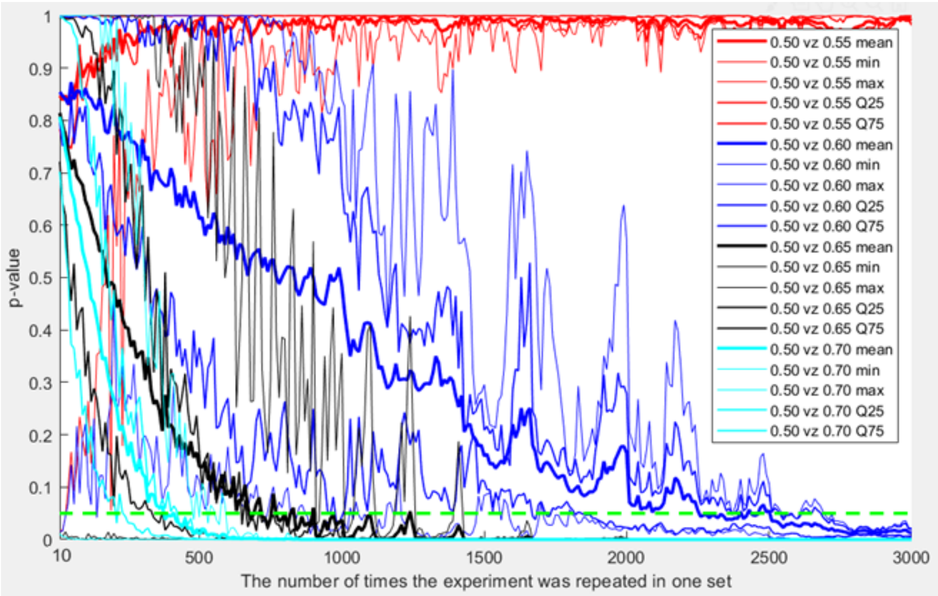

Fig.1. The course of the p-value of the comparison of different settings according to the number of repetitions of the experiment using the Kruskal-Wallis method

Average results for 10.000 repetitions: probability of crossing 50 % = 1014, 55 % = 1013, 60 % = 1012, 65 % = 1010, 70 % = 1009.
The figure shows a green line showing the 5% limit for rejecting the null hypothesis. That is, there is a statistically significant difference between the compared settings.
The average and min-max range of p-values are desitions making parameters to decide a minimal number of repetitions. The example can be the comparison of 0.5 and 0.7 crossover probability with 1000 repetitions where more than 50% of results have p-value range between 0.2 to 0.6. That means some results of p-value (0.2) indicates values not far from suggesting the statistical significance of crossover other is indication complete opposite (p-value=0.6).
Depending on the size of the difference in the results of a given setting, a different number of repetitions of experiments is required. According to the tests performed, the range is from 500 to 3000 repetitions.
Calculating the minimum number of experiments from formula (1) does not appear plausible for this testing. However, the purpose of the application was not sufficiently specified for the formula.

We reject hypothesis H0. More than 30 replicates of the experiment are required for Kruskal-Wallis comparison.

5. CONCLUSION

The research showed that the number of repetitions of the experiment of comparison is crucial for the evaluation of statistical significance by the Kruskal-Wallis method. It seems that for large differences in results, a number of repetitions of the experiment below 500 replicates may be sufficient. In the experimental area, however, 500 repetitions of experiments are at their edge for the largest difference of comparison between 50 % and 70 %. For smaller differences, this amount increases. Even 2500 repetitions of the experiment may be insufficient.
It is important to note that these comparisons have only been tested in one specific area of the whole issue. Globally, it is very difficult to determine a reliable minimum number of iterations.
Future research will focus on comparing these results with other sizes and types of problems to find an influence on a suitable number of experiments repetitions.

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Assembly plan, Risks, Simulation

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INCREASING EFFICIENCY OF THE ASSEMBLY PLAN IN TERMS OF RISKS

Abstract
The article deals with the presentation of the methodology for the protection of the assembly plan in terms of risks that may arise. Risks arise from the company's internal or external environment and have a negative impact on the assembly plan. This can result in the assembly being stopped, the order time is extended, the customer's trust is reduced, or the customer loses. The methodology consists of several modules and the result is the creation of an action plan. The action plan is activated in the event of a risk and mitigates or eliminates its negative impact.

1. INTRODUCTION¶

At present companies must be in good condition and manage flexibly respond to frequently changing requirements of customers. Companies must also be able to respond to unexpected events that may disrupt the production process, or worse, stop production, which may result in reduced customer confidence or loss of customers. Companies need to emphasize production planning and therefore use production planning systems (ERP system Company information systems have their advantages and disadvantages (limitations, price, difficulty and length of implementation in the company). Not every company may be comfortable with the system. In the past, the ERP system was used by large companies, but now the manufacturers of ERP systems also focus on small and medium-sized companies. From 2010, companies should use the ERP III system. It is an ERP system in combination with other systems (modules). The basic core of ERP III is the ERP system, SCM system (Supply Chain Management) and CRM system (Customer Relationship Management). These modules have been added the cloud infrastructure, working through social networks with customers, potential buyers, product experts, suppliers, potential suppliers, partners, potential partners, potential employees, and other categories of people with whom we need to communicate. ERP III is designed to create businesses without

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borders. Online interaction in social networks and online business platforms allows companies to respond dynamically to emerging opportunities and challenges, creating a flexible structure based on business processes and projects. The advantage of the cloud is that the ERP III system is not physically installed but sharing is used, and in terms of the data produced by the company, it is less costly to buy space in the cloud than to buy physical storage than it is with data forces. Although ERP III uses industry 4.0 technologies, there is still a lack of a module to identify and analyse the risks that may arise and to develop action plans for these risks. In the event of risks, action plans to eliminate or mitigate the negative impact of those risks would be activated. Only in ERP V (from 2030) is artificial intelligence assumed to handle this task.
Therefore, a methodology is currently being proposed to protect the assembly plan in view of the risks that may arise. This methodology would be used after the assembly plan has been drawn up. The basic methodology will be briefly described in the next chapter. [1,2,3,4]

2. METHODOLOGY FOR PROTECTION OF THE ASSEMBLY PLAN

The methodology for the protection of the assembly plan is proposed due to the fact that companies currently lack critical thinking and adaptability in the event of a sudden risk. In some cases, companies forget that there may be a risk, whether from an internal or external environment. Some companies do not take these risks into account when creating the assembly plan, and in the event of a risk, the assembly may be stopped, which will delay the completion of the order and possibly reduce the customer's confidence or loss.
The task of the methodology will be to use modules to create an action plan, which is activated in the event of a risk and mitigates or eliminates its negative impact. In Fig. 1 shows the state of the assembly plan without the application of the methodology (a) and the expected state after the application of the methodology in the event of a risk (b).

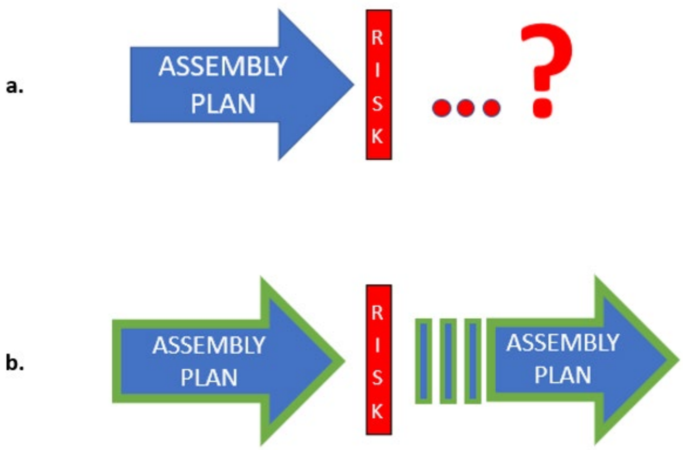

Fig. 1 Assembly plan before and after using the methodology

Currently, in some companies, in the event of an unexpected risk (for example, failure to supply the necessary material), assembly is stopped and the company finds out what to do in order to return back to production. As the company finds out how to proceed, it loses its time needed to complete the order. In some cases, this unexpected cessation of production (assembly

workplaces) can take weeks, depending on the available capacity of the company and the speed of the company to respond to the event (Fig. 1 – a).
If the company uses a methodology that is proposed or already contains potential risks and ways to deal with these risks during the preparation of the assembly plan, the company would be able to respond immediately in the event of a risk. The company should be guided by what needs to be done and who is responsible for it. The overall assembly plan would slow down but not stop. The company would try to make the most of this restriction until the impact of the risk is removed and the plan is in its original condition (Fig. 1 – b).

2.1 Proposed methodology

The core of the proposed methodology consists of three modules Fig. 2. Each module will consist of individual processes that must be performed to successfully complete the main module, and another module can be accessed.
The **Risks module** defines the risks that can jeopardize the assembly plan. Whether these risks are defined by the company itself on the basis of historical data or it uses studies that have defined the most common risks.
In the **Simulation module**, a simulation project is used and to create a simulation model of the assembly workplace (or assembly workplaces according to the company's requirements) and risk experiments are created. Based on the results of the simulation, the company will know approximately what impact the risk will have on the assembly (assembly plan). Then the measures are proposed, which are simulated and from the obtained results we proceed to the last **module Action plan** in which the action plan will be created. The action plan will describe how to proceed in the event of a risk (what is to be done, who is responsible for it and the time to individual actions).

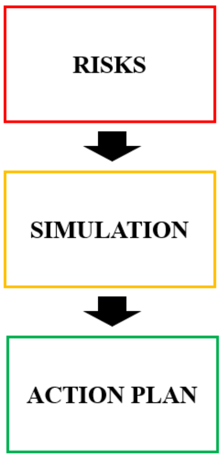

Fig. 2 Main modules of the proposed methodology

3. CONCLUSION

The article deals with the presentation of the proposed methodology for the protection of the assembly plan in terms of risks that may occur. These risks have a negative impact on the assembly plan and threaten to stop production, which may result in the loss of the customer. At present, companies must be in good shape and must be able to react immediately to risks that may jeopardize production and take these risks into account at the planning stage.

The proposed methodology consists of three main modules which are briefly described in subchapter 2.1 Proposed methodology. The methodology will be applied to the created assembly plan and will be used to create action plans to prevent the assembly plan from being stopped in the event of a risk.

Further research will elaborate on the individual modules and create the necessary links between them. A module will also be designed that will respond to the risk that the company did not anticipate at the beginning of the proposed methodology in the Risks module.

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Knowledge bases, production knowledge, production engineering, knowledge acquisition, production processes

Marcin MATUSZNY[1]

ALGORITHM FOR ACQUIRING KNOWLEDGE IN A PRODUCTION COMPANY

Abstract

The article presents the algorithm used to acquire knowledge as one of the methods that is focused on building a knowledge base for processes taking place in a manufacturing company. Development of the method begins with determining the basic stages and decision problems, starting with observation, through the creation of an appropriate teaching set in the field of technical preparation of production, and ending with the construction of rules and dependencies, which at a later stage of research can be used to build knowledge bases, and also creating an advisory system.

1. KNOWLEDGE AS THE FOUNDATION OF KBS

The current state of KBS technology is still in the development phase, which is affected by many changes, trends of the Industry 4.0 era, and even cultural factors beyond the scope of technology. The current development phase makes the AI department incredibly attractive in scientific terms. Nevertheless, the results so far, combined with exciting advances on the horizon, give us confidence that KBS and knowledge processing will continue to grow rapidly over the next few years. [1].

Production knowledge is a specific type of enterprise resources. Thanks to the knowledge accumulated in the company, it is possible to introduce changes that streamline 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 [2].

In the area of this management, key processes are identified, such as: locating, acquiring, developing, disseminating, using and preserving knowledge [3]. Current research in the field of knowledge acquisition includes attempts to implement elements of artificial intelligence in knowledge management systems. These studies are focused mainly on the strategy of knowledge codification [4]. However, this is too general an approach for knowledge management practitioners to be able to proceed directly to implementations on this basis [5].

2. APPLICATION OF THE KNOWLEDGE ACQUISITION ALGORITHM IN A PRODUCTION COMPANY

Before a knowledge base can be build, it is needed to get this knowledge from an expert. Well acquired knowledge is an introduction to a good expert system. It can be obtained in two very

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different ways. One of them is acquiring knowledge from data using algorithms or artificial intelligence tools. The second is the aforementioned method, which is acquiring knowledge directly from an expert, based on skillful cooperation with people. The presented algorithm is helpful in building decision trees from which rules are then created. Thanks to the Quinlan algorithm it can be specify the order of attributes selected when building a decision tree, the order of these attributes has a significant impact on the level of expansion of a given tree, and it is important to remember that it is better when that decisions tree is less developed [6]. This algorithm can be used when each of the objects that make up the data is characterized by a set of attributes and can belong to one of the classes.

X is the set of objects from previous observations: $X = \{X_1, X_2, X_3, X_4, ..., X_n\}$. Each of the elements of the set x is determined by a set of Y attributes, each of which assumes a value from a finite set: $Y = \{Y_1, Y_2, ..., Y_m\}$.

Let the set of attributes and their values consist of the following elements:

- Quality of the blank = {below standard, standard, above standard}
- Price = {<=5000,>5000}
- Production volume = {Unitary/Small-volume, Medium series/large series}

Objects can belong to one of two classes: A and B. These classes indicate their usefulness or not for certain tasks.

The set X created on the basis of observations is as follows Tab. 1:

Tab. 1. Training set

Price	Quality of the blank	Production volume	Suitability for certain tasks
<=5000	Above standard	Medium series/large series	B
>5000	Above standard	Unitary/Small-volume	A
>5000	Standard	Medium series/large series	B
<=5000	Standard	Medium series/large series	B
<=5000	Below standard	Medium series/large series	A
>5000	Below standard	Medium series/large series	A
>5000	Above standard	Medium series/large series	B
>5000	Below standard	Unitary/Small-volume	A
<=5000	Above standard	Unitary/Small-volume	A

The decision tree that was built based on the above data is shown in the Fig. 1 below.

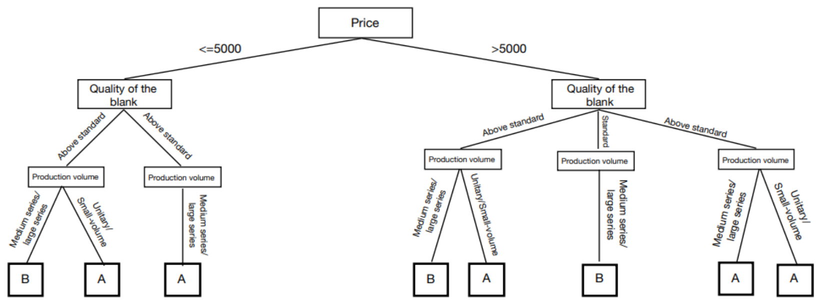

Fig. 1. A decision tree built on the basis of the initial data set

Eight rules can be generated from the above tree. The first of them reads: IF price <= 5000 AND quality of IS blank above standard AND production volume IS medium / large series THEN class = B

Others can be read from the decision tree above. Among these data are hidden simpler rules that allow to discover the presented Quinlan algorithm.

First, it is necessary to calculate the entropy of the n-element set. Entropy is a measure of information contained in a phenomenon that can take n states. Marking p_i - the probability of the appearance of the i-th element of the set, entropy is determined by the formula:

$$\boldsymbol{I = \sum_{i=1}^{n}(-p_i log_2 p_i)} \tag{1}$$

Calculation example: The probability that the object belongs to class $A = 5/9$, the probability that the object belongs to class $B = 4/9$.

$$I\ (n_{w1},\ n_{w2}) = -5/9 * log_2(5/9) - 4/9 * log_2(4/9) = 0{,}99943$$

Entropy is very high, which means that the system contains almost full information and it can be look for rules that govern data.

The next step in the algorithm is to find the amount of information that is contained in each of the attributes found in the data set. Entropy of the attribute Y_k in the set X is calculated according to the formula:

$$\boldsymbol{I(X/Y_k) = \sum_{j=1}^{M_k} p(y_k, j) * [-\sum_{i=1}^{N}(p(x_i\ /\ y_{k,j}) * log_2\, p(x_i\ /\ y_{k,j}))]} \tag{2}$$

Where:

M_k - the number of values that Y_k takes

N - number of classes

K - number of attributes

$P\ (y_k, j)$ - probability that y_k will take the value of j

$P\ (x_i\ /\ y_{k\ j})$ - probability of occurrence of class x_i when $y_k = j$

Calculating the entropy of the price attribute:

Of the nine described objects, four of them have a price not exceeding 5000. The probability that the price will be <= 5000, is:

$$P(price<=5000) = 4/9$$

However, the probability that the price will be >5000 is:

$$P(price>5000) = 5/9$$

Then calculate the probability of occurrence of individual classes, provided that certain price values are accepted. In the data set, it is necessary to count how many objects have a price <= 5000 (4 objects) and how many of them belong to class A (2 objects), and how many to class B (also 2 objects), thus it results that:

$$P(A/price<=5000) = 1/2, \qquad P(B/price<=5000) = 1/2$$

Similarly, consider how many objects belong to classes A or B when the price is > 5000

$$P(A/price>5000) = 3/5, \qquad P(B/price>5000) = 2/5$$

It can be now count the entropy of the *price* attribute:

$$I(X,\ price) = 4/9*(-2/4log_2 2/4-2/4log_2 2/4)+5/9*(-2/5log_2 2/5-3/5log_2 3/5) = 0{,}983861$$

The entropy of the other attributes was calculated in an analogous way:

$$I(X,\ quality\ of\ the\ blank) = 0{,}44444, \qquad I(X,\ production\ volume) = 0{,}612197$$

The next step is to calculate the information increment entered by each attribute. The increase of the Y_k attribute information is given by the formula:

$$\Delta I(Y_k) = I - I(X/Y_k)\Delta I(Y_{price}) = I - I(X/Y_{price}) = 0{,}99943 - 0{,}983861 = 0{,}01557$$

The price attribute is a negligible amount of information for the entire system.

$$\Delta I(Y_{quality\ of\ the\ blank}) = I - I(X/Y_{quality\ of\ the\ blank}) = 0{,}99943 - 0{,}44444 = 0{,}55499$$

$$\Delta I(Y_{production\ volume}) = I - I(X/Y_{production\ volume}) = 0{,}99943 - 0{,}612197 = 0{,}38723$$

The largest increase in information is associated with the attribute quality of the blank and from that it should be start building a decision tree. The second most important attribute is the production volume attribute. The new decision tree, built based on the presented algorithm, is presented in Fig. 2 below.

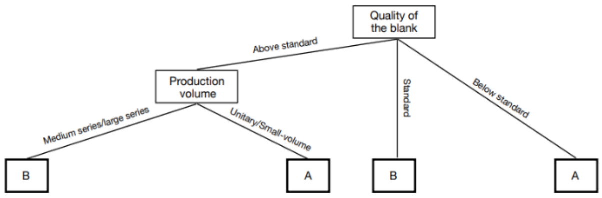

Fig. 2. Decision tree after taking into account the results of the Quinlan algorithm

Four simple rules were obtained from the data:

Rule 1.: IF quality of the blank IS above standard AND production volume IS medium/large series THEN class = B, **Rule 2.:** IF quality of the blank IS above standard AND production volume IS unit/small series THEN class = A, **Rule 3.:** IF quality of the blank IS standard THEN standard class = B, **Rule 4.:** IF quality of the blank IS below standard THEN class = A.

3. CONCLUSION

Key knowledge management processes, including acquiring knowledge together with the relationships that occur between them, allow for the systematic transformation of information, knowledge, experience, skills and competences into intellectual capital. As a result, the company can gain a competitive advantage, reduce production costs and optimize production processes. The presented application of the Quinlan algorithm made it possible to discover dependencies in data and formulate simple and legible rules.

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3D printing, PCL/HA/TCP, mechanical testing, porous structures

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MECHANICAL EVALUATION OF POROUS STRUCTURES CREATED BY ADDITIVE MANUFACTURING

Abstract
This paper provides the process of production of porous structures which were created from composite material Polycaprolactone (PCL), Hydroxyapatite (HA) and Tricalcium Phosphate (TCP) by using fused deposition modeling technology. Subsequently the samples were subjected to mechanical pressure testing to obtain the overall mechanical characteristics of the investigated material. The paper includes analysis of materials and methods of additive production, regarding the appropriate production of porous samples with aim to replace human hard tissues.

1. ANALYSIS OF THE CURRENT STATE OF TESTING POROUS STRUCTURES FOR HARD TISSUE REPLACEMENT

Bone tissue consists of two different structures the cancellous and the cortical bone. The cancellous tissue that forms the inner part of the bone is naturally spongy with 50 % - 90 % porosity. The cortical bone forms a dense surface layer of bone with less than 10 % porosity. Based on study from author Rho et al. the Young modulus (E) of cortical bone is 18,6 – 20,7 GPa, trabecular bone is 10,4 -14,8 GPa. Yang et al. measured that the effective modulus vertebrae disc is 5,8 – 42,3 MPa. Bone tissue has the ability to self-heal, but large-scale bone defects are not able to be completely cured by the body, and in most cases external intervention is needed to restore the basic function of the tissue. There are various options for replacing damaged bone tissue such as: Autograft (bone taken from the same patient's body), Allograft (bone tissue obtained from a donor), Xenograft (a transplantation of the tissue from a donor of another species). Bone tissue engineering deals with methods of synthesizing and regenerating bone to restore, maintain or improve its function in vivo. Scaffolds are an integral part of bone tissue engineering. They are three-dimensional biocompatible structures that can mimic the properties of the extracellular mass of bone, namely: mechanical support, cellular activity, and protein production through biochemical and mechanical interactions [1-3].

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1.1 Basic parameters of porous structures

Interconnected porosity is important for continuous overgrowth of bone tissue. The open and interconnected pores allow nutrients and molecules to penetrate the inner parts of the scaffold to facilitate cell growth, vascularization, and waste material removal. A minimum pore size between 100 and 150 μm is required for new bone to form. However, faster bone formation and vascularization are reported for scaffolds with a pore size greater than 300 μm. The size of the pores also greatly affects the formation of the extracellular mass and its arrangement. The effect of pore arrangement on the dynamic stability of scaffolds is currently being considered. Author Gong et al. performed a stress-controlled fatigue test to study the cyclic stress loading of porous PLA scaffolds with triangular and circular pores with 60 % porosity. Circular pore scaffolds have shown better fatigue resistance to cyclic loading than opposite triangular pores at moderate levels of cyclic loading. The strength of the scaffold increases as the pore size or density decreases. The maximum strength of 10.95 ± 1.28 MPa was found in scaffolds with a pore size of 500 μm, a porosity of 42% when sintered at a temperature of 1250 ˚C in a microwave oven for one hour. [3-6]

1.2 Materials used in the production of porous structures by 3D printing technology

Many natural materials are currently used in the manufacture of spacesuits using 3D printers such as alginate, chitosan, collagen, and hyaluronic acid, which are often of better quality than synthetic materials due to their natural biological functions. These natural materials show better biological activity in cell proliferation and differentiation than synthetic materials. On the contrary, synthetic materials show better mechanical strength, higher machinability, and easier controllable degradation than natural materials. To overcome these limiting factors, new composites are formed by a combination of natural and synthetic polymeric materials. The aim is to obtain a combination of advantageous properties of both materials [7].

2. METHODOLOGY OF TESTING

2.1 Used materials

PCL has an unusually low glass transition temperature of -60 ° C between bioresorbable polymers. It has a low melting point of 60˚C. Another feature of PCL is its stability at high temperatures. While the other aliphatic polyesters tested had a decomposition temperature Td between 235 °C and 255 °C, PCL had a Td of 350 °C. Mechanical properties of rigid PCL: tensile strength 16 MPa, tensile modulus 400 MPa, flexural modulus 500 MPa. Hydroxyapatite (HA) is calcium phosphate, its chemical formula is $Ca_{10}(PO_4)_6(OH)_2$. It is a ceramic material, especially the mineral form of calcium apatite. It occurs naturally inside the human body, showing good biocompatibility [8-9].

2.2 Sample design, production, and mechanical testing

The models that were printed were designed in SOLIDWORKS CAD software based on the ISO 604 standard with dimensions of 20 mm x ø 10. The modeled samples were divided into three groups: with a full internal structure, porous with 50 % infill and porous with 33.3 % infill. The samples had a solid outer shell and an inner porous structure except for the solid samples. The production of samples was realized on a 3D printer TRILAB, which works on the principle of FDM technology. After printing the samples, compression analysis was performed on an Inspekt 5 Table Blue machine. The mechanical analysis consists of a compression test performed on PCL-HA-TCP samples with a diameter of 10 mm and a height of 20 mm and 0˚ / 90˚ deposition of the pattern. The result will be determined the mechanical properties of the composite material of PCL-HA-TCP. According to the Fucile P. study, a compression speed of 1 mm / min is assumed until deformation is achieved at a speed of 0.5 mm / min. This value corresponds to 50 % deformation, which is much higher than the typical level of bone deformation. Based on this study, the same rate was chosen to determine the complete material characterization.

3. RESULTS

From the static pressure test were obtained the values Tab. 1 of compression module and stress for the given types of porosity

Tab. 1 Values of tensile strenght and tensile modulus of porous samples created by FDM technology

Samples	**σ [MPa]**	**E [MPa]**
33 % infill	13,96 ± 1,09	20,73 ± 3,18
50 % infill	23,20 ± 3,77	34,69 ± 6,58
100 % infill	28,53 ± 1,15	50,14 ± 2,02

Based on the calculations, it was possible to determine that with increasing pore size, the resulting values of compressive stress as well as the values of the compression modulus decrease. The highest values of pressure stress were reached by samples with 100 % infill. On the contrary, the lowest values of stress in cross section were reached by samples with 33 % infill.

4. DISCUSION

The largest variance of values was recorded for samples with 50 % infill, which could be affected by the selected 3D printing technology. Of the produced samples, the samples had the largest pores with a 33 % infill but showed the lowest values of mechanical properties. Additional comparison of the results with available scientific studies is difficult as there are few studies that deal with the mechanical compressive stress of PCL/HA/TCP. In addition, the shape and size of the samples, the printing technology, the chosen porosity, the mechanical testing procedures affect the resulting mechanical properties. This composite material is very promising for spinal bone implants.

5. CONCLUSION

This paper provided a comprehensive overview of the design, manufacture, and mechanical testing of composite samples from PCL/HA/TCP materials. The determined mechanical properties indicated the suitability of the application in bone tissue engineering. As the mechanical properties of the material must correspond to the properties of the replaced area, this material is suitable for the replacement of cartilage or vertebrae, which opens the possibility of further research in the future.

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advanced industrial engineering, new manufacturing concepts, competence islands

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CONCEPT OF COMPETENCE ISLANDS

Abstract
The article describes competence islands the new manufacturing concept for the factories of the future. The first part of the article describes the current changes to which the world takes place and approaches that are developed for production to cope with these changes. The second part of the article is devoted to describing the concept of the competence islands that will be used in the factories of the future by companies in personalized production.

1. INTRODUCTION

Changes in the world are now becoming more frequent and visible, especially in terms of customer requirements. The exponential increase in technology creates the importance of the environment in which the technological modernity of today's products are already obsolete technology tomorrow. The customer today has the choice of many products. Today, markets are characterized by high product precision, creating an environment that encourages innovation. The principle of customization is now used to cover various customer segments. However, it is increasingly beginning to talk about personalisation as a future of production, especially with high added value. Personalization is a trend that the current manufacturing systems must react to. The process of personalisation begins to discover the problem of high product variability, with which current manufacturing systems cannot cope. This problem translates into costs, with the growth of product variations rising costs. This is why there is a demand for developing new manufacturing concepts capable of rapid response to the ever-changing demands of customers. Thus, as the development of computational performance has brought the possibility of the realization of computer simulation and digital enterprise, the development of technology for data collection and processing in real time creates the foundations for the virtual enterprise. The newly emerging concepts are being driven by the development of technologies that can be managed in real time. Future concepts are calculated using a multi-agent control system in which production is decentralized and autonomy of agents allows to represent complex relationships similar to the social system. All new manufacturing concepts strive to meet one of the main objectives, and thus adaptability, the ability to react immediately to rapid changes in the environment, also referred

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to as turbulence. To meet the requirement of adaptability, it is possible to approach several ways, so scientists have developed, develop and test a whole group of new manufacturing concepts such as reconfigurable manufacturing systems, competence islands, multi-agency control systems, etc. For production, in which there is a high variation of products created by the Configurator, the concept of the competence islands is developed, which replaces today's "hard" production and assembly lines. In the context of Industry 4.0 the system of competence islands which used intelligence system elements like autonomous robots are connected through Internet of Things and for final decisions is used simulation. The competence islands are autonomous workplaces which have no fixed link to each other. The production line is made up dynamically, virtual so-called. "Virtual production line" based on the actual needs and requirements of the product. The product becomes the service applicant and the competence Islands by the service provider in which the route is chosen by the product itself.

2. CHANGES IN MANUFACTURING ENVIRONMENT

The production environment is characterized by constant changes due to turbulent market environments as well as paradigm changes. Modern society and technology produce an impatient customer. He is looking for constantly new products with better features, improved functionality and the possibility of product customization. In the result many manufacturers meet with the necessity to react quickly to constantly changing conditions [1]. In the past, businesses have addressed these changes in an extensive form, based on a delayed response to change [2]. The new progressive approach consists in applications of systems that are capable of rapid response to change while meeting the changes in the Time-Based Competition (TB). Under time competition, we understand the changes that on the one hand put pressure on the customization of products, making markets more heterogeneous and the life cycle of products is shortened. This is reflected in the requirement to reduce the time for product development and marketing (Time to Market). On the other hand, there are changes in new technologies and materials that lead to pressure on innovation, which is reflected in the constant effort to configure the production base [3]. In the global markets of the present and future, the launch time becomes the most important competitive advantage. How production is capable of producing and producing a wide range of constantly changing products directly influences the competitiveness and sustainability of the business. To provide this benefit to businesses, new approaches are emerging which are intended to address the TBC problem. Some of them are:

- Quick Response Manufacturing (QRM).

- Reconfigurable Manufacturing Systems (RMS).

- Competence Islands (CI).

- Reconfigurable Logistics System for Factory of the Future (RLS_FoF).

3. COMPETENCE ISLANDS

The Competence Islands (CI), as a system, are based on a decentralized control system in which each agent in the system knows its function. They are designed as small, highly flexible production units, which are deployed where there is sufficient real demand. Such manufacturing systems will be proposed for the production of the selected product family, which requires their concept to be built on the principles of reconfigurable manufacturing systems [4]. The competence islands can be imagined as cells capable of carrying out certain activities (competencies). Their task is to provide the service of the manufactured product in such a way that the product is complete after the execution of the operations on several competence island. The CI is not connected to any other device by a similar conveyor. However, they have the ability to communicate with their surroundings. The product agent is in this case a message as a customer and forms its own path called virtual production line. The decision-making agent of the product on the route being created is in decision points, in which the agent of the product, based on a number of indicators and negotiation, chooses its path. In such a system, many agents representing physical objects will move. Each agent will be guided by a strict logic of the parent level, which allows for relatively autonomous behavior. The function of the competence islands is to ensure the performance of the service for the product being developed. In order to meet such a requirement, it is necessary that at the time of arrival of the product the competence island should be met with the requirement for the assembled material, with the required technology, and the required service, where appropriate, by a specialized operator who is able to perform the requested action. The work of the competence islands is a high level of flexibility and efficiency. The transport is used by mobile robots, which are capable of transporting the product between the different competence islands. Manufactured products, production facilities and mobile logistics means are smart and communicate with each other together. In real time, they will exchange and share all the necessary data and information. The required operations and their order are chosen by the product itself on the basis of an assessment of indicators and negotiation with other products. Production in the concept of competence islands is an agent of production. This allows the autonomous behavior of the elements of such a system to be implemented. To achieve full synchronicity the coordination and communication of autonomous transport system and competence islands is used negotiation base on criterion. Such criterion could be availability of workplace, time needed for transport material on workplace, needed time for reconfiguration etc. Future production will seem to be a complete chaos for the outside observer. It will seem that material, intermediate, elaborate production, or mobile robots are moving unplanned, chaotically. However, each of them will be guided by a strict logic of the parent level, which will enable it to be relatively autonomous. In fact, it will therefore be an organized chaos. Fig. 1 show illustration of competence islands.

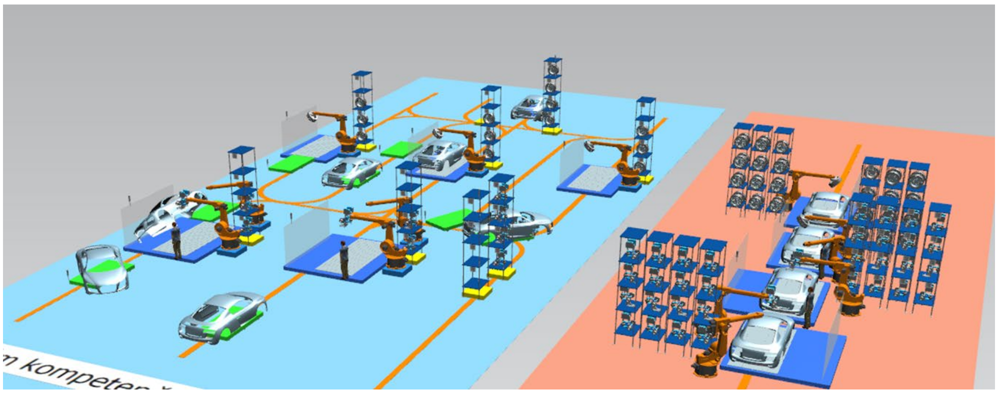

Fig.1. Difference between system of competence island (left) and common bound (right)

4. CONCLUSION

Competitiveness of the companies of the future is based on the satisfaction of customers needs, which are becoming increasingly complex during time. This phenomenon is influenced by new product personalisation trends. In the world at the same time, new technologies are emerging that allow real-time data to be collected and evaluated. These new technologies, together with new more complex customer requirements, lead us to a change in the paradigm of product production and the development of new manufacturing concepts. One of these concepts is also the concept of the competence islands. In the competence islands there is a change in the paradigm of view of the transport of the product in progress, namely that the track of the platforms transporting the product is not firmly given, but the platform is chosen by the runway. The same competence islands act as service providers who only react to product requirements. The competence island allows for a production-oriented assembly, which, compared to the current assembly lines, provides short continuous production times, a wide variation of manufactured products at preserved high quality.

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Scheduling, food manufacturing, dairy production

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INTEGRATED ADVANCED SCHEDULING TOOLS IN FOOD PROCESSING INDUSTRY

Abstract
This article deals with complexity of production scheduling in food production. Planning and scheduling might be considered as strategic division of every production company, many times not covered by any advanced solution. Tight connection between planning and scheduling might be explained as planning is long term vision, when we answer to key question what, when and where we will produce our product.

1. INTRODUCTION

The article describes a scheduling problem by providing information about tasks, resources, and an objective function. However, finding a solution is often a complex matter, and formal problem-solving approaches are helpful. Formal models help us first to understand the scheduling problem and then to find a good solution systematically. For example, one of the simplest and most widely used models is the Gantt chart, which is an analog representation of a schedule. In its basic form, the Gantt chart displays resource allocation over time, with specific resources shown along the vertical axis and a time scale shown along the horizontal axis. The basic Gantt chart assumes that processing times are known with certainty. The scheduler must evaluate the current workload and sequence the work at each machine, making sure that he meets the company’s scheduling objectives such as respecting capacity constraints, respecting material constraints, reducing setup times, respecting priorities of key clients, meeting on-time deliveries, reducing setup times, reducing WIP. In addition to this, the scheduler is responsible for making realistic promise dates. Using the current schedule and

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the previously determined earliest start date, the scheduler determines the promise date of each new order. [1-5]

2. PRODUCTION SCHEDULING IN FOOD PROCESSING INDUSTRY

Food industry is quite broad, as it encompasses notably diverse raw commodities and final products, which consequently entails different transformation processes. Food processing involves transforming a set of raw inputs coming from agriculture, stockbreeding, or fishing into finished food products, and the degree of transformation of the products may range from a selection and packaging of the raw materials to sophisticated processes involving different physical or chemical treatments of the inputs. 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 make adjustments 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. CASE STUDY – DAIRY PRODUCTION SYSTEM

It´s important to understand that each food production consist different set of operations. Food production is many times Make-To-Stock with complex constrains models. We can consider as challanges of food manufacturing hygienic norms, variable cycle times for same operations with raw material differenties. Filling and packing is another challange of food production. There are variations of same product in different size of the package or with diffrenet label. We see in picture below Fig. 1 an example of dairy production system.

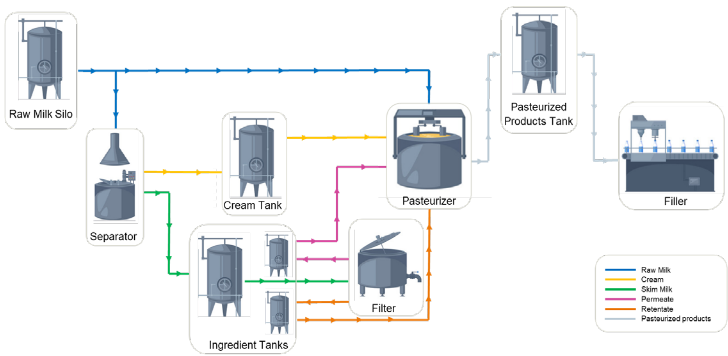

Fig.1. Scheme of dairy production system

Data Model: should be always up to date with production. It is required to have rapid response to change with tight integration and adherence to process and product data. Dairy is quite a unique batch industry with high mix and high variable volumes which requires precise modelling adapting to process complexity. Data model works with Orders, Products, Resources and Constraints. There is a tight connection between the ERP solution and shop floor solution. Whenever scheduler is preparing a plan for the next day/shift needs to take into consideration current WIP status as well as new orders. [6-8]
Constraint Modelling: manages variable and complex routings, setup times and versatility of resources capacity. In Dairy industry as constraint are Tanks/silos and hygienic requirements (Clean in Place). To model constrains properly, it´s necessary to understand available calendars of each separate resource. Clean in place constrain might be consider as setup operation after changing attribute or it might be modelled based on resource level (for example cleaning of some resource each 24 hours). [6-8]
Scheduling: in dairy industry coordinates demands and work orders. Scheduling correctly evaluates material pegging among orders for precise material flow and decoupling point management. We use algorithm scheduling system forward with priorities. When we schedule pasteurization, we take to consideration limited capacity of the tanks. [6-8]

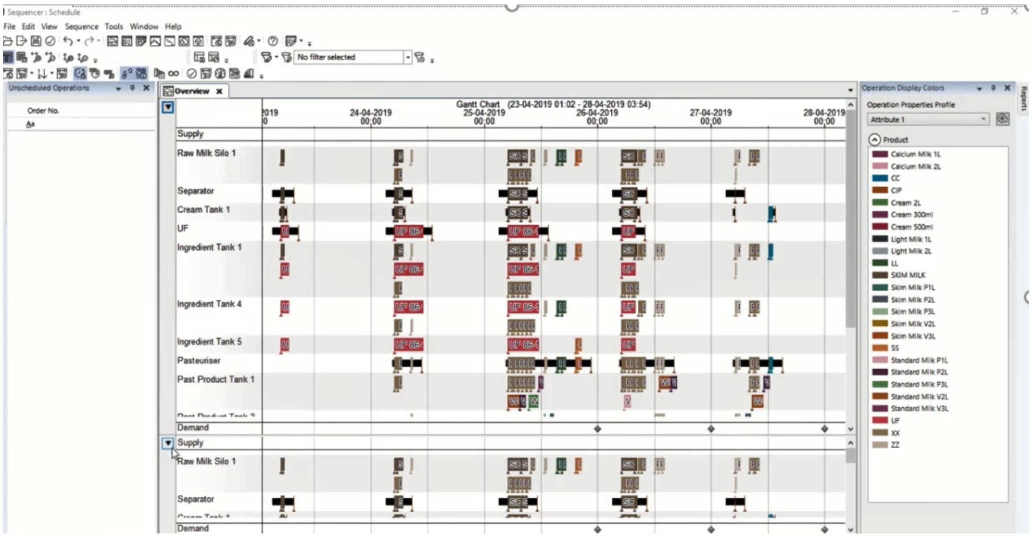

Fig.2. Example of Gantt Chart of Dairy scheduling system will scheduled all operations

What is expected after implementing advanced scheduling solution
Companies which successfully implemented APS solution are declaring faster reaction on orders sequencing (reaction on change). They are saving working times to schedulers (up to 6hours a week). 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. Food process industry is characteristics with changes (raw

material is late, promotion of customer or similar). Only companies with implemented right tools are able to react on change and be competitive.

4. CONCLUSION

Scheduling is the process of balancing demand for products with a company's available resources for the purpose of creating a valid action plan. Demand would include customer orders, stock replenishment orders and samples, while Resources includes machines, operators, tooling, and inventories of raw materials, sub parts, and finished goods. Production planning is nowadays well covered by ERP solutions and we might say, most of SMB to enterprise companies have successfully implemented it. There is different story with production scheduling. Most of the companies were able to move their schedules from scheduling boards to spreadsheets. With characteristics of food processing industry, Spreadsheets are not able to fulfill needs of those companies. Many times, we see that scheduling is overloading planning department and causing from time to time production issues with inconsistent plan. That´s reason why is important to automate scheduling operations with Advanced scheduling tools and centralize it.

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Wastewater treatment, Waste dump, Evaporation technologies

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REDUCING THE VOLUME OF WASTEWATER BY USING RESIDUAL HEAT

Abstract
This article deals with the topic of reducing the volume of wastewater by evaporation. Each liter of wastewater processed in Municipal Wastewater Treatment Plants means costs. On the places like a landfill, there is a possibility to use cogeneration unit residual heat for evaporation process. For this purpose, the methods of evaporation process using the exhaust gases was tested. Efficiency evaluation of various methods is described in this article.

1. INTRODUCTION

Wastewater disposal entails significant financial costs and energy intensity [1]. Each liter must be treated in a Municipal Wastewater Treatment Plants (MWTP). The costs of wastewater treatment increase with the level of its contamination and they are classified into wastewater categories according to the relevant MWTP price list. In the case of specific wastewater such as seepage landfill water, the disposal price can be determined according to the analysis of the disposed water. Nevertheless, it is more advantageous to treat a smaller amount of more contaminated water than a large volume of less contaminated water. Both from the point of view of the costs of disposal in MWTP itself, and from the point of view of wastewater handling and transport.
Reducing the volume of wastewater can be achieved by its evaporation. The method of wastewater evaporation does not purify them but concentrates the waste substances. It is an energy intensive process. However, it offers the possibility of safe disposal of highly toxic wastewater, such as water contaminated with cadmium and other hazardous substances [2].

2. REDUCTION OF WASTEWATER VOLUME BY EVAPORATION METHOD

Reducing the volume of wastewater can be achieved by its evaporation. The method of wastewater evaporation does not purify them but concentrates the waste substances. It is an energy intensive process. However, it offers the possibility of safe disposal of highly toxic wastewater, such as water contaminated with cadmium and other hazardous substances [2].

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The usable mthods of evaporation are natural evaporation tanks, evaporation by forced air flow, injecting boiling water into the air stream, evaporation of water by heating it, evaporation of water using exhaust gases, evaporation using a heat exchanger, heating by heat exchange from waste gases, flash evaporator and vacuum evaporation.

3. EVAPORATION OF WASTEWATER BY USING THE EXHAUST GASES

It has been already mentioned, evaporation of water is an energy intensive process. To heat and evaporate 1 liter of water at 20 ° C is needed about 2600 kJ of energy without considering efficiency. However, if we have a source of thermal energy in the form of exhaust gases, which would otherwise be released into the air, it is a great opportunity to use this energy locally.
As a result of chemical reactions and biological processes, landfill gas containing methanol is formed inside landfills. This gas is commonly used for combustion in so called cogeneration units. Reciprocating engines that consume cleaned landfill gas as fuel and their torque are mostly used to drive an electricity generator [3]. During the combustion process, there is generated a large amount of heat and the thermal efficiency of diesel engines is around 30 % - 40 % [4]. The rest of the thermal energy is removed in the form of exhaust gases and then discharged to the engine cooler.

3.1 Proposed variants of evaporating devices

For the needs of evaporation of seepage landfill water using the thermal energy of the exhaust gases of the cogeneration unit, three designs of the evaporation device were designed. Each of them is based on a different principle and it is intended to determine the efficiency of wastewater evaporation using exhaust gases.

3.1.1 Separate chambers

In this variant is one chamber used for the outlet of exhaust gases. A separate chamber passes through this chamber, into which wastewater is being fed. The exhaust gases heat this chamber and it causes the wastewater evaporation.

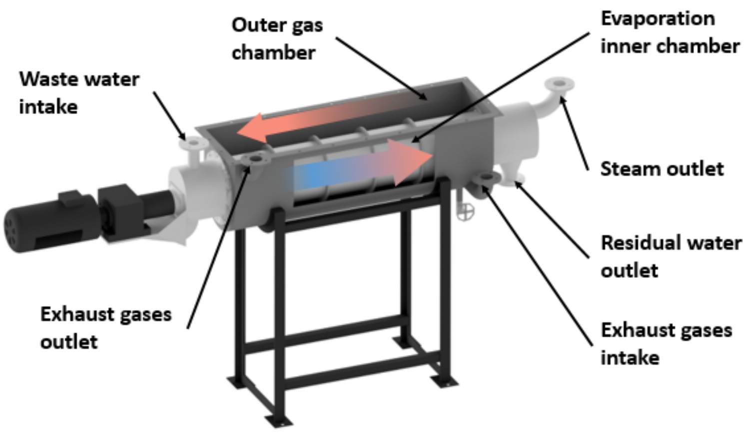

Fig. 1 Separate chambers model

3.1.2 Heat transfer surfaces

In this variant there is a direct contact between flue gases and wastewater. Metal rings are placed in the evaporation vessel, after which the water gradually flows from top to the bottom. Exhaust gas is fed into the vessel from below, which passes through the evaporating vessel, heats the metal rings and leaves the vessel at the top.

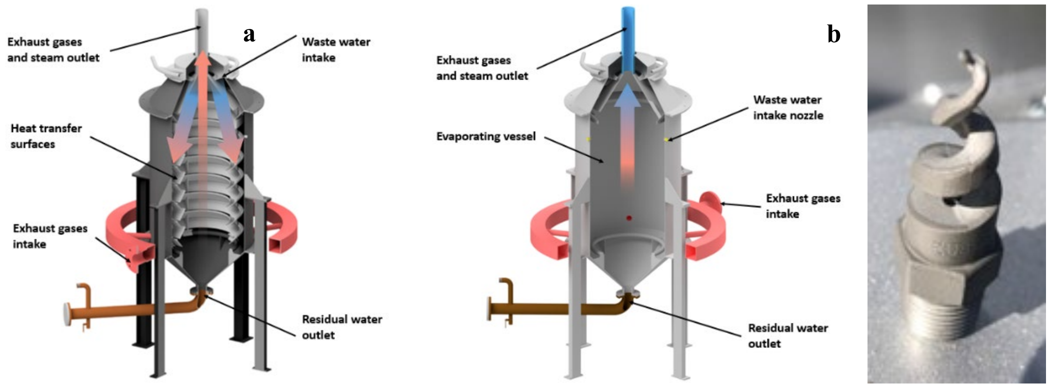

Fig. 2 a Heat transfer surfaces model, b - Spraying into the flue gas stream model and nozzle

3.1.3 Spraying into the flue gas stream

In this design is used the method of spraying wastewater into the flue gas stream. Using a nozzle, the water is sprayed as a mist into an evaporator vessel through which the exhaust gases pass. Thanks to the spraying, the surface of the evaporated water is increased and it is possible to use the heat of the passing gases more efficiently.
It was used the EUS M-B9-6S 120 spiral nozzle with a solid cone spray with a peak spray angle of 120°.

4. TESTING THE EFFICIENCY OF EVAPORATING EQUIPMENT

It was designed an evaporative efficiency test using the exhaust gases of a cogeneration unit. The principle of the test consists in the supply of flue gases to the evaporator, wher the temperature of the incoming gases and their pressure are measured. Thanks to the known cross-section of the exhaust pipe, it can be determined the amount of thermal energy entering the evaporator. Furthermore, there are few recorded parameters: the temperature of the incoming wastewater, its volume at the intake and the volume of wastewater at the outlet. From the difference of these data we obtain the volume of evaporated wastewater.
Ambient conditions during test: ambient temperature: 18 ° C, humidity: 32%, ambient air pressure: 986 hPa.

4.1 Efficiency evaluation

During the test the values of temperature and volume of the incoming exhaust gas to the device as well as the temperature of the incoming waste water differed. Therefore, the data on the total volume of evaporated water are not relevant, but the data on the evaporation efficiency. This is calculated as the ratio between the energy of the incoming flue gas and the energy needed to evaporate the amount of water just evaporated in one hour.

Tab. 1 Efficiency evaluation results

Evaporation variant		Separated phases	Surface evaporation	Sprinkling to flow
Physical quantity	unit			
Pressure p_{ex}	Pa	110	12	12,5
Input temperature T_i	°C	280	215	220
Output temperature T_o	°C	120	90	95
Volume flow V	m^3/h	113,424	207,386	213,115
Evaporated volume V_{H2O}	l/h	1,29	2	4,2
Heat transfer efficiency η	**%**	**16,3**	**15,7**	**31,9**

The phase-separated evaporator shows approximately the same efficiency as the surface evaporation, i.e. about 16%. Spraying into the space is significantly more efficient when the efficiency of the EUS spiral nozzle has been doubled, ie. 32%.

5. CONCLUSION

For the purpose of wastewater volume reducing on the landfill, the study of evaporation methods was presented. From the mentioned methods, the 3 most suitable for use with cogeneration unit exhaust gases were selected. This 3 designs were built and tested for the needs of evaporation of seepage landfill water using the thermal energy of the exhaust gases of the cogeneration unit. First design has separate chambers for exhaust gas and for wastewater. Efficiency of evaporating process achieved under the stated conditions was 16,3 %. Second design work with heat transfer surfaces. This model reach similar efficiency as a first model, 15,7 %. As a last, the model with spray nozzle atomizing the wastewater into the flue gas stream was tested. This solution brings double efficiency in compare with previous two variants, specifically 31,9 %. Thanks to utilization of thermal energy contained in exhaust gases produced by cogeneration unit, the costs on wastewater treatment can be reduced.

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Future production system, Flexible production workplace, Production layout

Vladimir RUDY[1], Peter MALEGA[2]

FUTURE PRODUCTION SYSTEMS AND TYPE MODERNIZATION PROJECTS FOR SMALL COMPANIES

Abstract
This article is oriented on the future production systems, respectively modernization projects for small companies, which are in this time one of the most discussed problems. The first main section deals with future production system. Crucial part of this first section is oriented on the construction of flexible production workplace. The second main section is oriented on type modernization projects of production systems for small companies. Crucial part of this third section is the concept of product development for modernization support.

1. INTRODUCTION

Production companies are under the influence of strong domestic and foreign competition, which is constantly growing with the globalization of the market environment. This situation forces producers to adapt to new circumstances and to respond flexibly to their surroundings.
The focus on customer requirements is crucial for current mechanical engineering development strategies. These requirements are connected to new product functions, the environment, education, humanization of life, production culture, etc. Their satisfaction creates pressure to reduce innovation cycles in product development and production.

2. FUTURE PRODUCTION SYSTEM

Mass-produced products are no longer attractive due to individualized and rapidly changing customer requirements. It pays principle to prepare the right product in the right quality, in the right time and in the right place. Competitiveness is associated with the use of new types of products and their functions, new materials, new technologies as well as information and knowledge.
Competitiveness strategy requires flexible production. It is required [1]:

- Rapid adaptation to new product.
- Fast customer satisfaction.
- High quality.

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• Reasonable price.

The production of intelligent systems is designed on the basis of the customer's individual requirements and also on the minimization of delivery dates.
Designing of such production in the future must become a financial priority, guaranteeing the company a market dominance based on promoting efficient and qualitatively flexible production with minimized delivery dates and real conditions for employment growth. In Fig. 1 is 3D model of flexible production workplace.

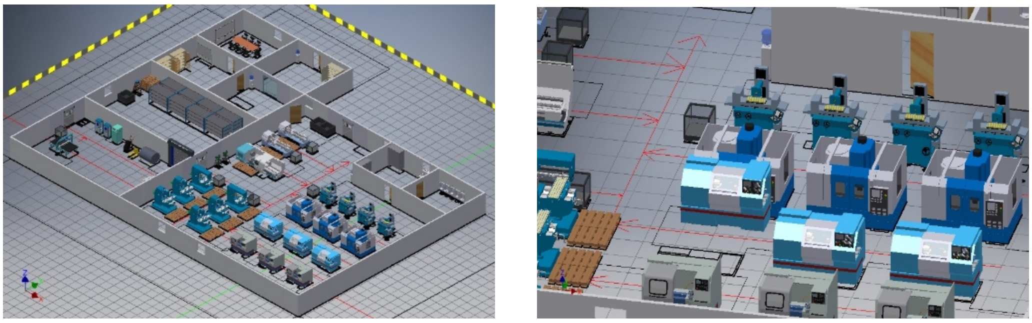

Fig.1. 3D model of flexible production workplace [1]

Coordination of a large number of information and knowledge is necessary to meet individual market requirements. This applies to customer relationships as well as to corporate processes and relationships with suppliers.
To make customer production more effective, the future production system has to have much greater production potential in these areas:

• Technological adaptability of production facilities to changed tasks with minimizing unproductive times.
• Modularity of construction of the means of production guaranteeing:
- adaptability of the production system to very small production batches,
- adaptability to rapidly changing properties of production objects (flexibility of processes, see Fig. 2).

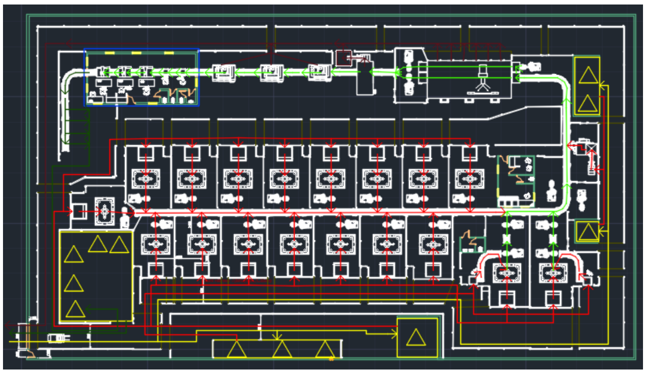

Fig.2. 2D layout of flexible production workplace [1]

- Highly functional integration of various technologies combined with a modular technology configuration guaranteeing the speed of production system transformation.
- Flexible use of the available components of the modified production system at a given moment, including peripheral equipment and handling equipment.
- Opening new forms of cooperation with customers based on the perception of the customer as a co-creator of value added and its participation in product development.
- Transparency of product added value creation throughout whole life cycle chain for customers and also for competitors (producers).

Requirements that are currently being placed on modern mechanical engineering production, oriented on eco-innovation, high productivity and flexibility for small series of produced products, shortening of the continuous production time, increasing the time and performance utilization of machines, increasing the quality of production and products, reducing of warehouses and material stocks, minimizing of production costs, etc., are well known.
Today, in the world recession of mechanical engineering production, flooding the market of the low-cost products of the Asian countries, etc., are a dominant requirements and the decisive factors of the success and future of the company [2]:
- Continuous improvement of product functions.
- Ability to dynamically respond to customer requirements.
- Transformation these requirements into properties of future products in a very short time.

Meeting the requirement to shorten the overall product cycle, from its design to delivery to customer, with the lowest production costs is the most important prerequisite for business success.

3. TYPE MODERNIZATION PROJECTS OF PRODUCTION SYSTEMS FOR SMALL COMPANIES

Typical projects represent a significant reference solution, which can help you in eliminating design disadvantages in terms of cost, preparation time, implementation time, quality, or competitiveness. With their application, you can get the following effects:
- Narrow selection from a set of solution options.
- Achieve higher degree of optimization due to the application of known solution.
- Ensure higher level of unification and stabilization of the production system.
- Ensure consistency of design, implementation and operational approaches.
- Develop the modularity of project solutions and modularity of implementation.
- Create conditions for the development of project process automation.

The concept of product development for modernization support is based on the transfer of knowledge and information databases from the subject area to alternatively integratable, modular, interactive information systems, professionally oriented to the dominant stages of modernization decision making. [6]
Based on the targeted, expected functions of the system, they allow to obtain:
- Interactive selection and input of production system elements and modules.
- Generation of any variants of the spatial solution in the production system.
- Selection of type reference solutions from factographic and information databases, information and project knowledge.

- Comparison of own solutions with type, their optimization and possibility of function simulation, respectively critical modes in system operation.

In Fig. 3 are shown generated layout variants using CAD system.

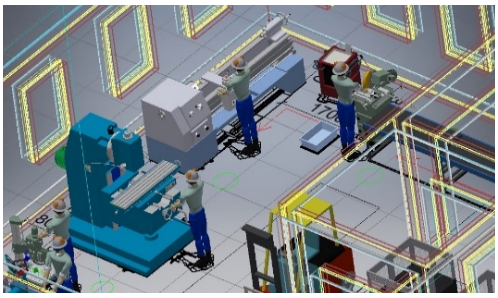
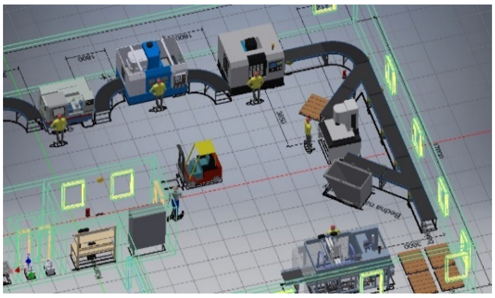

Fig.3. Generated layout variants using CAD system [1]

The creation and realization of the company's development possibilities must be enriched and added by external development forces. Utilization of this support development source are forced through factors such as the growing technical complexity of industrial products, the geometric rises in the costs of R & D of new products and technologies, the rapid increasing in demands for high quality parameters, and other innovative demands that most companies can´t obtain themselves, but they need a variety of cooperatives. Counselling plays a special role here.

4. CONCLUSION

Today, there are many well-known “innovative and prototype parks” of varying degrees in the world. They are no longer oriented just on typical R & D tasks, but also provide prognostic studies; they ensure counselling functions, and project, diagnostic, financial, organizational, training, and other activities that professionally assist in development of business activities.

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Designing production systems, Digital Factory, SMART Factory, Factory Twin

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THE FACTORY TWIN CONCEPT

Abstract
The relevant article deals with the use of the digital twin in the design of production systems. Therefore, the introduction and analysis of the current state of the design of production systems are briefly described at the beginning of the article. Subsequently, the article contains a proposal of basic steps for the introduction of the concept of the digital twin in the design of production systems, i.e. Factory Twin concept.

1. INTRODUCTION

The current design of production systems has undergone several modifications from the classic design, where 3D objects were used in the real world, which was later implemented in 2D, respectively, 3D digital world. We call this concept a digital factory. In addition to the transformation of these objects into a digital world, it was possible to perform various types of analysis that help users create the best required detailed solution in a digital world, which is later applied in a real environment. The concept of the digital twin in the design of production systems consists of the creation of a digital twin of the whole factory, which consists of digital, real and virtual enterprise, which is a fundamental difference between designing production systems in the concept of the digital factory and the concept using digital twin [1].

2. ANALYSIS OF THE CURRENT STATE OF DESIGN OF PRODUCTION SYSTEMS

At the turn of the 20th century, a digital factory solution came to the very digitization of factory design. The digital factory included the digitization of the three most important business areas. These were products, processes, and resources. Manufacturing companies had at their disposal the entire digital production system, which was presented by a set of static, kinematic, and dynamic digital models, which were integrated into a single digital unit, i.e. a digital factory. As a result, production performance could be studied and analyzed before being put into real operation. The database used for decision-making contained results from dynamic

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computer simulations. Therefore, at the beginning of the 21st century, manufacturing companies were confronted with two worlds, real and digital [2].

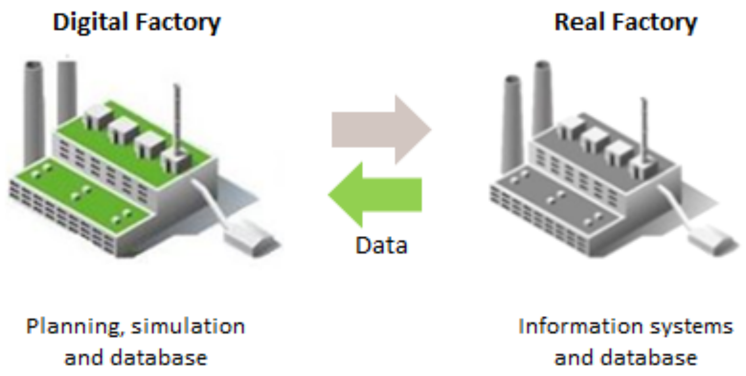

Fig. 1 The concept of the Digital Factory

The CEIT SMART Factory solution, which owns the concept of a digital factory superstructure, extends this concept directly into the virtual world and searches in the virtual world, which is called the digital twin factory. The virtual world is a data representation of the real world of the actual operation. This whole production process takes place in real-time, where it is possible to adapt the production possibilities as much as possible. This is the main difference between designing production systems using the concept of a digital twin and designing in the concept of a digital factory.

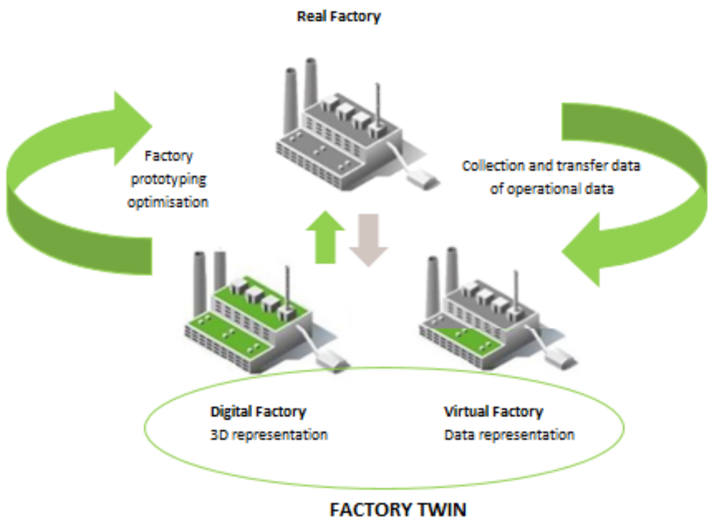

Fig. 2 The concept of the Factory Twin

To create the Factory Twin concept, it is first necessary to create a SMART Factory (Intelligent Factory) which can be used to create all the conditions for collecting, processing, and evaluating data for monitoring production operations and possible optimization of production processes in a real company [3].

2.1 Design of basic steps for the implementation of the Factory Twin concept

To create the methodology of the concept of the digital twin in the design of production systems, I designed a primary flow chart that describes the sequence of steps for the implementation of this concept.

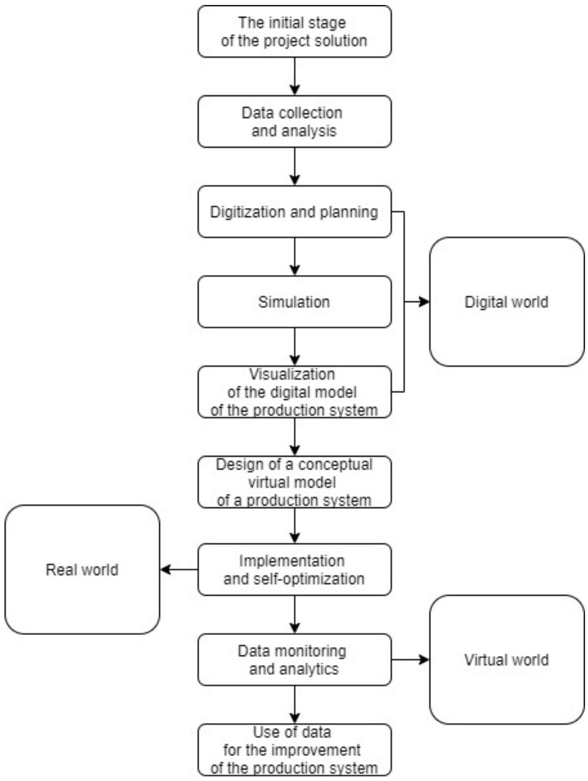

Fig. 3 Design of basic steps for the implementation of the Factory Twin concept

The structure of the methodology for the design of production systems, therefore, consists of the following basic steps:

- The initial stage of the project solution - describes the compilation of the project, its definition, determination of the main and partial goals within the digital factory.
- Data collection and analysis - the main goal of this stage is the collection of input data on the product range, for which a new production layout is to be designed.
- Digitization and planning - creating a digital image of a real business in a digital world, using the tools of a digital business that can enable changes to be made and see their impact before they take effect.

- Simulation - with the help of simulation we can simulate real production and logistics processes in a virtual world, where we can reveal the possibilities for their optimization before the actual implementation.
- Visualization of the digital model of the production system and its subsequent use in virtual presentations and training - with the help of virtual trainers it is possible to prepare employees for the production process in a virtual world, thus saving time for starting new employees in the production company.
- Design of a conceptual virtual model of a production system - is a proposal from which production and non-production parts and by what methods data will be collected from the production company, how they will be transmitted, stored, processed, and evaluated.
- Implementation and self-optimization - after selecting the most suitable solution from all solutions, the solution is applied to the real world. Complex automatic logistics systems are designed up to the design of production lines, where the operation of these solutions is autonomous. These production lines can optimize themselves in real time and communicate with the company's management system.
- Data monitoring and analytics - design of data collection from the production and logistics process and their transfer, where the actual data representation of the operation of the entire production process and its 3D representation will be displayed.
- Use of data for the improvement of the production system - real use of the collected data, which can be used to optimize the production process in the phase of operation, management, and overall improvement of the production system.

3. CONCLUSION

The article describes a brief overview of the current analysis in the design of production systems, which describes the difference between the design of production systems in the concept of the digital factory and the concept of Factory Twin. Subsequently, are described as the methodological procedure for the implementation of this concept and a description of the individual steps.

This work was supported by the Slovak Research and Development Agency under the contract no. APVV-16-0488.

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Industrial Engineering, Digital factory, Software Solutions

Radovan SVITEK[1], Martin KRAJČOVIČ[2], Radovan FURMANN[3]

CEIT TABLE, SYSTEM FOR INTERACTIVE EVALUATION AND CAPACITIVE DIMENSIONING OF PRODUCTION WORKERS

Abstract
Businesses are primarily focused on improving the efficiency of internal processes. Therefore, production plants need a realistic picture of their current status. All this will only be possible through the implementation of new technologies and the transformation of existing factories through digitization. This combination must be based on planning that is currently provided by interactive software scheduling systems. The article deals with the use of software solutions for interactive evaluation and capacitive dimensioning of production workers.

1. INTRODUCTION

Management lacks data, information, methods and tools for clear decision-making. The problem is that planning is based on principles that have been in use for more than a hundred years. In companies, the vast majority of data in electronic form (about 60%) is a problem, however, that the data do not form structural units that could be used for capacity planning and evaluation of production workload.

Other data are collected and evaluated at one-day intervals and stored in paper form in company archives. Their use is very laborious and time consuming. At present, companies also lack a unified software solution for detailed capacity planning of employees, which would be based on data from production processes, linked to specific activities of the production process. The combination of long-defined principles of capacity planning with digitization brings a completely new quality of data needed for decision-making [1].

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1.1 Problems related to the evaluation of the capacity utilization of production workers

At present, the production companies dealing with the production of components for automobiles are experiencing problems related to the evaluation of the capacity utilization of production workers. The main problems are [2]:

- Inaccurate planning due to inaccurate or incomplete data.
- Missing or inconsistent software and evaluation rules, shortcomings in the inform. flow.
- Human mistakes resulting from an insufficient system of work, missing rules, motivation.
- Oversized, undersized capacities (workers, handling equipment, areas, warehouses).
- Problematic data acquisition, insufficient validity and outdated data.
- Undefined or partially defined activities, insufficient overview of material flow.

2. SOFTWARE SOLUTION TO SUPPORT PLANNING

Best methodological procedures, which were at a high level, are today supplemented by new technologies for data processing. Designing and planning actually consists of collecting information, processing it, creating analysis, finding the best design and verifying it. It is an old known methodological procedure, but new technological possibilities give it a completely different dimension and added value [3, 4]. A digital copy of a real system is easier to analyse with a software tool than would have been done in the past.

Ceit Table software solution is a tool for design and planning of capacity utilization of production workers in 3D environment [5]. The system contains functions and work modules through which it will facilitate work and decision-making in the design of production layouts and logistics systems. The capacity planning of employees in this software is based on the very beginning of the processing of input data. The basic input data needed for the analysis of the capacity utilization of workers can be divided into the following categories, data directly related to the machinery:

- Regular activities (activities related to the volume of production).
  - Loading / unloading on a belt, directly into the machine with workpiece clamping, into a pallet.
  - Visual inspection of the part machining.
- Semi regular activities (semi - regular activities).
  - After a certain number of pieces, check the sample (hardening process, etc.).
- Irregular activities (activities that do not change with the volume of production).
  - Service activities at the workplace, cleaning, morning consultation with the manager.
- SMED activity (proportion of sorting time per change, or another time window).
- Autonomous maintenance activities (share of autonomous maintenance time per change).

Data relating jointly to the machinery and the product manufactured (degree of difficulty):

- Measurement according to the test procedure (prescribed activities).
  - Several predefined part measuring points according to the selected product.
  - Measuring the part after changing the cutting tool.
  - Measuring the part after aligning the machine.
  - Measurement of the part after changing the machine parameters.
- Change tools according to the setting plan.
  - Tool change at the end of the prescribed service life.

From the collected data, a digital data model is then created in the software environment, which is supplemented by a 3D Fig. 1 representation of the production space for a better perception of the connections of some data.

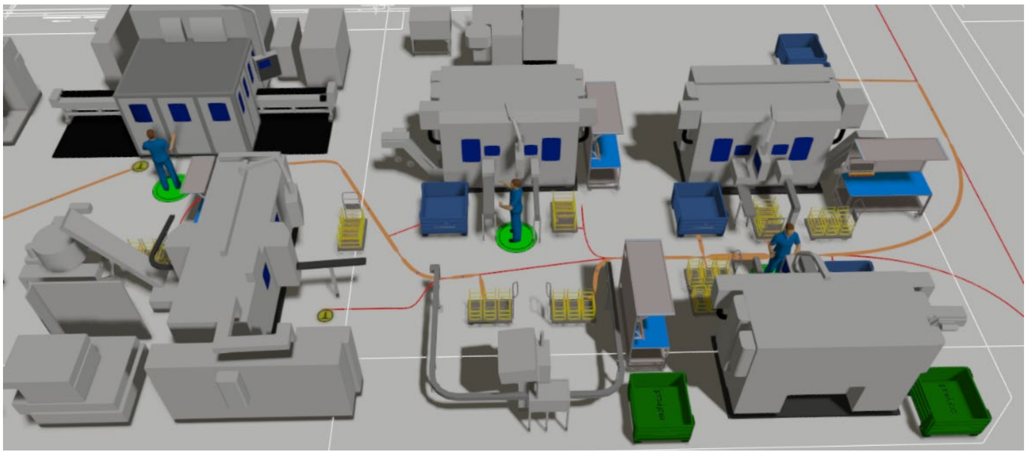

Fig. 1 Virtual representation of production space in a software environment

In this way, it is then possible to directly assign activities to workers according to the production process, multi-machine operation, or the solution of uneven utilization of production capacity. Based on the assigned activities in the technological process, machines for the purpose of multi-machine operation, setting the produced quantity of specific products, the system evaluates the capacity utilization of individual production workers Fig. 2.

At this point, there is a discrepancy between the software evaluation and the opinion of the employee responsible for production capacity planning. After the presentation of all input data, the opinion is concluded that some activities are not prescribed by valid documentation, or they are not clearly quantified in terms of frequency / duration. Subsequently, the question arises of the customer calculation of prices for the product, which does not take into account undefined activities Fig. 4, which ultimately make the released production more expensive and the production company thus generates a loss.

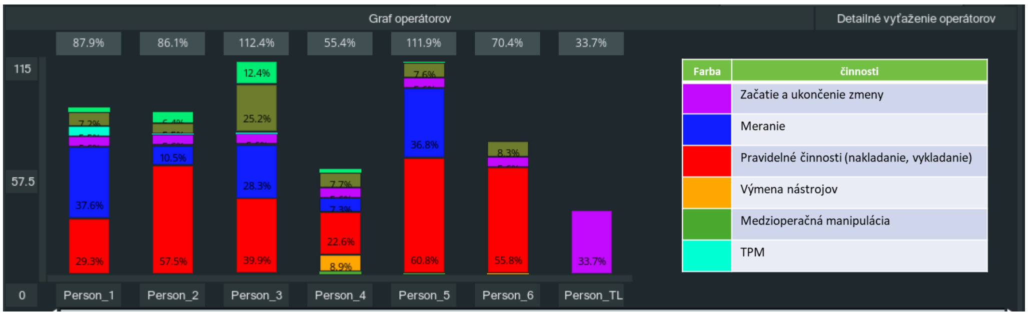

Fig. 2 Capacity utilization of employees by prescribed activities in valid documentation

In Tab. 1 shows the capacity evaluation of the workers of the production stage by the activities defined by the valid documentation. Subsequently, an increase in capacity utilization by activities that do not have a valid agreed regulation, but from the point of view of the process are necessary to comply with the quality set by the customer (absent in the calculation, generating a loss of 28.9 % capacity).

Tab. 1 Analysis of capacity utilization of production workers according to valid documentation

Rank:	According to the documentation [%]:	At the discretion of Team Leader [%]:	Difference [%]:
Person 1	87,9	90,0	2,1
Person 2	86,1	86,1	0
Person 3	112,4	112,4	0
Person 4	55,4	82,2	26,8
Person 5	111,9	111,9	0
Person 6	70,4	70,4	0
Person TL	33,7	33,7	0
		Spolu:	28,9

3. CONCLUSION

New functionalities of software solutions are now necessary in creating and evaluating the design of complex production structures. Software solutions that encourage mutual communication and interaction of individual system objects offer an effective tool for creating a design, which can then be changed without demanding changes to each element of the system. Thus, a supportive design tool with interconnected and communicating elements can provide information and feedback in the process of creating changes for further decision-making of industry organizations. It helps to reveal a discrepancy between the design and reality, quantifies the difference, helps to reduce unnecessary losses of the production company.

This work was supported by the Slovak Research and Development Agency under the contract no. APVV-16-0488.

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3D scanning, 3D scanner, Contactless technology

Peter TREBUŇA[1], Marek MIZERÁK[2], Jozef TROJAN[3],

COMPARISON OF CONTACTLESS SCANNING TECHNOLOGY

Abstract
This paper deals with the issue of contactless 3D scanning and also a comparison of two scanning devices that are used for educational purposes. The scanners that were compared are the Matter & Form scanner and the Sense 3D scanner. The article will define their basic parameters and will describe in detail the individual scanners and determine their advantages and disadvantages. At the end of the article, these scanning devices will be evaluated in terms of several criteria.

1. INTRODUCTION

With the advent of computers, it was possible to create a highly complex model, but the problem arose in making this model. A contact probe was therefore created in the 1980s. This enabled the creation of a precise model, but it was time consuming. Of course, the idea arose to create a system that could capture these precise details in a shorter time, which would make the use more efficient. This triggered the development of optical technology. Using light was several times faster than using a physical contact probe. The use of optical technology also made it possible to scan objects made of soft materials, which could be damaged by the use of contact technology. Contactless laser technology became the main 3D scanning technology, but it soon became apparent that the real challenge for scanning was software for processing the acquired data. To capture a real object in three dimensions, the sensor performed several scans from multiple positions. The challenge was to combine these scans into a single unit and eliminate duplicate and redundant data, which inevitably arises when collecting several million point data at once.

1.1. Contactless 3D scanning technology

Contactless 3D scanning technologies, as the name suggests, do not make physical contact with the surface of the object being scanned. Instead, contactless technologies work on the basis of active and passive object scanning techniques. The result is a cluster of high-precision points that can be used for reverse decryption, virtual assembly, structural analysis, surface and feature inspection, or rapid prototyping.

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<table>
<tr><th colspan="2"></th><th>3D SENSE</th><th>MATTER & FORM</th></tr>
<tr><td rowspan="4">Scanner size</td><td>Height</td><td>17,8 cm</td><td>34,5 cm</td></tr>
<tr><td>Width</td><td>3,3 cm</td><td>21 cm</td></tr>
<tr><td>Length</td><td>12,9 cm</td><td>34,5 cm</td></tr>
<tr><td>Weight</td><td>0,5 kg</td><td>1,71 kg</td></tr>
<tr><td colspan="2">Scanner accuracy</td><td>± 1 mm</td><td>± 0,1 mm</td></tr>
<tr><td rowspan="3">Dimensions of the scanned object</td><td>Max. size</td><td>300x300x300 cm</td><td>25x18x18 cm</td></tr>
<tr><td>Min. sice</td><td>20x20x20 cm</td><td>1x1x1 cm</td></tr>
<tr><td>Max. weight</td><td>-</td><td>3 kg</td></tr>
<tr><td colspan="2">Power supply</td><td>USB 3.0</td><td>100 – 240 V</td></tr>
<tr><td colspan="2">Operating temperature</td><td>10 – 40 °C</td><td>15 – 32 °C</td></tr>
<tr><td colspan="2">Software</td><td>3D Systems Sense</td><td>MFStudio (+Quickscan)</td></tr>
</table>

Tab.1. Basic parameters of used scanners

2. 3D SCANER MATTER & FORM

The 3D scanner from Matter & Form is, in the true sense of the word, a 3D scanner for ordinary user. Its affordability and easy handling are the bridge between professional and amateur 3D scanning. Of course, its compactness is not without certain restrictions, such as the size and weight of the scanned objects. Accuracy scanning is more than satisfactory given the cost of the scanner, but this is reflected in the scanning time. The scanning length of an object of more complex shapes and details is approaching the limit of 60minutes.

3. SENSE 3D SCANNER

Sense 3D scanner is an affordable handheld 3D scanner with relatively high scanning accuracy, which, however, greatly depends on the quality of illumination of the scanned object and its size. The manufacturer also states in the specification the minimum size of the scanned object. The scanner is not able to actually capture smaller objects. Its compactness is a great advantage, but the length of the power cable has paid for it, which greatly limits the manipulation of the scanner.

4. EVALUATION OF THE USED SCANNING TECHNOLOGY

Availability

The criterion of availability greatly influences the overall evaluation of scanners. In case that. Procurement of a scanner is a very complicated process, it significantly affects this factor of achieving the final model. This criterion includes affordability and overall availability. Total availability represents the availability of a particular scanner on the market. The price of the Sense 3D scanner is approximately € 525, the price of the Matter & Form scanner represents approximately the amount of € 730. Obviously, Sense 3D is smaller for the user financial burden. Matter & Form compensates for its worse affordability with better overall affordability. It is supported by the fact that the Matter & Form scanner is significantly larger in the assortments of online retailers representation.

Handling

The manipulation criterion represents the extent to which the operation with a specific scanner is demanding. Provided the scanner operations are simple and intuitive, the scanner will evaluated positively in this criterion. The Sense 3D scanner is extremely easy to prepare for scanning. However, during the scanning operation itself, it is necessary for the userhe focused and devoted himself to the scanner with great precision. In our opinion, this difficulty is possible greatly simplified by using a tripod. The Matter & Form scanner, on the other hand, has a complex preparation process, but the scanning activity itself it hardly requires the user's attention. The user sets them all before starting the scan activity parameters that the scanner then performs independently.

Scan setting options

The criterion for evaluating scan setup options is based on a range of options that individual scan software is offered to us before the actual operation. This criterion is not limited to the number of features that the software offers, but also their effectiveness on the scanning activity itself. The Sense 3D scanner does not offer us before the actual creation of a digital model large selection of options. Most settings apply to the software environment itself. Itself scanning affects the choice of object type, which offers us only 3 options. However, this fact represents a significant reduction in scanner operation complications for the new user. The Matter & Form scanner offers us a significantly greater number of options. Each of these options will significantly affect the scanning process as well as the achieved digital model of the object. Many of these features will greatly extend the time required for a new user's ability use the full potential of this scanner

Time intensity

Time intensity is a criterion that will be of significant importance, especially on the side user. A significant factor is the average time from preparation to complete digital object model. The Sense 3D scanner could be described in this area as a highly dynamic 3D scanner. Scanning all tested objects did not take us more than 30 minutes in any case. Its intuitive operation and ease of setting itself contribute to this fact scanning. The Matter & Form scanner loses significantly in dynamics compared to the Sense 3D scanner. The preparation itself is a lengthy process. The time requirement is also negatively affected by the fact of a large number of choices. Each of these settings affects the duration scan, which the software signals to us by displaying the estimated scan time.

Fig.1. Samples of the models on which the scanners were tested

5. CONCLUSION

3D scanning is one of the most important parts of digitization. Creating quality digital 3D model and subsequent modification in software significantly affects the quality and the speed of innovation. It can be achieved through the effective use of digitization techniques excellent innovation performance.

This article was aimed at creating a comparison of two contactless scanners Matter & Form and Sense 3D, which are owned by the Institute of Management, industrial and digital engineering. Conditions such as availability, handling, scan settings and time requirements were investigated. In terms of experience and overall view, it is worth saying that the 3D sense scanner is at a higher level than the Matter and form scanner.

This article was created by implementation of the grant projects VEGA 1/0438/20 Interaction of digital technologies to support software and hardware communication of the advanced production system platform, KEGA 001TUKE-4/2020 Modernizing Industrial Engineering education to Develop Existing Training Program Skills in a Specialized Laboratory, APVV-17-0258 Digital engineering elements application in innovation and optimization of production flows, APVV-19-0418 Intelligent solutions to enhance business innovation capability in the process of transforming them into smart businesses

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Automation, Digitization, Industry 4.0, Tecnomatix

Jozef TROJAN[1], Peter TREBUŇA[2], Marek KLIMENT[3], Miriam PEKARČÍKOVÁ[4], Štefan KRÁL[5]

DESIGN AND IMPLEMENTATION OF OPTIMIZATION OF THE WORKPLACE FOR THE PRODUCTION OF ELECTRIC MOTORS

Abstract
Digitization opens up new opportunities for manufacturing plants to speed up and streamline production. The role of man is to provide a responsible "smart" infrastructure for modern requirements. Therefore, it is important to understand the impact of digitization on business or the economy, the impact of intelligent technologies on the environment and individual processes. With the help of the Tecnomatix Process Simulate tool, we will model, analyze and verify processes at the level of the production plant up to the level of production lines and workstations.

1. INTRODUCTION

Industry 4.0 is a transition based on data and automation technology that can transform every step of the production process from the supply chain and the enterprise to business and end users. The goal is to increase productivity and innovation and strengthen business in an integrated, data-driven manufacturing environment [1], [2].
In our article, we will focus on the optimization of a selected workplace in a manufacturing company using Tecnomatix Process Simulate software from Siemens. The workplace urgently needed technological and software upgrades, the elimination of some unnecessary tasks and the reduction of a large number of operations. In the mentioned software, we created the current state of the workplace and gradually transformed it into a more modern and economical required state [3].

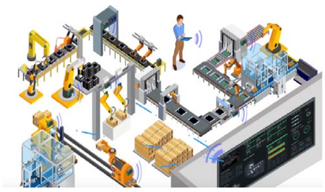

Fig. 1 Smart Factory

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2. COMPARISON OF THE ORIGINAL STATE OF THE WORKPLACE WITH THE NEWLY DESIGNED

From the point of view of innovative technologies, the original state of the workplace is outdated. Many tasks are performed manually here, so reorganization and optimization is required [4]. The workstation for the production of an electric motor consists of 27 operations, marked with the capital letters PI and the corresponding number of the operation. The process of production indicated in this way is from initial inspection, through pressing, testing, curing, gluing, assembly to final inspection. Fig. 2 shows the original layout of the workplace.

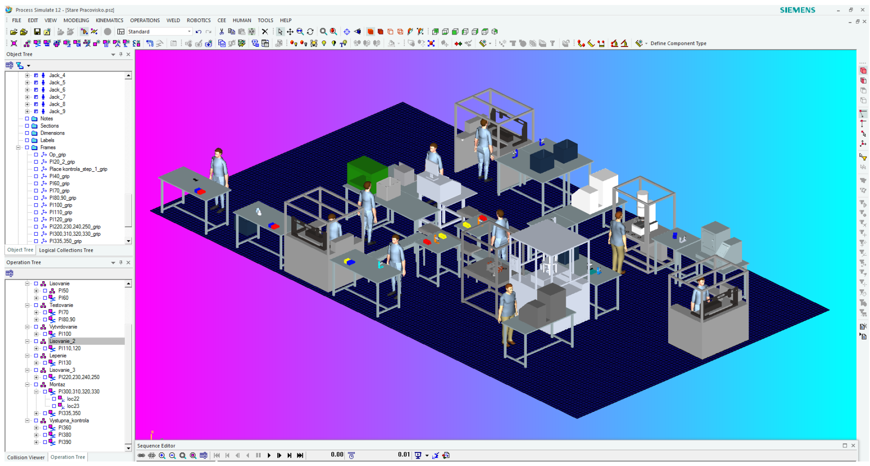

Fig. 2 Original layout of the workplace

In Tab. 1 we can see the respective times during which operations are performed at the workplaces and the total engine production time. The operations that we will then group together are colored in color.

Tab. 1 Duration of individual operations

Operation designation	**Time (min.)**	**PI - 100**	0,0333	**PI - 320**	0,0333
PI - 20	0,7725	**PI - 110**	0,2525	**PI - 330**	0,283
PI – 20_2	0,236	**PI - 120**	0,1801	**PI - 335**	0,0457
PI - 30	0.2390	**PI - 130**	0,0717	**PI - 340**	0,0765
PI - 40	0,268	**PI - 220**	0,1301	**PI - 350**	0,0693
PI - 50	0,1967	**PI - 230**	0,146	**PI - 360**	0,4438
PI - 60	0,1336	**PI - 240**	0,144	**PI - 380**	0,192
PI - 70	0,2813	**PI - 250**	0,2661	**PI - 390**	0,0929
PI - 80	0,1196	**PI - 300**	0,01	**Total engine production time**	5,3158
PI - 90	0,3042	**PI - 310**	0,0396		

After merging the operations, which were marked in yellow, blue and purple in the table, we created a more complete and transparent layout and a smoother material flow during production. We have replaced the color-coded operations with three high-precision robotic machines that perform the task much faster and more efficiently Fig. 3. The task of man was to place the material in certain defined places in these machines and then to take away the finished products [5], [6].

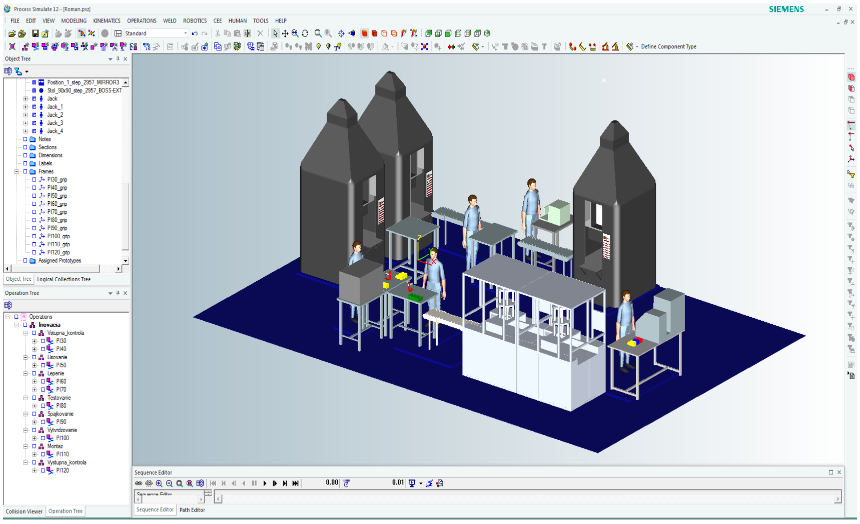

Fig. 3 Optimized workplace

In Tab. 2 we can see production times at individual workplaces after the change. We can see that the number of operations decreased from 27 to 11, which is more than half. The replacement of manual work by robots has allowed us to reduce the production time of one electric motor from 5.38 minutes to 2.24 minutes, which is of great importance for this company.

Tab. 2 Duration of operations after the change

Operation designation	**Time (min.)**	**PI – 90**	0,3948
PI – 30	0,239	**PI – 100**	0,0259
PI – 40	0,2812	**Machine 1**	0,2666
PI – 50	0,2589	**Machine 2**	0,2666
PI – 60	0,1777	**Machine 3**	0,2666
PI – 70	0,2893	**Total engine production time**	**2,2415**
PI – 80	0,2951		

3. CONCLUSION

Today, robots can perform various tasks and are used in almost every industry. Human-machine interaction will soon become a common daily practice. At the given workplace, we therefore decided to replace manually demanding operations with robots [7], [8]. The result is a smoother material flow, simplification of the production process and, firstly, shortening the production of the electric motor by more than 3 minutes. After the introduction of this innovation, the company can produce more electric motors in the same time.

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Artifact, Additive manufacturing, Computer tomography

Patrik VARGA[1], Marek SCHNITZER[2], Rastislav PENCIAK[3]

DESIGN AND PRODUCTION OF REFERENCE SKULL AND IMPLANT MODELS AND THEIR TESTING IN CONNECTION WITH ARTIFACTS IN CT DIAGNOSTICS

Abstract
On CT scans artifacts caused by metal implants can be detected. In this study, implants with thicknesses of 1 mm and 1.5 mm were made by additive manufacturing from titanium powder Ti6Al4V ELI with the size of one-third of the frontal cranial part of the skull. Measurements showed that the artifacts caused by produced metal implants were relatively small. In terms of post-surgical diagnostics and safety, cranial implants made of Ti6Al4V with small thicknesses can be used for follow up examination using computed tomography.

1. INTRODUCTION

In the field of implantology and orthopaedics, implants are used for various bone injuries and defects treatment, e.g. for cranial implants various materials such as plastics, metals, metal alloys, ceramics are used. When diagnosing patients with metal implant using computed tomography and magnetic resonance imaging, we must pay attention to high patient safety. For implants made of materials with different attenuation properties, scanning with different energies is used in computed tomography (CT) diagnostics. The most well-known computed tomographs include spectral CT and monoenergetic CT, while in spectral CT we obtain a set of several images [1]. Implants made of metallic materials or metal alloys are formed by so-called artifacts that cover surrounding tissues and the area around the implant in diagnostic images and thus impair the visibility for radiologists in diagnosing various pathological findings [2]. These artifacts in computed tomography (CT) diagnostics of patients with a metal implant can be caused by various factors such as beam hardening, beam scattering, photon absorption, and a combination of these factors. Common methods of reducing these artefacts include optimizing parameters by increasing voltage and current, where by using this method we reduce photon

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absorption. Other methods are reducing section thickness by using CT algorithms from various companies working on the principle of colouring and dividing images by frequency [3-4].

2. DATA AND METHODOLOGY

Three reference models of skulls and implants were designed for computed tomography diagnostics. For the design of reference models of skulls, CT data of the patient were obtained, where defects were subsequently created in MIMICS software (Materialize, Belgium) in 3 different sizes: a quarter, a third and a half of the cranial part of the skull. To reduce the length of production by additive production, individual bones were removed from the bottom of the skull in Meshmixer software (Autodesk, USA). Skull models in STL format were uploaded to Insight software for 3D printer FORTUS 450mc (Stratasys, Germany), where ABS-M30 (acrylonitrile-butadiene-styrene) was selected to produce reference skull models and SR 30 support material (soluble support material). The printing time lasted approximately 56 hours. After the production of the skull models, the supporting material was removed manually and then chemically. After dissolving the support material, final skull models were obtained. The created data of 3D skull models from MIMICS were uploaded to the 3-Matic software (Materialize, Belgium), where models of cranial implants for individual defects were created using various tools.

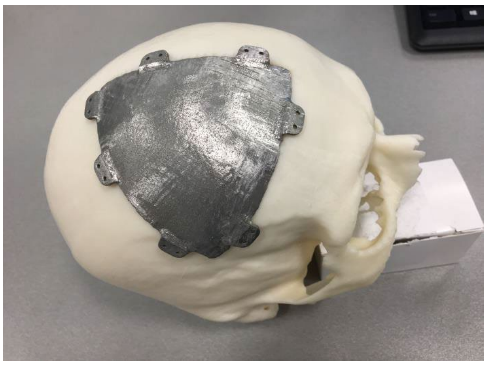

Fig.1. Final titanium implant on a plastic skull

These reference implants were made on the same 3D printer from ASA (acrylonitrile-styrene-acrylate) and subsequently, for CT diagnostics, implants were made of Ti6Al4V composite on a 3D printer Mlab cusing R (GE - Concept Laser, Germany) Fig. 1. [5-6]
A 3D model of the skull was made appropriate to diagnose individual images, on which the HU scale was verified. The skull model with individual implants was inserted one by one into a Siemens Brilliance 40 slice CT (Siemens, Germany) and diagnosed in the anatomical position. Standard filter setting was used to obtain the most detailed picture Fig. 2. Data obtained from CT diagnostics of individual models were evaluated based on density change. Images were taken from a range of displayed CT values from -1000 to +3096 HU. TomoCon Lite software was used for measurement and evaluation. The accuracy of CT images depends indirectly on the pixel size of the images.

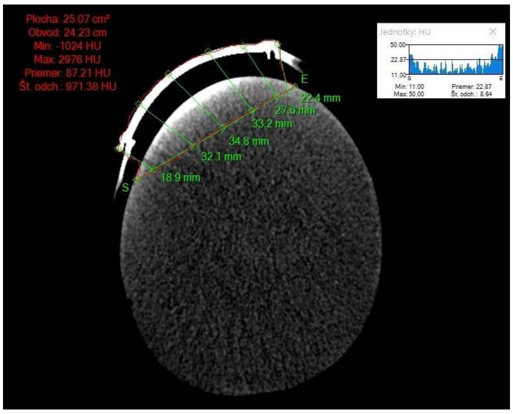

Fig.2. 2D image at maximum values with a limit of 40 HU (left)

Tab. 1. Affected area values of measured cranial implant with a thickness of 1.5 mm

Values measured at the limit of 40 HU	14,8	D= 27,02±√2x0.436 mm
	25,4	D=27,02±0.93 mm
	32,0	S= 23,83±4√23,83x0.436 cm^2
	34,5	S=23,83±12.89 cm^2
	31,7	MEDIAN: 27,02
	23,7	
Values measured at the limit of 50 HU	13,2	D= 23,62±√2x0.436 mm
	24,5	D=23,62±0.93 mm
	30,3	S= 20,88±4√20,88x0.436 cm^2
	29,4	S=20,88±12.06 cm^2
	25,7	MEDIAN: 23,62
	18,6	
	17,7	

3. RESULTS AND DISCUSSION

Measurements of an implant with a thickness of 1 mm in the axial plane showed that the area with a content of 18.62 ± 11.39 cm^2 was the most affected area with an artifact and the critical distance from the implant area was 26.56 ± 0.93 mm. Furthermore, for the 1.5 mm thick implant, the area containing 18.50 ± 11.36 cm^2 was found to be the most affected area with the artefact. The critical distance from the implant surface was 22.5 ± 0.93 mm.

4. CONCLUSION

The aim of this study was to examine the possibilities of CT diagnostics in connection with metal implants, which create artefacts and have traditionally been considered as a contraindication. Metal implants present significant CT imaging challenges, especially when near implant diagnostics is necessary. Knowledge of the different types of artefacts, their origin, and possible foreign bodies recognition is essential to remove them or reduce their negative impact on CT scans. The reduction of artefacts can be minimized by positioning the patient with the metal implant for optimal orientation and using optimal parameters in image acquisition and reconstruction. To reduce metal-related artefacts in CT imaging, the metal implant should be positioned as parallel as possible to the direction of the main magnetic field. We can conclude from our measurement titanium implants made of Ti6Al4V with small thicknesses can be used for follow up examination using computed tomography. However, extensive study need to be performed.

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Plant Simulation, Simulation, Reconfigurable Manufacturing Lines

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THE SUGGESTION OF SIMULATION MODEL FOR VALIDATING THE RESULTS OF ALGORITHM FOR RECONFIGURABLE LINES

Abstract

The article describes the simulation model created for the algorithm of reconfigurable lines. The result of this simulation model are main part of the validation of the determined reconfigurable configurations. The conclusion contains the suggestions for the further widening of this new paradigm for the designing simulation model for the reconfigurable line.

1. INTRODUCTION

The basic approach of computer simulation is to abstract the real system, which means that the model will not represent all the elements of the real system, but only those that are important in terms of design. We understand modeling as imitating the structures and behavior of real or conceptual systems. Its logical basis is the abstraction and output model. The model is actually a simplified image of reality and the displayed reality is the subject of modeling. The created model needs to be verified and its validity verified, then the experimenter can perform a series of simulation experiments with the help of a simulation model. Using a variation of the parameters, the experimenter suggests various "improvements" to the model until the desired results are achieved. The results of the experiments can be applied to a real system and in this way to achieve the desired improvement of the properties of the real system.

The suggested algorithm for design of reconfigurable lines must be validated via a simulation model which is implemented as a concrete submodule of this algorithm. The simulation submodule solves the problem of verifying the proposed configuration of the product family. For simulation and use of Tecnomatix Plant Simulation software, a parametric simulation model was reserved on site. A parametric simulation model can be used to mark a simulation model that allows quick change of set data and other entered parameters. The simulation model for reconfigurable lines was used to be able to quickly imitate changes in a given configuration, product production volumes, as well as other time simulators. These parameters can be used to check for optimal configurations.

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2. THE DESIGN OF RECONFIGURABLE PRODUCTION LINES SIMULATION

The description of the functionality of the simulation model can therefore be logically divided into the following three parts:

a) Basic logic of the simulation model. The simulation model must meet the criteria defining the concept of a reconfigurable production system. It must also be able to change the configuration dynamically depending on the values of the results calculated via MS Excel. The structure of the simulation model thus consists of individual production stages, at which a specific operation determined by the product family will always be processed. The products go through these production stages depending on whether they are to be processed at a given stage. This means that if the operation at a given stage is not intended for the incoming product, the product proceeds to the next production/operational stage.
An important specification of the created simulation model are also its limitations concerning the production stages and the quantity of products. The first limitation of the simulation model is the total number of devices in the production stage. Each production stage in the created model contains a maximum of 20 devices, also the total number of stages of the model is 20. Therefore, if the capacity calculations exceed these values, the simulation will not be performed because the model would have to be extended by the required number of machines or stages. Another limitation is the number of incoming products, while the model can generate only 10 types of products. However, to verify the methodology, the set parameters are sufficient, and it was not necessary to adjust the model for the described limitations.

b) Elements of the simulation model. The described simulation model shows a schematic design of the model (Fig. 01), the elements of which are identical to the proposed model in the Tecnomatix Plant Simulation software. However, the schematic design, unlike the simulation model, does not show all the production stages, as the individual stages are identical and do not need to be plotted.
The basis of the simulation model is the generation of input products. A method ***(MSOURCE)*** was created for input using the SimTalk 2.0 language. The method writes the MS Excel value calculated for the production quantities of the products to the input tables ***(TABk1 to TABk10)*** for each product separately.
After starting the simulation, these values are generated at the input, from where they pass to the element ***S_VS1***. The element contains the output rule defined by the ***Md1*** method and the input variables ***k1*** to ***k10***. The variables determine the state of the product transition through the operational stage based on data from MS Excel. Thus, based on the acquired value of 1 or 0, the method assesses the passage of a given product through the production stage and, if the product does not pass through the operational stage, proceeds to the next element ***S_VS2***. If the variable obtains the value 1, the product will be processed at the operational stage, and thus proceeds to the element ***VS_1***. The following element addresses the product only to the required number of devices based on the input data for the given production/operational stage. In this case, this is decided by the proposed method ***MVS1***, which, based on the value of the variable ***VS1***, determines the path of the product to a specific material flow distributor (element ***FC2*** to ***FC20***). The distributor element determines the number of used machines intended for processing products for the operating stage. If necessary, e.g. 2 devices, products

will go to distributor ***FC2***, if necessary 3 devices products will go to distributor ***FC3***, etc. When one machine is needed, the products proceed directly to the machine element ***S1***.
Another important part of the simulation model is the determination and recording of operating times for specific products. Thus, the ***Mvst1*** method reads the necessary data on the operating times processed at the production stage and writes them to a defined place in the element (table) ***TABvst1***. The table elements are always assigned to each machine in each stage, so that the machines identify the operating time based on said table elements.
The last part is the ***Mt*** method, which overwrites the simulation time based on the SimulationTime variable, the time defined for the product family T_{α}. After starting the simulation, the last method ***Mo*** is activated, which has the task of writing the final volume of processed products to the variable Output. The result is then read back into MS Excel as the value ns_p.

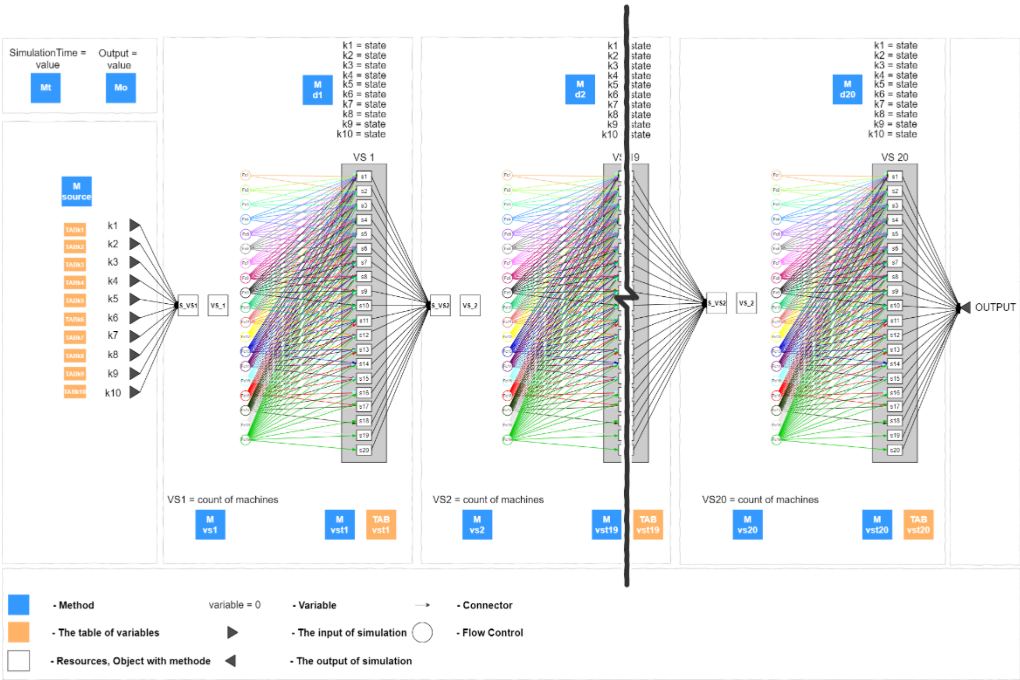

Fig. 1. The schematic representation of simulation model

c) Data exchange of simulation model and MS Excel via DDE. The simulation model is subject to the process of MS Excel procedures, using the mentioned dynamic data exchange (DDE). The functionality of the mentioned dynamic exchange is based on the execution of individual methods and the direct writing of the determined values of MS Excel into the defined simulation variables. The above VBA procedure is repeated until a suitable solution to the calculated configuration is found. The procedure in each step sends the data to the simulation model, which was implemented in the Tecnomatix Plant Simulation environment and evaluates the results in the MS Excel environment.

3. CONCLUSIONS

The article introduction describes the relationship between algorithm for reconfigurable manufacturing system and simulation model for validation of data. The simulation model is an inherent part of the methodology for the design of the manufacturing line with dynamic parameters, as is a reconfigurable manufacturing line. This case provides an opportunity for a more precise design of the configuration of the manufacturing line. The simulation model described above is only for a limited count of resources and inputs, but for the proposed algorithm model setup was sufficient in this stage. These set-up of simulation models can be a problem for extensive line configurations. Therefore, the best option for design the configuration reconfigurable manufacturing lines is the integration simulation model in the base stage of the algorithm. This possibility will be subject to future research in this field of interest.

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