

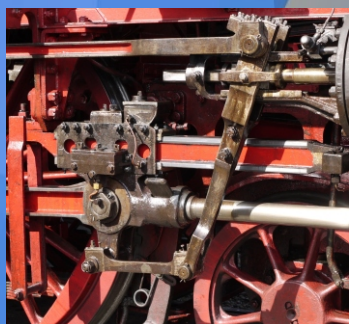
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ASSESSMENT OF READINESS FOR „INDUSTRY 4.0“

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Abstract: The Industry 4.0 initiative poses great challenges to the world, countries and companies connected with the provided digital transformation and the new intelligent technologies in all areas of the industry. This requires the development and follow-up of a national strategy for the adoption and implementation of Industry 4.0. It is important in this case to assess the Industry 4.0 readiness of each country for transformation and change. The main aim of the paper is to present, analyse and compare some of the most promised existing approaches for calculation of Industry 4.0 readiness at national level. Some results are presented and compared.

Keywords: INDUSTRY-4.0, READINESS, MANUFACTURING, ASSESSMENT

1. Introduction

The European Commission's strategy for European Reindustrialization aims of increasing the industrial sector's share of gross value added in the European Union to 20% in 2020, based on European strengths in the fields of engineering, automotive, aeronautics, etc. [1]. The Industry 4.0 platform is an initiative of the German Federal Government to support German industry in the transition to digital production with intelligent, digital networks and systems that enable largely self-control and self-management of manufacturing processes [2, 3]. Especially strong is the focus of Industry 4.0 on the functions of future intelligent adaptive and predictive technical systems that need to be self-optimizing, self-configurable and self-diagnosable, enabling cognitive information processing and intelligent networking in continuous interaction with environment. That is why the strategic initiative Industry 4.0 implies integration of Cyber-Physical Systems (CPS), the Internet of Things (IoT) and cloud computing leading to what is called "smart factory".

The speed and scope of technological changes coupled with the emergence of new technologies and trends makes the task of developing and implementing new industrial strategies too complex. The Industry 4.0 initiative is a great challenge for both national economies and individual companies. To deal with it, countries should develop national strategies tailored to the specifics and capacities of their economy, based on an in-depth analysis of the factors, indicators and conditions that have the most impact on business and production systems. With regard to the national strategy, there must be a consensus of industry, academia and civil society.

An important role in building a life strategy for Industry 4.0 are the results of an assessment of the readiness of national economies to adopt and adapt the initiative. Readiness according [4] is defined as "the ability to capitalize on future production opportunities, mitigate risks and challenges, and be resilient and agile in responding to unknown future shocks." There are different approaches to such an assessment that use different quantitative and qualitative key indicators, both for the assessment the readiness of countries and individual companies. Among the approaches to assessing the readiness of countries and national economies, some of the most significant assessments are derived from the approach developed by the World Economic Forum [4], the approach of the Danish Institute Industry 4.0 [5] and the Roland Berger readiness index [6]. In the area of company stand-alone assessment of readiness, the IMPULS model [7] is the most popular, assessing the maturity of manufacturing enterprises in 6 dimensions: strategy and organization, smart factory, smart operations, smart products, data-driven services and employees. The analysis, proposed in this paper is limited to the approaches for readiness assessment of countries. Reasoning and conclusions about global, local and group trends and initiatives are also possible. The results from assessment may be used to identify specific opportunities and challenges for individual countries for the future of production.

The main aim of the paper is to analyse the existing approaches and methods for assessing the readiness of the countries and their economies to adopt and implement the Industry 4.0 initiative. Some comparisons and analysis of the obtained results regarding the position and readiness of Bulgaria are also discussed. After the introduction, in the second part of the paper the challenges of Industry 4.0 and the main difficulties with its perception are briefly discussed. Sequentially, in parts 3, 4 and 5, three of the most representative and complete readiness assessment approaches have been shortly presented and analysed. In the last part, as conclusions, some comparisons and recommendations on the implementation of the results in preparing of national strategies for Industry 4.0 are presented.

2. Challenges and difficulties in implementing Industry 4.0 initiatives

"Industry 4.0" or IIoT are related to the new industrial revolution and focus on the integrated use of state-of-the-art information (IT) and operational technologies (OT) such as IoT, cyber-physical systems, big data and advanced data analytics and decision making methods, artificial intelligence and robotics, cloud and fog calculations, virtual and augmented reality and others, as shown in Fig.1. With a view to a more rapid adoption of the new concept by industry, it is desirable to ensure a smooth transition to these new technologies through the use of transition technologies and standards and reasonable investment to achieve the objectives, including OT and IT integration (Fig.2). There are a number of industry prerequisites: embedded devices and controllers, wireless sensor networks, RFID technologies, and more. While the hardware industry is relatively well prepared for a transition to IIoT, there are serious challenges to software applications and architectures.



Fig.1: Basic technologies for Industry 4.0

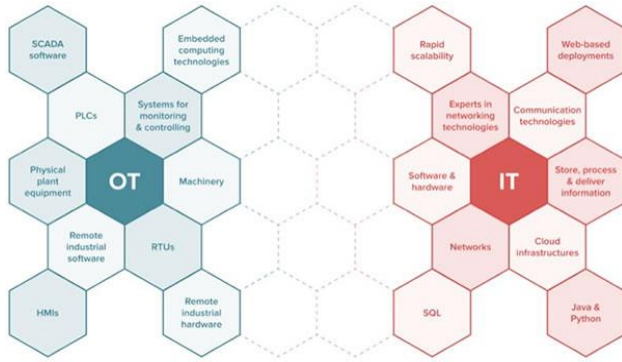


Fig.2: Integration of OT and IT

3. The approach of World Economic Forum

The readiness assessment of the World Economic Forum [4] includes two main components: the Structure of Production and Drivers of Production, or the key enablers that capitalize on the Fourth Industrial Revolution to transform production systems. The Structure of Production as shown in Fig.3 is assessed in terms of its complexity and scale, while the component “Drivers of Production”, shown on Fig.4 includes categories such as: technology and innovation, human resources (capital), global trade and investment, institutional framework, sustainable resources and the demand environment. The study, conducted in 2018, includes 100 countries and their economies, which are valued on 59 key indicators, which are measured by internationally recognized organizations. The assessment also includes indicators from the World Economic Forum’s Executive Opinion Survey (EOS) measuring different qualitative aspects of some indicators, or are used as a substitute in the case when statistical data was not available. All indicators as well as the total scores are in the interval from 0 to 10, with a maximum value (10), representing the best situation. Indicators values are normalized in the range from 0 to 10 based on the min-max approach. The normalized scores are combined to produce the aggregated and total scores.

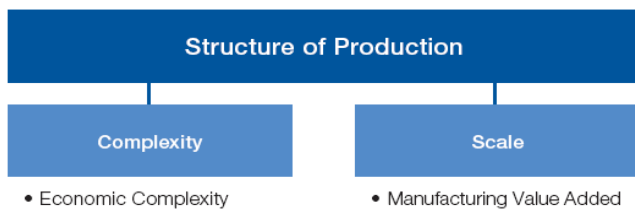


Fig.3: Component “Structure of Production”

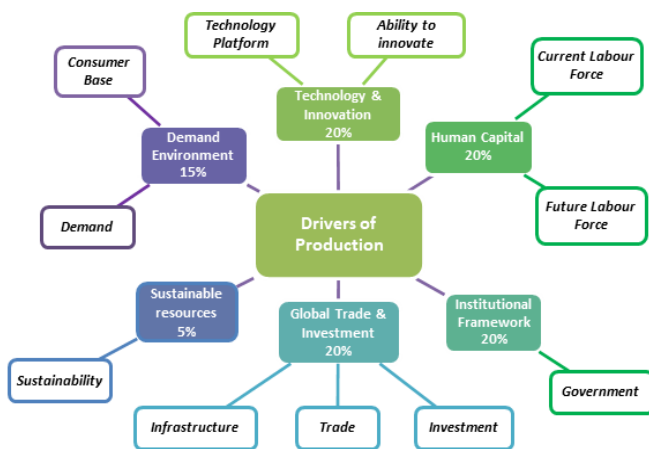


Fig.4: Component “Drivers of Production”

The approach does not offer a global ranking, but classifies the countries into one of the four archetypes, the boundaries of which are determined by the average estimates of Drivers of Production

(5.7) and Structure of Production (5.7) for the Top 75 countries, ordered by the Structure of Production rating (Fig.5). These 4 archetypes are named: High potential, Leading, Nascent and Legacy. They are determined by the complex assessment of the existing basis (limited or strong) and positioning for the future (at risk and well). The countries in the Leading archetype are with a strong production base today and a high level of readiness for the future. The countries in the Legacy archetype are with a strong production base today but they are at risk for the future due to weaker performance across the Drivers of Production component. The countries from the High-Potential archetype are with a limited production base today but have good score in respect to Drivers of Production component. This is an indication for existing capacity for increasing of production in near future. Countries in the Nascent archetype are with a limited production base today and a low level of readiness for the future.

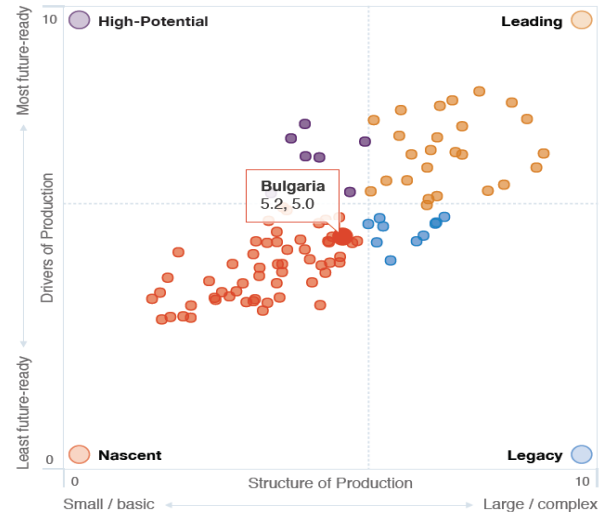


Fig.5: Readiness assessments according the approach of WEF [4]

On Fig.5 some of the results are shown. From 100 countries and economies included in the assessment, 25 of them are “Leading” countries, 10 “Legacy” countries and 7 “High-Potential” countries/economies. The remaining 58 countries are “Nascent” countries. The majority of the EU Member States belong to the first three archetypes. 5 EU countries fall into the archetype “Nascent”. Unfortunately, one of these countries is Bulgaria, which has a score of 5.23 for Structure of Production and 5.02 for Drivers of Production and occupies 40 and 48 rang respectively. For comparison with the other approaches only, in the first six are the United States (1 st rank), Singapore (2 rank), Switzerland (3 rank), the United Kingdom (4 rank), the Netherlands (5 rank) and Germany (6 rank).

4. Danish global Industry 4.0 readiness approach

The DII 4.0 approach for calculation of Industry 4.0 Readiness Index [5] is a part of Danish Institute of Industry 4.0's annual global analysis supporting governments, companies, academics and institutions interesting in implementation of Industry 4.0.

The Industry 4.0 readiness of the countries is assessed based of 7 main pillars, which are weighted as shown in Fig.6. Each pillar comprises of different measurements, which are a total of 24. The measurements have its own weights in the overall score according to their relevance and importance. The Global Industry 4.0 Readiness report includes 120 countries. In order to obtain more adequate assessments in this approach, a score correction based on simple exponential regression is used. It corrects with higher value the higher scores and with lower value – the lower ones, according to equation (1).

$$\text{Adjusted score} = e^{0.24 \cdot \text{original score}} - e^0 \quad (1)$$



Fig.6: Basic pillars of DII 4.0 approach

On the basis of the assessments received, a total of 9 groups of countries worldwide are identified, as shown in Fig.7. To all these groups certain strategies for Industry 4.0 are recommended. For groups 1 and 2 the strategy is named "Foster manufacturing & strengthen position" for 3 and 4 - "Further strengthen position", for 5 and 6 - "Catch up to protect", for group 7 is "Foster manufacturing & Complete turnaround", and for 8 and 9 - "Complete Turnaround".

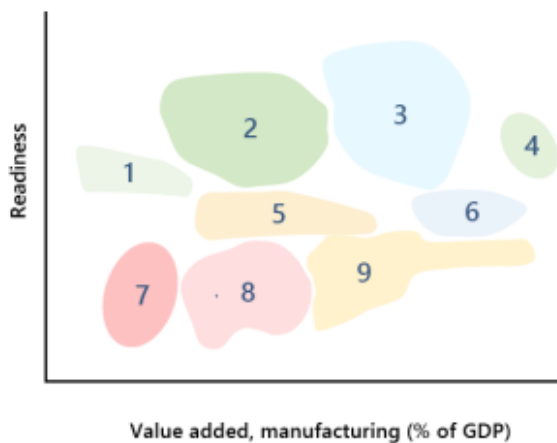


Fig.7: Readiness assessments according DII 4.0 approach [5]

The results of Bulgaria put it in 9 group and occupies 63 place with a rating of 2.5 in ranking of countries by Readiness index. With the same rating are Croatia, Ukraine, Iran and Jamaica. Leading positions are for Singapore (6.6), Switzerland (6.6), Finland (6.0) and Germany (5.9). For the countries of group 9 the manufacturing is an important driver of their economies, they are not well-positioned for Industry 4.0 but quite the contrary and probably they will have problems with their status quo. Bulgaria's scores on individual pillars, compared to the average world scores are shown in the radar diagram of Fig.8.

The clustering results of the European Union countries are also presented. Similarly to the first approach presented in part 3, four groups of countries are identified: Growers, which are well-positioned for Industry 4.0, and thus their manufacturing sectors are likely to grow in the future; Leaders with high level of Industry 4.0 readiness and an important position of manufacturing; Laggards: manufacturer is moderately important but they lack of readiness and therefore the outlook is rather negative and Unprepared: manufacturing is very important however but they are not prepared for Industry 4.0, and they will probably have problems. Bulgaria falls again into the group of countries Unprepared for Industry 4.0, although it was omitted from the graphical illustration of the results.

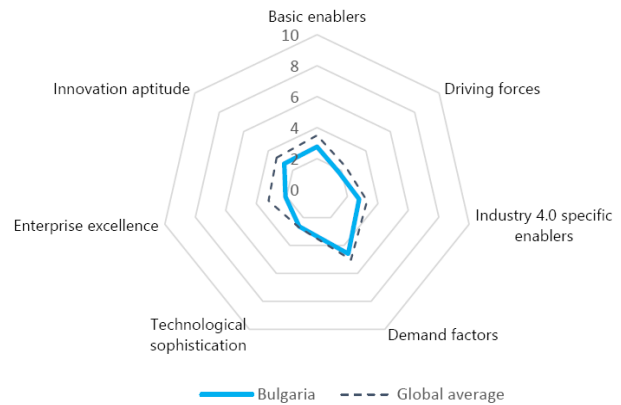


Fig.8: Comparison of Bulgarian scores with the global average [5]

5. Roland Berger readiness index

The RB Industry 4.0 Readiness Index [6] is calculated using two categories of indicators. The first category, named "industrial excellence" includes production process sophistication, degree of automation, workforce readiness and innovation intensity. The second category covers high value added, industry openness, innovation network and Internet sophistication, and is labeled "value network". The indicators of both categories are evaluated on a five-point scale with score "5"signifying that the country is excellently prepared for Industry 4.0. Assessments of both categories are the averages of the indicator scores included. The RB Industry 4.0 readiness index is a combination of category assessments. In the graphical representation of the assessments, the index is plotted on the vertical axis, the horizontal axis is represented by the production share.

The approach is applied to the European economies as shown in Fig.9. On the basis of the assessments in both categories, a matrix is formed that roughly divides European economies into four main groups: Frontrunners, Traditionalists, Hesitators and Potentialists. Frontrunners are characterized by a solid industrial base and modern, promising business conditions and technologies (Sweden, Austria and Germany). Traditionists have a solid industrial base, but have few Industries 4.0 initiatives. This group mainly includes Eastern European countries. The third group of Hesitators includes countries with an unreliable industry base, many of them with fiscal problems. Their joining the initiative now is difficult, even impossible. Most countries in this group are from South and Southeast Europe, among which, unfortunately, Bulgaria. Potentialists are the fourth group that is characterized by a weakening industrial base but with signs of modern, innovative thinking, however, having the potential to find the right approach to Industry 4.0.

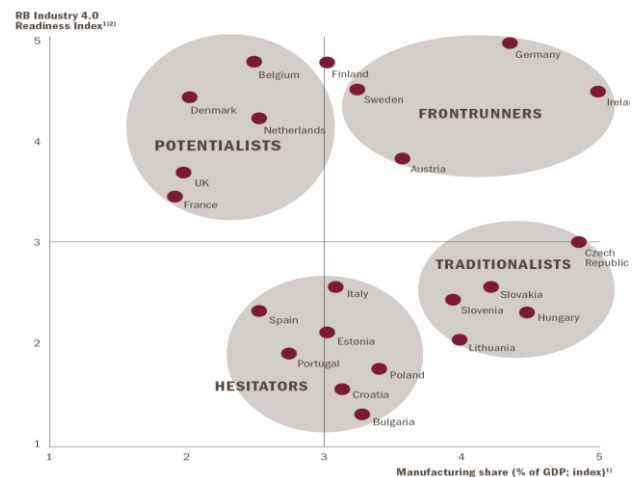


Fig.9: RB Industry 4.0 Readiness Index [6]

6. Conclusions

The presented and analyzed approaches for Industry 4.0 readiness assessment have many similarities and differences. The similarities are that they use relatively simple clustering methods based on the stand-by index and production share. The differences are in the selected indicators and indicators and the selected evaluation methods, as well as the evaluation scales used. The results obtained and the analysis of the hidden, not obvious knowledge is of substantial benefit for the stakeholders, related to the development of strategies and policies for raising the index of readiness. Their in-depth comparison and analysis is forthcoming with a view to revealing the strengths and weaknesses of each of the approaches considered.

There are some shortcomings common to the approaches considered, such as:

- There are no quantitative estimates of key concepts, so indirect estimates are used.
- Strong variability and uncertainty of the information received and used

The evaluation, made using different approaches, imposes the following main global conclusions: When building national strategies for Industry 4.0, account should be taken not only of national solutions, but of global and regional conclusions. National solutions must be consistent with assessments and conclusions on readiness, as well as with the country's specific positioning. The fourth industrial revolution will cause changes in global value chains, global transformation of manufacturing systems leading to a two-speed world. There are few countries that can create a cluster of

new industries. Countries can cope with transformation using different paths, each country having a way and a chance to improve its readiness for Industry 4.0. Each of the defined groups of countries with approximately equal readiness faces common challenges that can be shared by finding common solutions.

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MODEL-BASED APPROACH OF A DECISION PROCESSING UNIT IN A SMART WOOD-PROCESSING COMPANY

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Abstract: The paper deals with the development of a new type of production planning and control in a wood-processing company. The production is already highly automated and data from the production processes are gathered and stored in a database. The project picks up these technical basements in order to automatically provide intelligent decisions and make the factory even smarter.

Keywords: SMART FACTORY, OPTIMIZATION, DATA-DRIVEN PRODUCTION PLANNING AND CONTROL, ARTIFICIAL INTELLIGENCE, DECISION SYSTEM

1 Introduction

For a manufacturing company, the logistical performance is a fundamental competition factor just like high quality and low prices of the products. It is measured in short order throughput times and great adherence to schedules [1, 2]. In order to achieve high logistic performances, the production planning and control generally takes care of the best possible usage of the given resources of the enterprise. Thus, it has to take control of a high capacity utilization level, a low level of work in progress, short setup times and a low production delay [3]. Therefore, these logistical objectives are manipulated by defining production programs in the form of processing sequences and capacity allocations [4].

Improving one of the mentioned logistical objectives often leads to deteriorating at least one of the other objectives. This is well known as the dilemma of production planning and control [5]. Practically these tasks result in complex, multicriteria optimization problems. On the one hand these are complicated mathematical problems [6]. On the other hand there may be untapped logistical potentials which could be practically used by solving these problems. Nevertheless, these tasks are often still performed manually [7].

Innovative technologies in the context of industry 4.0 like CPS (Cyber-Physical Systems) and the IoT (Internet of Things) are found in smart factories. Besides the technical automation of processes and material flows, these technologies can lead in combination with ERP software (Enterprise-Resource-Planning) and MES (Manufacturing Executive System) to a high quality data base [8]. This even increases the logistical potentials by using modern computers and technologies to process the (big) data and automatically use it for planning and controlling a factory [8]. Nevertheless this is a highly nontrivial task and still requires a lot of engineering.

The subject matter of this paper is a project with a company called hobb Holzveredlung GmbH & Co. KG which is a german system manufacturer of fixed sizes for the wood-processing industry. It is part of a group of companies of a well-known german furniture brand and delivers semi-finished products for the furniture and the flooring industry as well as interior construction. The company already uses modern technologies regarding automation of processes, transportation, material handling and tracking. The last links in the chain of automation are the decisions taken in the production planning and control.

A cooperative research project was started in 2016 together with the Münster University of applied Science and the University of Wuppertal in order to develop a so-called decision processing unit [9]. This paper deals with the overall problems and issues which are identified within that development and will present integrated solution approaches.

In section 2 the prerequisites and the problems are presented. An approach for a solution to the problem is presented in section 3.

The results and the current status of the entire system are presented in section 4.

2 Prerequisites

While nearly all relevant technical aspects of the production regarding material flow, material handling, booking of confirmations and technical processes are automatized, the supervising tasks of planning and controlling the production is still done by hand. As described in the previous section, a high quality data basis which includes the production data necessary for the decision taking already exists. Therefore, a decision processing unit which is able to process this data into useful decisions is in development.

2.1 Description of the discussed process

Production processes can basically be distinguished between the following three criteria [10].

- The technique differentiates between a continuous and a discontinuous process manufacture of products as well as a process of a single product.
- Different quantities of production are unit production, batch production and large series production.
- Last there is the relationship with the customer. Production to stock concerns a push-flow production while production to order concerns a pull-flow production.

Based on the introduced criteria, the discussed production process of the case study can be described as a discontinuous pull-flow batch production to order.



Fig. 1 Automatized sawing machine

All products in the discussed processes are rectangular shaped wooden boards. These boards are produced exclusively to order, so that every board has a reference to a customer and a production

order and no product is produced without a customer order. Master data like order number, material number, geometric dimensions, quality, surface design etc. as well as process related data is part of every order, even if one specific product will never be ordered again. The range of products consists of three different types of semi-finished products respectively processes.

- There is the craft-based production of coating materials for furniture boards. This can on the one side be the manufacturing of veneer boards with specific dimensions. On the other side there is the trimming of artificial coatings like decor foils, paper, vinyl, etc.
- There is the cutting and trimming of wooden boards on automated saw machines (see Fig. 1). Boards made of chip, mdf, hdf, solid wood, etc. are cut to size on these machines.
- There is the pressing and gluing of the coating materials onto the cut to size boards (see Fig. 2).



Fig. 2 Automized material handling of a pressing machine

The manufacturing process comprises a manual and an automatized part. While the production of the coating materials consists of many craft-based and manual processes, the production of the wooden boards (cutting and coating) is nearly fully automatized and controlled by RFID. Thus, the development of the decision processing unit focuses on this modern area of the production. The considered manufacturing system consists of two sawing machines, four pressing machines and one area for the crafted manufacturing of coating materials. As described, the coating area is not part of the decision processing. Furthermore there is a managed raw material warehouse which contains the „motherboards“ for cutting to size on the saws. If boards have to be coated on a pressing machine after sawing, they are transported to the machines and stored on roller conveyors.

The sawing machines are fed with boards from the warehouse by a forklift and there are no relevant setup times between different materials and production orders. On the pressing machines there are setup times between 15 minutes and 8 hours. The setup times depend on the different coating materials which need to be processed with different glues, different processing temperatures and different equipment. Some of the coating materials leave residues on the press plates, so that after processing these materials several times the machine must be cleaned. This results in possible setup times for heating up and cooling down, changing the glue for a pressing machine which implies cleaning up the gluing system and mounting different tools for handling different coating materials.

The boards are transported as stacks via automated roller conveyors on slave boards, while each of these stacks only consist of one material and one production order. The slave boards are equipped with a RFID tag (radio-frequency identification) which is linked to the production order of the board stack. This is in

combination with RFID antennas the basis of locating and tracking the board stacks in the production. Behind and between specific and relevant production cells there are RFID gates, where the RFID tags of the slave boards are registered by passing them. This triggers logic processes in the ERP system like booking of confirmations and goods movements. The result is a production controlling process which is highly automated and exact to the second. This leads to a high quality data basis, which is the technological basis of the new decision system [9, 11].

2.2 Description of the problem

The requirements of the decision processing unit for controlling the factory are on the one side the computation of allocations of production orders to pressing machines and on the other side the computation of production sequences for each sawing and pressing machine. The further requirements of the system are to take care of the following four criteria:

- minimizing production delay,
- minimizing setup times,
- minimizing work in progress and
- maximizing machine utilization.

It was recognized quickly that planning the production system within a planning horizon longer than one day would be impracticable and that a high amount of flexibility is needed. Due to the knowledge and expertise of the process, scheduling over one day with a rolling horizon in periods of 30 minutes is desired. This follows from the fact that there are frequent events that lead to a new data basis of decision-making. These events are mainly changes of the availability of materials, so that either new raw material has arrived or the coating area finished a production order. Both cases are not predictable and lead to new situations which the system has to re-evaluate.

There are some special characteristics of the production process which require particular attention.

- On the one hand sawing is a separating manufacturing process, where boards with different dimensions are cut out of one board. From a material managing and production controlling point of view this means that a production order for sawing one specific material results in many other production orders with specific materials. In practise, many customer orders which are cut from the same raw material are bundled together to one production order so that they can be cut out of the same raw staple of boards. This allows the use of a software based waste optimization system in order to increase the efficiency and the economy of the sawing process. But from a production planning view this results in a significantly higher level of complexity as it is shown in the following.
- Each of the production orders which are bundled together to one raw material can contain material for a pressing machine or not. As a result one bundled production order can be a mixture of saw-only orders and production orders with material for different pressing machines. Furthermore the pressing production orders can be allocated to different pressing machines. Thus, different production sequences for one sawing machine have huge impacts on the whole production system.
- Not only the production sequences of the sawing machines can be varied, also the decisions taken at the pressing machines have a huge impact on the whole system. There are different opportunities of feeding the pressing machines. The machines can get material over roller conveyors directly from the sawing machines. Material can be buffered and sorted after

sawing before being transported. The pressing machines can additionally be fed without sawing with external material from the warehouse.

- The configuration of a pressing machine (temperature, glue, cleaning and tools) depends on the processed materials. Additionally, for many of the materials there are more than one possible configuration. The machines have different cycle times, so that the processing time of a production order depends not only on the material and on the count of boards, but also on the machines.

2.3 Analysis of the problem

Following detailed issues result from the discussed problems. Scheduling implies in this case the simultaneous computation of sequences of production orders for 6 production cells and the computation of allocations of production orders to a pool of 4 production cells. This is a type of np-hard combinatorial problem with multiple criteria [5]. This type of problems is well known for its complexity so that even small problem instances are practically not solvable [12]. In order to find practically useful solutions of such a mathematical problem, the use of metaheuristics is a proven way [13, 14, 15].

A metaheuristic is a kind of an iterative algorithm which finds solutions to a problem, but it cannot guarantee that it finds the best ones and it doesn't need to know the problem structure [14]. Instead the use of an evaluation function is necessary for the application of a metaheuristic. This leads in this case to three more problems which are described in the following.

1. First there is the question of how a metaheuristic can be applied in general. Therefore, explicit variables of the production system have to be formulated which can be manipulated in order to be optimized. Furthermore there is the question of how possible solutions can be evaluated. A metaheuristic needs to compare different solutions, so that they are evaluated in an adequate way.
2. The second identified problem is the fact that not every single objective and restriction of the production processes can go into this evaluation and not everything will influence the evaluation. The (only) mathematical optimization of a combinatorial problem does not necessarily need to be the best decision in a practical way. As a result, the application of a metaheuristic has to allow to take rule based decisions within a mathematical optimization process. Therefore the metaheuristic shall be combined with different constructive heuristics. A constructive heuristic is generally a rule-based algorithm which is often adapted to a specific problem [16]. It creates a solution for a given problem by following rules instead of mathematically optimizing it.
3. Third there is the problem that not every kind of data that is needed is present in an usable form. Thus, additional data are needed. These are in particular processing times and set up times for the pressing processes. They are of fundamental importance for an automated scheduling process. The effort of additional data maintenance should naturally be low, so that setup times and processing times for each material and for each machine should not be entered manually, because this would be an immense effort.

3 Solution

The general solution of the scheduling problem is divided into the approaches of the discussed sub problems.

1. An approach for the acquisition of the additional data is presented. Therefore, a data model for the production system is developed.

2. A decision model is presented, which allows the application of a metaheuristic to the scheduling problem. Furthermore, this decision model allows the application of constructive heuristics.
3. An agent-based scheduling model is created, where the decision model is combined with an agent-based simulation of the machines.

3.1 Application of a production model

For the scheduling process itself, the missing processing and setup times have to be generated and an additional high amount of data maintenance should be avoided. Thus, confirmation data from the ERP system shall be used for a statistical computation of real processing times. This makes the creation of a data model necessary which allows the analysis of these data in an appropriate way. Therefore, materials, production orders and machines are designed as a data model. Furthermore this model shall be used as a simple way for entering model-based setup times. It is shown in the Fig. 3.

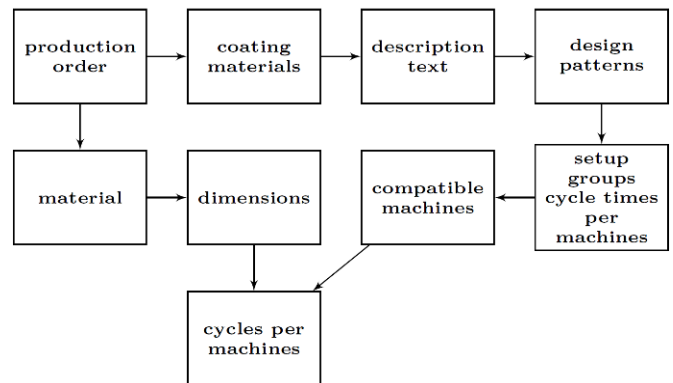


Fig. 3 Generating data with a production data model

The data model for the materials consists of the material number, the material description text and the geometric dimensions. These information are directly read from the ERP system. Additionally these information are complemented with the properties material type and material design. Depending on the description text, the materials are categorized by matching design patterns.

The data model for the production orders consists besides the order number and the delivery date additionally of the material designs of the coating materials. Therefore, depending on the different design patterns of the coating materials, production orders are automatically classified in possible setup groups for each possible pressing machine.

The pressing machines are modelled with the properties of their geometric dimensions. There are different rules for the process temperatures, the glue systems, the needed equipment and the residue behaviour, which can be entered for each compatible design patterns. Setup times are entered as cleaning times, times necessary for changing the glue system and time constants for heating up and cooling down.

This production data model is applied in two ways. First it is applied on a large set of historical data. Confirmation data for each pressing machine is interpreted with this model, so that for each confirmation dataset the machine cycles are computed and then cycling times can be estimated and average values are stored in a data base. Second it is applied on the scheduling task. The stored average values for cycling times are used in combination with the model for estimating cycles of new orders in order to compute production times for the production orders on all compatible machines.

3.2 Application of a decision model

For the application of a metaheuristic, specific input variables have to be defined. Therefore, a decision model is created, where discrete, real decisions are formulated. This allows a distinction between real decisions which should be enumerated and optimized and rules which should be implemented as constructive heuristics.

The decisions are modelled separately for the sawing machines and for the pressing machines. They result from a process analysis and are defined as follows. A sawing machine can on the one side be used to produce customer orders, which only have to be formatted without being coated. On the other side it can decide to produce materials, which have to be coated after formatting.

A pressing machine can also decide from a set of decisions. For each setup group the pressing machine can decide to change its setup and produce only orders which are compatible. Additionally it can decide to acquire production orders from the other pressing machines if they are compatible with its current setup.

The advantage of this approach is the concentration on real and relevant decisions so that uncritical or not predictable decisions are not optimized and can be modelled as sets of constructive heuristics [17].

3.3 Application of an agent-based scheduling model

The combination of the decision model with constructive scheduling heuristics is done by creating an agent-based scheduling model. This scheduling algorithm is based on a discrete-event simulation where production cells are implemented as software agents with heuristic-based behaviours. The agents can take the modelled decisions within a simulation run. Different decisions lead to different constructive heuristic behaviours. In this way, scheduling is done by constructive heuristics for each machine agent in a simulation run. The discrete decisions which the agents take shall be optimized by a metaheuristic. Therefore, the model computes a target value to evaluate different selections of the decisions.

During a simulation run, the planning horizon is divided into discrete time intervals. Within these intervals the machine agents can take decisions from their decision sets. The scheduling itself is implemented as constructive heuristics in the agent definitions. The basic sequences for each agent are created by sorting the production orders for each setup group depending on their delivery deadline. Further constraints are implemented as follows. If possible, production orders are sorted additionally depending on the customer and the raw material, in order to reduce travels distances of the forklifts.

3.4 Application of a metaheuristic

The first work on a stochastic optimization method goes back in 1952 [18]. There are many different types of combinatorial problems, so that these types of problems are a well-known matter of researches. Some of them are mostly theoretical problems, but most of them result from practical problems, as it is in this paper. They have in common that they are np-hard, which means, that they can only be solved with exponential time effort. As a result, even small instances of these problems are practically not solvable [19]. This leads to the development of metaheuristics. The most prominent and relevant ones (relating to this paper) are introduced in the following.

The traveling salesman problem is a synonym for finding the shortest way between a given set of points [20]. Typical applications are logistics where a car has to visit different places in a short time and drilling operations where a machine has to drill several holes into a workpiece [20]. Packing problems are in general problems where a given set of items have to be put into a container. A typical application is minimizing the waste of a sawing machine [21]. Scheduling problems are basically problems where processes have to be allocated to limited resources [6]. Prominent

applications are besides production planning the scheduling of tasks in a central processing unit (CPU) and the gate assignments at airports [22]. Furthermore there are parameter optimizations in general where individual parameters of a given system shall be optimized [23].

They have in common, that even apparently small instances result in practically not solvable complexities. Thus, there are different approaches of getting sufficiently good solutions in a reasonable amount of time. These metaheuristics are mostly independent of the given problem structures. Proven metaheuristics which are based on swarms and populations are ant colony algorithms, genetic algorithms, simulated annealing algorithms and particle swarm algorithms [14, 24]. They are iterative procedures with a wide range of possible applications. At the beginning of the algorithms they randomly produce populations of possible solutions. These are then compared to each other and based on the quality the algorithms are influenced in certain ways. As a result, these algorithms only need to evaluate many possible solutions without actively knowing of how they are created. By positively feeding the algorithms back with the information of the solution qualities, the algorithms can converge to practically good solutions.

For the application of a metaheuristic to the scheduling problem, a modification of the ant colony optimization is a proven approach as it is presented in [17]. It is applied to the decision model in order to find the best possible decisions for each machine agent.

4 Results

The entire system is technically implemented as a service application with a database on a server. It has a software interface to the ERP system, which enables the transfer of data between the systems.

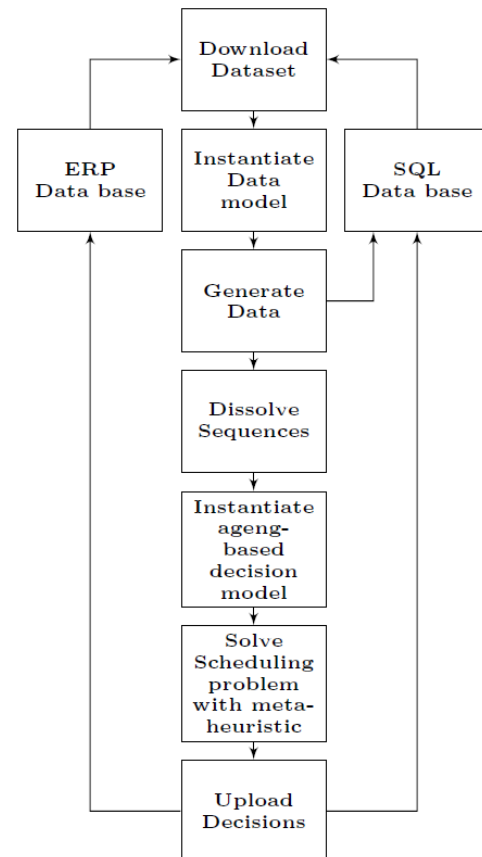


Fig. 4 Program operation of the decision system

The program operation is presented in the Fig. 4. It starts with downloading a dataset from the ERP system and instantiating the data model. After generating additional data and storing in the

database, the iterative scheduling process begins. The results in the form of production sequences for each machine are uploaded into the ERP system and into the database. They are visualized in a web application as well as in the ERP system itself.

The system is integrated into the running production process and the computed decisions are already practically used. Field tests and long-term evaluations are performed. Feedback from the production management is discussed in order to evaluate and improve the decision system.

Thus, the target goals of the project are largely achieved and the quality of the decision system is currently analysed. The advantage of the system is the implementation of constructive heuristics in combination with a mathematical optimization using a metaheuristic.

5 Conclusion and future work

This paper presented model-based solution approaches for solving a practical scheduling problem in a highly automated wood-processing company. The main focus was a combination of constructive heuristics with the application of a metaheuristic in order to combine a rule based controlling system with a mathematical optimization method. Furthermore, additional data in the form of processing times had to be generated.

The modelling approaches have been implemented into the new decision system, which is already applied into the running production process. As a future work, an in-depth analysis of different metaheuristics is planned, in order to examine the best possible configuration of the decision system.

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COMPUTER-AIDED SOLUTIONS TO SUPPORT THE OPERATION OF A MANUFACTURING COMPANY, WITH THE USE OF PERSONALISED IT SOLUTIONS

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Abstract: Computer-aided information flow affects the operating efficiency of manufacturing companies. Personalised IT solutions (PITS) may appear to be helpful. The article discusses the rationale and requirement for the use of computer-aided solutions at manufacturing companies and the practical applications of such solutions in selected areas. Computer-aided management of technical documentation (CAMTD), computer aided items design (CAID) and total productive maintenance (CATPM) and options of further work have been proposed. These solutions were prepared in the form of DBMS systems. The final solution will be to integrate PITS into the IT system supporting the information flow in the production company.

Keywords: COMPUTER AIDED, PRODUCTION, COMPANY, DBMS, PERSONALIZED IT SOLUTIONS (PITS)

1. Introduction

The use of computer-aided solutions at a production company, including the use of CaX [8] techniques, may cover all of the company's basic processes or selected areas or tasks. The flow of information may be supported by integrated management systems (IMS), production management systems (PMS) or personalised IT solutions PITS) [2]. MES's (Manufacturing Execution Systems) in production management can be used to integrate several functional areas [13]. The choice of the solution to be implemented will depend on a number of factors, particularly the capacity of the production company, which is linked with the size of the company.

Industry 3.0 focused on the computerisation of certain functions or areas of significance for the delivery of basic processes [3], while industry 4.0 places emphasis on the integration of computerised processes [14]. An important aspect is the automation of design, production and distribution processes, which requires the use of computer-aided solutions [16].

To be able to improve communication between its units (such as production sites or departments) as well the management of information flow [10] and, as a result, the management of its resources [7], the production company under analysis should employ adequate functional solutions. Such solutions may include computer-aided solutions [9], which can take the form of personalised IT solutions (PITS). A company without such solutions in place will find it difficult to deliver its processes efficiently, control them precisely and respond to events quickly.

If the resources necessary to deliver processes are limited, solutions designed to support the processes are needed. However, before any such solution is implemented at a particular company, it is necessary to identify the company's needs.

Even a company with an integrated management system in place will have some room for PITS's, as the company's IMS will normally cover between 70% and 80% of the company's processes. For the remaining processes, the company will need solutions that reflect its specific requirements as well as future changes. One area where this may be the case is production maintenance, including product, system and process improvement, and this will require the integration of data from various sources [1]. Therefore, it is advisable for manufacturing companies to monitor, on an ongoing basis, their requirements for computer-aided solutions.

The purpose of the work was to find solutions to improve the operation of a production company. The work was based on the assumption that computer-aided solution would improve the operating efficiency of the company under analysis and that employing a dedicated procedure to identify the company's needs would help design and develop dedicated IT solutions for certain areas or functions. Different options and methods were employed to find the final solution.

The analyses in the area of computer-aided solutions were conducted in 2017-2013 at a medium-sized company manufacturing industrial fittings. The products offered by the company are catalogued. [12].

All production is preceded by its preparation [3]. The analyses were focused on finding solutions to support the company in the production preparation process and to ensure the efficiency of production. One example of the work as part of the analyses is computer-aided preparation of production documentation, which is discussed in [11].

2. Prerequisites and means for solving the problem

The full information flow covers production preparation and preparation with accompanying activities. In the area of technical production preparation (TPP), the important aspects include not only the discipline of technology, design and engineering computations, protection of machinery and equipment, but also the procedures and regulations that apply to the company's products and the company itself, which should be taken into account.

The company under analysis had an IMS in place. Therefore, the analyses included three development options: (1) keeping the company's IMS in place, (2) replacing the IMS in place with a production management system (PMS) or (3) supplementing the IMS with other solutions (PITS) based on the company's needs and, as far as practicable, compatible with the IMS [15]. The second option would be the best one for the company under analysis, as it means moving away from a large IT system that is not working at its full capacity and implementing a solution that will support the company's basic process, i.e. production, and integrating it with the other processes. This means that the company's resources and processes would be interconnected by an IT solution to control and manage the company's production. However, following consultations with the company and based on an cost/benefit analysis, the third options was chosen, i.e. to implement dedicated solutions to support certain areas or tasks.

For the flow of technical product documentation, it is necessary to ensure that the flow of such documentation is controlled, that such documentation is archived and that hard copies of it can be digitalised into a database. It was, therefore, necessary to prepare a dedicated solution that reflected the needs of the technical department in this respect. A DBMS was proposed as a way to support the flow of documentation. [6]

The first stage in the technical production preparation process is product design. In this process, the customer's requirements (such as standards) must be taken into account. The solution was to support the design of the face and flange of a valve (these two parts are components of the body of the valve). It was also important for the designers to visualise the results of the design work in a CAD environment and to ensure efficient archiving of the 3D models of

the designed products. The solution to this problem was a DBMS [4].

The efficiency of the company's production process is also linked with its machine park. The maintenance of machinery and equipment is normally the responsibility of the company's production maintenance team, although it may be the case that this responsibility is assigned to a particular person or a company's technical team. This area generally includes day-to-day and scheduled maintenance of machinery and/or the keeping of operation/maintenance records. Once again, a dedicated DBMS can be the solution. [5]

In all the above cases, it is necessary for the company to be able to gather the required information systematically, with access, archiving and processing being not less important. It was decided that DBMS's were an effective response to the user's needs and, therefore, the solution proposed to the company was based on a DBMS.

3. Solution of the examined problem

3.1. Managing technical documentation

In the case of PITS's, the challenge was to organise the system for managing the company's technical documentation to ensure that the documentation is archived systematically and that searching for the necessary documentation was a smooth process. Based on the analysis of the company's needs, it was necessary to design a solution that would incorporate a standardised, continuous document numbering system and provide the company with full information on the flow and status of its documents. Therefore, the proposed solution (Figure 1) should allow the company to (a) register new documents, (b) search for existing documents and (c) register the flow of documents. In other words, the company can use the solution to register new documents and, subsequently, to archive them and find them quickly in the database.



Fig. 1 Elements PITS-CAMTD.

It was also necessary for the company to be able to use its (a) product catalogue, (b) operations and maintenance (O&M) manuals and (c) list of materials. (Figure 1)

The documentation was divided into three types: design documentation, process documentation and assembly documentation (Figure 2), divided by content.

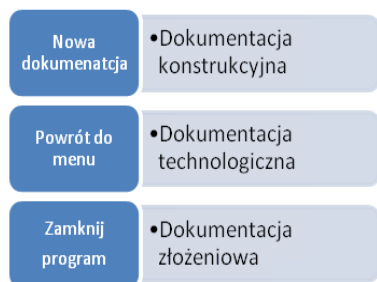


Fig. 2 Documentation catalog.

The solution also allows the user to access the company's product catalogue (Figure 3) to search for a product in the catalogue or to register a new one, to view all the products or only new ones.

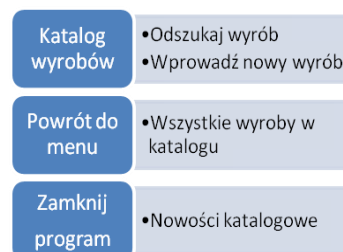


Fig. 3 Product catalog.

One aspect of efficient management of documents is the ability to control the flow of document, is a challenge. The proposed dedicated solution allows the company to control the release and return of documents. The information provided by the system includes who a document was released to or returned by, the release and return dates, the type of document and the number of copies.

As regards O&M documentation, it is necessary for the company to be able to archive such documents, to register new ones and to find existing ones. The solution offered the option to keep English-language documents and templates of O&M documents that could be downloaded and edited.

The search criteria are the same, regardless of the required resources, e.g. O&M documents or the product catalogue.

3.2. Design work support

As regards the product design process, it was necessary to design a 3D model generator for flanges. Such a generator (Figure 4), which is part of the dedicated solution, allows for defining the parameters of the flange and face of the valve and for viewing standardised values.

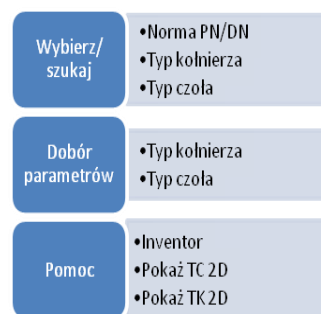


Fig. 4 Generator of flanges

When the selected parameters of the flange are approved, the modelled part can be visualised in 3D using the selected graphic design software (Figure 4) and 2D documentation can be produced.

In the process of designing the solution, the challenge was to think of a way to archive 3D models efficiently and to work in groups, i.e. to make such models available to other users, and allow for such models to be exchanged between work group members. Therefore, it was necessary to ensure that the solution allowed the user (a) to create a model of a flange, (b) to search for an existing model and (c) to change the settings. The response was a PITS-CAID solution, which is shown in Figure 5.

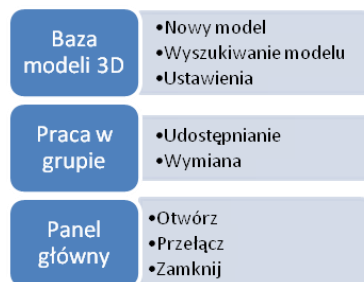


Fig. 5 The main panel IRI. Elements PITS-CAID.

The company also required a solution that would provide it with (a) access to a group of standards in respect of certain parameters and (b) access to the application (i.e. the solution) anywhere within an LAN.

The last step in the process was to prepare a standard file to allow the user to install the application on the user's workstation.

3.3. Production maintenance

In the case of total productive maintenance (TPM), the fundamental purpose was to ensure efficient and effective management of the company's technical resources (machinery and equipment).

The response was a solution based on the processing of information in this area. Therefore, the proposed dedicated solution should allow the user (a) to gather information on the company's machines, (b) to keep machine operation records, (c) to issue machine maintenance requests and (d) to generate reports, which was provided (as shown in Figure 6) by means of a computer aided total productive maintenance (PITS-CATPM) solution.



Fig. 6 Elements PITS-CATPM.

The PITS-CATPM solution (Figure 6) was divided into five 'thematic groups' (modules), i.e. machines, maintenance requests, personnel, orders and reports.

The Machines module is used to enter and store information on the company's machines and to keep machine operation/maintenance records. The Maintenance Requests module allows the user to issue day-to-day maintenance requests or scheduled maintenance requests and to monitor the maintenance work. The module can include information identifying the request, the machine(s) covered by the request and the personnel responsible for performing the requested maintenance work.

The Reports module is a report generator (Figure 7). The user can both view and print reports. The Reports module can also be used to generate various useful reports/summaries.



Fig. 7 Module Reports.

The Orders module allows the user to generate orders for spare parts necessary for the requested maintenance work. The user can keep a record of the necessary spare parts and use the module to easier calculations of spare part purchases. The Personnel module contains information on the company's personnel.

4. Results and discussion

Computer-aided management of production at the operating level requires, *inter alia*, the use of solutions for automated exchange of data between IT systems in a way that reflects the user's specific needs and requirements. The response could be a production management system (PMS) or the integration of a number of standalone IT systems (e.g. PITS's), in which case it is necessary to address the question of compatibility [3].

The analysis included the option to implement a PMS. A PMS reflecting the company's needs and requirements would improve the quality of the computer-aided management solutions in place at the company. The process of designing such a system would be a complex and multi-stage process. The preparations for the process would take a long time and require remodelling the flow of information within the company. Issues might occur both before and during the implementation of the system, as well as during the initial period of its operation.

Another possibility is the design of a PITS based on an analysis of the company's needs, with the option to allow for the exchange of data between the PITS and the IMS in place at the company. In the case of catalogue-based production, a PITS allows the user to coordinate its production work based on the process-oriented approach. As long as the company's hierarchical organisation is maintained to ensure the stability of its operation, this allows the company to adopt, for certain processes, solutions based on modules, i.e. particular operational units.

One example of this approach is an enquiry from the company's customers about a non-standard product for which online reporting by a few departments is required. The computer-aided solution would cover the company's sales, technical, purchasing and production departments. The response to the company's requirements in this example would be a system for identifying non-standard solutions and allowing for a flow of documents in line with decision-making procedures.

The 2007-2013 analysis of the company's operation included the flow of information, with special emphasis on decision-making processes and the resulting flow of documents. It was, therefore, necessary to ensure control of the flow of information and of decision-making for different areas or tasks. For example, the suggestion was that standard orders should be separated from non-standard ones in customer service. In particular, the latter may be very difficult to deal with. Handling such orders requires the use of a dedicated solution to control the flow of documents. Also, the time needed to design the requested product should be reduced and the production process made more efficient. These activities are the responsibility of the company's technical department and can be supported by a computer-aided solution. Therefore, the proposed solution designed to support the work of the technical department (covering document management, design work and production maintenance) needs to be supplemented with a PITS for non-standard orders.

Based on the analyses of the company, the response could be a PITS for "the identification of non-standard order processing" that would allow for data to be exchanged electronically between the company's units involved in the production of such orders. The solution should allow the company (a) to archive input data and the documents produced in the course of work, (b) to access such resources from multiple workstations operated by such units of the company and (c) to control the production of the order. Databases with product indexes and (spare) part indexes.

Implementing such a solution would help improve the flow of information in the processing of non-standard orders, resulting in improved customer service. This, however, would require further work on a computer-aided solution, i.e. a PITS.

5. Conclusion

The exchange of information within a manufacturing company requires the use of an information system supported by IT solutions. Such solutions may include integrated management systems, production management systems or personalised IT systems. They can be used to support the flow of information within the organisation or in respect of a specific process, area or task. In addition, the designers should take into account the scalability of the IT system or the addition of applications for new tasks in response to the company's needs identified through analyses.

The company under analysis had an IMS in place and used a PITS based on previous analyses. However, five years later, new analyses revealed that both the IMS and the PITS needed some upgrading. This shows that the analysis of a company's needs to decide what IT support the company requires should be a continuous process, based on the PDCA (Plan-Do-Check-Act) cycle.

The technical department of virtually any company needs solutions designed to improve the flow of information. The problems such departments usually encounter are related to product design, production planning or production maintenance. The response to such problems should include efficient preparation of technical documentation for the product to be made, efficient flow of such documentation and the provision of technical resources to ensure uninterrupted production. These issues were addressed by the proposed PITS solution for the company's technical department, as it covered technical document management, design work and production maintenance.

PITS's cover certain operating areas and provide support for defined processes. They help to improve the flow of information to the extent of the support provided by them. PITS's are dedicated solutions designed to offer specific functionalities and to be used in a specific operating environment. PITS's can be operated from multiple workstations. Although the input data in such systems is stored in one place, the data can be accessed by multiple users. In such a case, it is necessary to define access priorities. As a result, a member of the company's personnel will have access, to the extent of their authorisations, to the PITS from their workstation.

In the case of the company under analysis, the PITS's in place allow the company to gather and systematically store and process information according to the company's needs. They could also be used at other companies, provided the required software and hardware are available.

The analysis of the three options shows the directions and possible actions as regards industry 3.0 computer-aided solutions for companies, as well as within the context of industry 4.0. Regardless of the option, there is room for PITS's.

The proposed approach to supporting the operation of a manufacturing company with IT solutions is in line with the efficient business management philosophy. Efficient use of the proposed solutions will depend on many factors, including the human factor, i.e. the users of the solutions. However, the directions for development within the context of industry 4.0 leave no doubt as to whether the use of computer-aided solutions is justified or even.

Acknowledgment

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SMART SERVICES AS SCENARIOS FOR DIGITAL TRANSFORMATION

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Abstract: Digital transformation, new business models development and business processes automation ranks among the key business concerns and company priorities. In this context, smart services propose new models for service automation, combining data, analytical components and physical infrastructure in unique customer offerings. The present research aims to present the smart services potential, exploring its characteristics, perspectives and fields of application. First, the paper makes an overview of smart services features and concepts, then, it determines smart services perspectives and last, it presents use cases and industry sectors for smart services implementation.

Keywords: SMART SERVICES, DIGITAL TRANSFORMATION, INDUSTRY 4.0

1. Introduction

Within the framework of digital transformation and Industry 4.0 wider adoption, the role of companies is continuously changing from manufacturers and traders of mass products to data integrators and providers of complex and customer-oriented services. Many opportunities exist for companies to extend their value-creation offering and business models by developing focused and personalized services, by implementing Industry 4.0 technologies such as big data, cloud computing, Internet of Things, robotics, virtual reality and others. That is the reason smart services and smart service integration to be on the next frontier of Industry 4.0 ecosystem.

However, the development and smart service offerings requires new set of prerequisites such as technological advances: industry standards, cybersecurity, appropriate infrastructure and new business scenarios: organizational practices, new business models and customer-oriented business processes. In this context, the present research aims to identify the main features of smart services and to outline the companies' potential to develop and implement smart service scenarios on practice. The first part of the paper provides a short background overview of smart services, discussing its main concepts and perspectives. The second part defines the main layers and characteristics for smart service offering. Last, there are identified different application models and use cases for smart services implementation in new value-offerings. The present paper is partially supported by INTERREG project DIGITRANS - Digital transformation in the Danube Region.

2. Background

The common definition of smart services states that they combine digital services, data analysis and physical infrastructure within complex "smart product-service ecosystem". In this context, smart services are considered as individually configured systems, merging physical layer (infrastructure), digital services (access to computational capacity), and data (integrating contextualized and personalized data) [1]. Other definitions state that smart services are interconnected, data-driven and personalized, and "smart" stands for context-sensitive data and customer orientation. Smart services are digital services, adapted and delivered based on specific user requirements, and stepping on data analytics and contextual data [2]. They are individually configured and often delivered physically, covering digital services and physical products, usually performed on integrated platforms [3]. From data perspective, smart services are data-driven applications (set of traditional and digital services, integrating various data sources on technology platforms) [4]. Smart services come as result of the progress in machine intelligence, global connectivity and big data.

As alternative terms for smart services in literature are used: data-driven services, Internet of Services, Smart Web Services, intelligent or smart products, smart product-service systems, intelligent ecosystems and others.

Smart services advance on the increasingly blurring differentiation and convergence between physical products and services [5, 6], providing personalized customer offerings as "complex service packaging" [7]. Thus, smart services allow companies to use smart digital products as "distribution mechanisms for service provision" [5] extending their opportunities to digitally transform and personalize their customer offerings.

3. Smart services perspectives

The emergence of smart services is largely due to new intelligent or smart products, improved cybersecurity and encrypted data transfer, data analytics models and customer-oriented business models [8]. Smart services can be analyzed from three main perspectives – technology perspective (technology infrastructure), customer perspective (context of service delivery and value co-creation) and business perspective (value offering, based on integration of data and inter-organizational networking capacity).

-Technology perspective covers technological architecture for smart services, including smart products or smart objects, assuring connectivity and infrastructure, such as sensors and actuators (IoT/IoT), wearables or access to local physical devices. Technology perspective allows company to connect, to analyze and to adapt to specific customer preferences and context. Technology perspective consist of in-place technology infrastructure, determining the elements of the context and delivering physical components of the smart service.

-Customer perspective builds on business scenarios and personalized user profiles. Extending data analytics and context recognition, companies can customize and adapt its smart service offerings to specific users based on preferences, patterns and experiences. Improving access and analysis to personal and general data statistics, models of use customization and recommendation services can further extend opportunities for value co-creation.

-Business perspective aims to extend the capacity of the company to explore vertical and horizontal industry integration in order to enhance value-creation and value offering for its clients, by combining personalized features and general elements within smart service configurations. The business perspective integrates internal company resources and business processes with extended company ecosystem and network of partners, suppliers and end-customers.

The three general perspectives provide general understanding for the physical, customer and business layers, defining the smart service structure. In order to identify scenarios for smart service development, we will go deeper by examining the smart service platform model of Smart Service Welt [1].

Visually, the smart service system architecture covers five platform layers (fig.1), consisting of: 1) infrastructure and physical components, 2) smart products/smart objects, 3) data analytics, user profiles, 4) smart service platforms and 5) business models configuration. These five layers combine technology infrastructure (layer 1 and 2 – technology infrastructure and physical platform),

customer service infrastructure (layer 3 and 4: software platform – data, computational and analytical layer and service platform – smart service or customer layer) and business infrastructure (smart service integration layer- smart business model ecosystem and smart business processes).

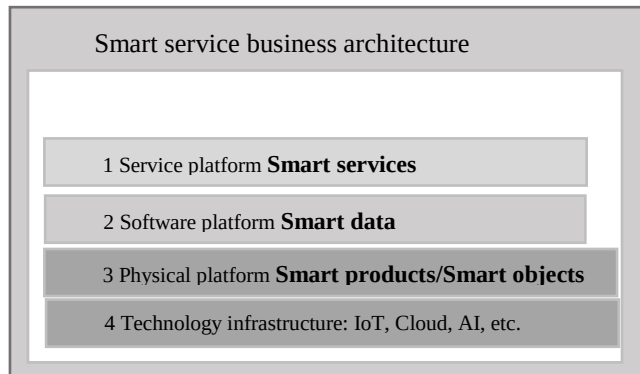


Fig. 1 Smart service business architecture based on Smart Service Welt [1]

3.1. Physical infrastructure (smart product)

Smart products or smart objects are the backbone of the physical infrastructure within the “smart service system”. Intelligent (smart) objects (products) are able to sense its own condition and its surroundings and thus allows for real-time data collection, continuous communication and interactive feedback [9]. Furthermore “smart products” enable monitoring, optimization, remote control, and autonomous adaptation of products or objects [10]. Smart products use sensors (IoT) to obtain contextual data, exchange data with other actors (cloud technologies), store and process data locally (edge computing), make autonomous decisions, and act physically by means of actuators [1].

Smart products can include smart devices, smart objects, and cyber-physical systems. They embed hardware and software systems into physical goods that can connect digitally to other products and information systems. Smart products obtain contextual data from the field, analyze these data, automatically make decisions and take actions. The smart products (objects) may be associated with an individual customer (e.g., health monitoring), a group of customers (e.g., family home monitoring) or a firm (e.g., monitoring of industrial equipment) [9].

Some of the main features of smart products include [10]: unique identification, localization, connectivity, sensors, data collecting and computation (edge computing), actuators, interfaces, invisible computing. In this perspective, smart products act as service-distribution mechanisms.

It is important to underline that smart products can mediate the interactions between service providers and service consumers in two ways. First, when consumers use the products' embedded functionality as a self-service. This way, the smart products transfer the configuration of customer service. Second, smart products can act as point of interaction or interface between the end-users and the service providers. In this scenario, smart product transmits data on its use, condition, and context back to the service provider, who analyses these data to offer additional value propositions that fit the detailed contextual situation of the customer. The technology infrastructure and physical platforms, based on smart products (objects) (layers 4 and layer 3 from fig.1) can deliver different scenarios for remote and continuous services, routinized and technology-mediated interactions and personalized and contextualized customer services.

3.2. Customer orientation (smart service)

On one side, smart services rely on the application of specialized competences, through deeds, processes, and performances that are enabled by smart products. On the other side,

smart services require customer orientation and customer focus. Therefore, for the design and development of smart services it is essential to understand the customer and his surroundings, to explore various data sources and to analyze, integrate and process these data into valuable personalized offerings. Within smart data software platform – layer 2 and service platform -layer 1 (fig. 1), smart services build on “smart data” concepts and integrate them in new user-oriented service modules, new diagnostic applications, new control and automation solutions. The customer perspective allows companies to extend the use of the growing volume of contextual data and to combine it in innovative ways creating on-demand, personalized solutions for customers [3].

- Customer profiles

Customers and customer experiences are the cornerstone for any smart service scenario. By defining and extending user profiles, smart service technologies can personalize and enrich the user experience by developing individual combination of service elements reflecting individual preferences and expectations. The customer profiling is defined by algorithm or user acquisition model. This model can combine both explicit and implicit user information, including on one side explicitly submitted user information and on the other side, by observing and tracking user preferences, service usage and behavior patterns. In order to rely on appropriate customer profiles, the user acquisition models scenarios should evolve and extend over time, upgrade user preferences, skills and competences, combining various types of data and measuring their relative weights.

- Context recognition

Customer orientation or service personalization requires on one side to understand the customer profile (personalization based on personal preferences) and on the other side - to recognize the specific context of service delivery (personalization based on external conditions). The context is determined in plan recognition module that integrates historical data (plan libraries), input observations and potential plans, adapting the service delivery pattern to local conditions.

The smart services main feature is the individual approach to customers based on their context and personal preferences. The service platforms can develop and support individual profiles and context recognition patterns using various artificial intelligence technologies (such as chatbots, image or text recognition), allowing development of scenarios for three types of personalized services:

1. Interactive configurations: customized smart services, adapted both to the customer profile (explicit data and implicit preferences) and to the service delivery context (taking into account the context).

2. Recommendation systems: customized service models, supporting decision-making and choice options, based on personal preferences, past data and environmental/contextual information.

3. Personalized interactive processes: application of different models of service interactions, so that the services are tailored to the individual preferences and context/environment data.

Smart services usually support customers for taking decisions and selecting one or another solution, based on personal preferences, evaluation criteria and decision-making patterns, conformed to the specific context. Smart service platforms have to facilitate the decision-making process, but in the same time, they have to provide relevant explanations of its own logical models. In the same time, the smart service platforms have to allow the end-users to apply and customize other solutions that may differ from the system recommendations.

3.3. Business infrastructure (smart service integration)

Smart services often require individual organizations to extend its capacity by delivering boundary-objects that integrate resources, data and activities provided by different actors from the ecosystem

[10]. As customer-oriented, platform-based and service-oriented business models are expected to replace traditional product-oriented business models, development of new smart services will require new mechanisms for value adding and value integration.

Within business perspective, companies should define new opportunities for re-integration of resources and processes from the ecosystem in order to improve or extend its value offering. For example, it can exploit open data, work in open innovation processes, collaborate in open communities or rely on open source infrastructure.

In the concept of the Smart Service Welt [1], business models stand as the outermost layer of smart-service architecture functionality (fig.1), supporting digital transformation and directly affecting inter-organizational business processes and workflow configuration. In this context, the most important elements of Smart Service business model are [8]:

- Content or the specificity of the smart service, how it is created and used and what is the customer added-value;
- Customer or focus of the smart service, customer preferences and level of satisfaction;
- Platform or the technology infrastructure, supporting the delivery, personalization and access to smart services;

The role of the business ecosystem is crucial for smart service configurators and integrators. As different social and economic actors use different data, resources or services, the possibility for networking, partnerships and exchange of digital assets and physical infrastructure can extend the capacity and value co-creation potential for smart service providers.

3.4. Smart service characteristics

The characteristics and elements of smart services vary, but usually they are considered as: data dependent, agile and customer focused, cross-company and cross-sectoral delivered[12].

The smart services classification in [8] distinguishes the following five characteristics: 1) smart services are the connection between the physical and the digital world, 2) they upgrade the value creation and economic efficiency; 3) they provide extension of products and services with a digital layer; 4) they transform the product into a part of service-offering; 5) they require transformation from product-centred to customer-centred business models.

The elements of the services consist of the following dimensions [13]: service structure, service delivery process, service outcome and service business model. In this context, the components of smart services are physical delivery, digital services, technology-based services and data-driven services.

The characteristics of smart services, defined by [11] are:

- (1) Smart services rely on embedded information and communications technology that allows data transmission and information generation.
- (2) Smart services integrate and are enabled by big data analytics.
- (3) Smart services are automated (at least partly) and they are perfectly aligned with human interaction. Such automated service actions are only possible by the integration of smart components like cognitive systems.
- (4) From a customer perspective, smart services allow for greater customization of services by reacting on environmental-conditions or customer requests (smart services adapt based on users data).

Finally, smart services elements include physical infrastructure or smart and connected products, they rely on encrypted and secured data transfer, they are developed based on data analytics and data-based intelligence, they are developed on new business models and new mindsets and customer-driven business scenarios.

4. Discussion and conclusions

The successful generation and development of smart service scenarios within companies rely on different factors such as analysis and optimization of organizational processes (communication and coordination processes), good governance and management structure (sufficient resources, access to capacity, competent decisions), appropriate culture (rewarding creativity and trust). Development of smart services start with focus on customers and trigger additional digital transformation processes. The expected benefits from smart service implementation come in two main directions: source of new revenues and cost optimization:

- Smart services can provide additional revenues, improved efficiency, increased visibility & cost reduction, enhance customer base, relationship and satisfaction, larger mobility and independence, stronger interconnectedness, faster decision making. Delivering intelligent customer service can improve customer interaction, customer data collection and analysis, customization and customer value improvement. All these characteristics can lead to: increased innovation, turnover and profit, increasing customer loyalty, creating competitive market advantages, higher employee productivity, satisfaction and qualification.

- Implementing smart services in organization can lead to savings, process optimization, dependency, virtualization and process automation, flexible combining, and enhanced functionality. This would increase the efficiency of processes, reduce resources and waste, solve problems at an early stage.

High complexity for the development of smart services requires systematic approach for defining complex "product-service systems". Smart service ecosystems aims to link data and information connecting different sources, smart objects and products, contextual information, user profile and additional data. Therefore, customers can have different concerns, related to smart services wider adoption.

It is important to state that customers perceive smart services as highly risky if they are invisible, feature a high level of automated decision-making or enable the service provider to access sensitive information [9]. The increased risk perception is mainly driven by the fear of privacy violations and concerns about data security [14]. Different levels of perceived embeddedness might trigger different emotional responses in consumers. The customer concerns about smart services dramatically increase with the increasing of the embeddedness of the technology in their lives and bodies. Research has identified that technology characteristics, customer characteristics and context specific perceptions such as privacy concerns are the main factors affecting the perception and adoption of smart services [9].

Some of the other smart service challenges include [8]:

- Technology (lack of smart service standards and interoperability issues),
- Data (data management, data protection, cybersecurity, data ownership and security),
- Business (high initial investment and uncertain return on investment models, need for new business models and new business logic, differing from traditional markets),
- Competences (lack of practical experience, skilled workforce and management experience);

Smart services have the potential to digitally transform many industries and companies' business models. Combining data, customer focus and data analytics with new hardware applications such as autonomous cars, robots, drones, wearables, IoT/IIoT, smart city infrastructure and others, smart services can provide many value offerings. Examples of smart industry services, smart urban services, and smart senior care services are already provided in the research of [9]. Other smart services use cases are explored as well in education, in health care, utilities, retail, manufacturing and

transport [8]. ICT companies and leading service providers already promote successful use cases for smart services and customization opportunities within smart factory, smart mobility, smart city, smart farming and smart agriculture, smart energy (FIWARE platform), smart trade, logistics, smart predictive asset management and maintenance, smart industry (SAP Leonardo system). Therefore, smart services have the potential to enable next scenarios for customer-oriented digital transformations.

5. Acknowledgement

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INFRARED OPTICAL SENSORS IN BUILDING AUTOMATION

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Abstract: Speaking about Industry 4.0 we can't help mentioning the role of optical sensors in building automation, especially in smart factories and automation of SCADA system. Building smart factories in concept of Industry 4.0 requires intelligent sensors and seems relevant. The paper considers management system of distributed factory and information security of it if there are used optical sensors.

Keywords: INDUSTRY 4.0, INFORMATION SECURITY, INFRA-RED SENSORS, CYBER-PHYSICAL SYSTEMS

1. Introduction

Nowadays we are in a technological revolution that will fundamentally change the way we live, work, and interact. In this paper smart factory is considered as building which is going to be automated. Smart factory concept gives tremendous opportunities in comparison with classical factories in case of performance, cost-efficiency and flexibility. However, it is necessary to remember the problems that come with new opportunities.

When introducing new technologies developers often forget about the need to take into account information security up to the implementation stage when the changes required for reduction of the system's vulnerability become too expensive. The problem is relevant despite the fact that the first cyber attack occurred even before the advent of the Internet - in 1982 (Russian sources deny it). Then a group of hackers was able to install a Trojan in the SCADA system which controlled the work of the Siberian oil pipeline. It led to a powerful explosion [2]. The attack was organized by the CIA, although this was not known until 2004. Almost 35 years later, in November 2016, residents of apartment buildings in the Finnish city of Lappeenranta spent a week without heating and hot water. The reason was a powerful DDoS attack on a "smart" system for monitoring water temperature and pressure in radiators [3].

2. Smart Factory Security

Over the next ten years more than 70 billion devices connected worldwide will constantly exchange information with each other. This huge network of devices analyzing, transmitting, outputting data will anticipate our needs and change the perspective of the world (Fig.1, 2) [1].

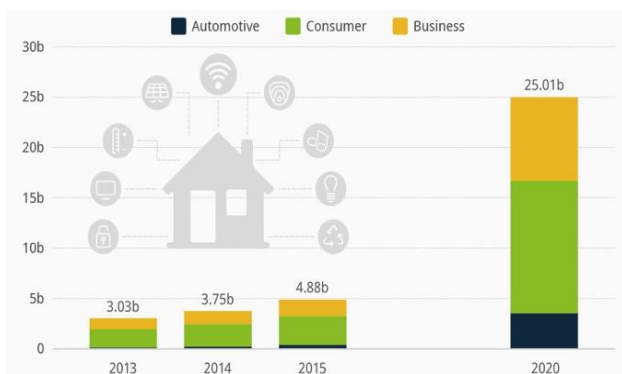


Fig. 1. Internet of Things to Hit the Mainstream by 2020

Industry 4.0 refers to the rapid growth of digitization in smart factories [2].

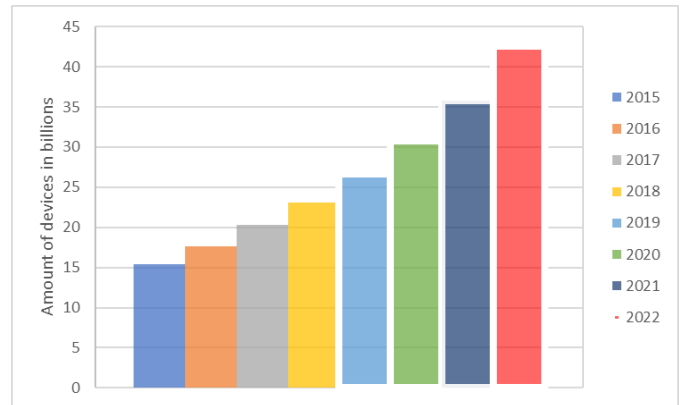


Fig.2. Forecast of the number of devices connected to the "smart factory"

Factories of the future are divided into three categories: digital, smart and virtual. Digital factory involves the use of a wide range of digital tools at all stages of design and manufacturing of products - from the research stage to the prototype. The concept of "Smart Factory" allows you to combine stand-alone machines into a single, controlled and easily analyzed production area, allowing you to evaluate the performance, the need for maintenance, the efficiency of the means of production and much more. It seems relevant to supply factories with a large number of various sensors, collecting information from which it is possible to increase the efficiency of production by reducing equipment downtime and warehouse loading, minimizing staff labor time, and hence optimizing the economic sector of an enterprise. The purpose of this study is to reduce time for recover of a smart factory after cyber-attack equipped with infrared sensors through the implementation of organizational arrangements. (fig.3) [3]. Virtual factory is integration of digital and/or smart factories into a distributed network.



Fig. 3. Smart Factory Interconnections

Smart factory devices can be characterized by attributes which are synthesized into the acronym S-E-N-S2-E2 – Sensing, Efficient, Networked, Specialized and Everywhere [4]:

1. "Sensing" means the application of sensors;

2. "Efficient" goes to the possibility to add "intelligence" and "efficiency" to processes by collected data;
3. "Networked" is about wireless connection between devices;
4. "Specialized" considers the specificity of the IoT tools and Computerized and Numerically Controlled (CNC) machines;
5. "Everywhere" means that the invasion of such objects are will exponentially grow in our daily life and in business processes.

The main principles of Smart factories are the following [5]:

1. Interconnection: using sensors and wireless communication CNC machines can provide people remote monitoring of production process for effectiveness and efficiency;
2. Information transparency: a lot of information is collected and analyzed which helps to optimize process, but at the same time creates several vulnerabilities of process;
3. Decentralized decisions: first two principles provide decentralized control of production area and possibility to find inner and outer weak features of the process;
4. Technical assistance: great number of decisions can be made by machines without human interference.

The principle of operation of passive infrared motion detectors is based on the registration of changes in the intensity of infrared radiation during the movement of a thermal object in the detection zone of the sensor (as any thermal object has infrared radiation). The detection zone is formed and configured (its exact geometrical dimensions are determined) using a multi-segment mirror and an optical system on Fresnel lenses, respectively. It consists of a plurality of rays (called detection rays) directed at different angles and in different directions.

Movement detection in the detection zone occurs as follows: the intersection of the rays with thermal object leads to the entry of infrared radiation pulses onto the sensitive element of the device. Modern detectors for signal processing use digital methods with microprocessor. The sensor has a spherical lens that provides a detection zone without distortion, a high collecting ability, the formation of anti-tampering zones in the volumetric and linear detection zones, as well as temperature compensation of the detecting ability when the ambient temperature changes.

Traditional approaches to ensuring information security do not solve the main task for smart factories - ensuring the continuity of the management process in conditions of destabilizing influences. This is primarily due to the lack of thoughtfulness of the security point of view, namely:

- ability to identify machine tools and software in local and global networks;
- use of obsolete general-purpose hardware and software in modern machines;
- weak authorization and authentication tools (default authentication data embedded into the software, unreliable algorithms, etc.);
- weak audit and event logging tools.

3. Cyber-tolerance of smart factory

As at present, the work of production is mainly based on staff, which is both directly working and administrative staff (fig.4). At the same time, even the choice of the optimal schedule and algorithm for the operation of production does not make it possible to promptly redistribute resources and personnel, which impedes production flexibility and introduces errors caused by the human

factor. And though concept of smart factory means automation, we have to take people into account.

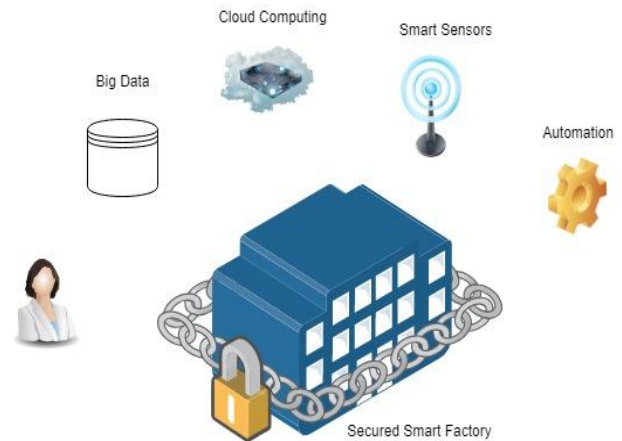


Fig.4. Staff in Smart Factory

One of the possible ways to overcome this problem is the use of expensive simulation software and decision support systems that generate recommendations for the organization of the enterprise. However, to work with this software, highly qualified specialists are required, as well as a huge amount of basic data on the actual work of production, which are often unavailable. According to statistics, every second company was subjected to cyber-attacks, and these attacks were mostly ignored by enterprises. At the same time, less than 2% of those attacked report incidents (a blow to reputation and a decrease in the value of shares). To ensure the safe operation of a smart factory infrared motion sensors are used but there are common ways to circumvent them:

1. Screening. The easiest way to "close" sensor is using a piece of glass or other material. The main thing is to know the location of the sensor. When ceiling mounting the sensor should be closed from above, with wall mounting - from the side. You can shield the sensor itself.

2. Movement with interruptions. Most sensors detect a target with a speed range from 0.1 to 5m /s.

3. In the afternoon, when there is a lot of movement and the guard is removed, you can try to short circuit and block the motion sensor. But sometimes a case tamper switch is installed on the detector. In this case, the use of such a method of bypassing the motion sensor is useless.

Cyber-tolerance implies planning actions not only before and during the cyber-attack process, but also after. It is determining who should be informed inside and outside the organization.

As far as infrared optical sensors only help to detect intrusion and are not guarantee information security that is why special measures are required:

1. System-wide measures for the creation of scientific, technical and methodological foundations for the protection of the network to which the CNC machines and other devices are connected;

2. Conducting special tests of used computer equipment and carrying out measures to protect information from leakage through channels of spurious electromagnetic radiation and interference;

3. Development and approval of the functional responsibilities of computer security officials;

4. Determinations of the procedure for the appointment, modification, approval and granting to specific officials of the necessary authority to access system resources;

5. Determination of the procedure for recording, issuing, using and storing removable magnetic storage media containing reference and backup copies of programs and arrays of information, archive data, etc.;

6. Organization of accounting, storage, use and destruction of documents and carriers with non-public information;
7. Distribution of access control details (passwords, encryption keys, etc.);
8. Analysis of system logs, taking action on detected violations of work rules.

4. Conclusions

When developing measures to ensure the information security of smart factories, it is necessary that people and organizations change their thinking and take into account interdependence and sustainability in order to be prepared for such scenarios where cyber risks can arise and affect the operation of systems. In this context, it is advisable to introduce the concept of cyber-tolerance - the ability of the system to resist cyber events.

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PREPARATION AND CHARACTERIZATION OF NANOSTRUCTURED FERRIC HYDROXYPHOSPHATE ADJUVANTS

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Abstract: This article describes part of the results obtained during the development of a new generation of vaccine adjuvants based on nanostructured hydroxyphosphates of tunable composition and physicochemical characteristics. Colloidal gels of ferric hydroxyphosphates of various iron/phosphate ratios were prepared by precipitation techniques, sterilized by autoclaving and analyzed by transmission electron microscopy (TEM) and dark-field optical microscopy. The obtained materials were composed of a network of amorphous nanoparticles (<20 nm in size) that were aggregated into micron-sized structures in physiological saline. Preliminary adsorption experiments indicated the ability of the obtained materials to adsorb protein substances, which is an important prerequisite for their potential application as vaccine adjuvants and further optimization of the production process to achieve reproducibility of the physicochemical characteristics.

Keywords: ADJUVANT, IRON(III), HYDROXYPHOSPHATE, MORPHOLOGY, ADSORPTION

1. Introduction

Iron is vital for the majority of organisms by participating in the structure of many different enzymes (catalase, lipoygenases, various oxidoreductases, etc.) and in metabolic reactions, including electron transfer, processes of transport, storage and use of oxygen [1]. Its importance for health had been recognized by the ancient inhabitants of the Balkan region, who used iron-containing red stones (the so-called *Argilla rubra*) prescribed to weak and anemic people [2]. Nowadays, nanosized colloidal dosage forms of ferric hydroxide have found clinical application as formulations for parenteral administration in the treatment of severe iron-deficiency anemia [3-5].

Interestingly, injectable suspensions of the sparingly soluble ferric hydroxide and ferric phosphate have been found to potentiate the immune response against protein antigens and therefore have been proposed for vaccine adjuvant use. The preparation of ferric-based adjuvants and their use in adjuvanted vaccines have been described mostly in patents [6-8] and rarely in scientific articles [9]. It has been found that colloidal iron hydroxide behaved comparably to aluminium hydroxide with respect to supporting induction of an antibody response to tetanus toxoid and also induced long-lasting antibody responses, which protected animals from tick-borne encephalitis virus (TBEV) infection even one year after vaccination [9]. It should be noted that the use of colloidal iron hydroxide as adjuvant had the additional advantage to reproducibly support induction of HIV-1 envelope-specific cytotoxic T lymphocytes (CTL), when used as an adjuvant for a HIV-1 env-carrying recombinant fowlpox virus and being applied via the subcutaneous route, while aluminium hydroxide was much less active in this respect [9]. The ferric phosphate has also been demonstrated to be a good adjuvant; as regards the IgG1, the results obtained have been clearly superior to those obtained when the antigen was administered alone, even though the results were not quite as good as those obtained with aluminium hydroxide; as regards the IgG2, the titers obtained were as high as those obtained with aluminium hydroxide [8]. Also, it has been found that ferric phosphate is a good adjuvant for tetanus toxoid, clearly better than ferric hydroxide under the same conditions [8].

Previous studies on aluminium hydroxyphosphate adjuvants have demonstrated that the metal/phosphate molar ratio has a significant effect on some physicochemical properties [10,11], while similar studies on their ferric-based analogues could not be found in the available literature. Here, we present our research on the preparation of ferric-based hydroxyphosphates of variable iron/phosphate molar ratio as potential candidates for adjuvant use. We studied the effects of the iron/phosphate molar ratio on the ultrastructural morphology and the formation of micron-sized

aggregates in physiological saline solution. Preliminary experiments on the electrokinetic properties and protein adsorption were also performed.

2. Materials and Methods

2.1. Reagents

For the preparation of ferric hydroxide and the various ferric hydroxyphosphates, we used iron(III) chloride-6-hydrate (>99%), sodium hydroxide (>98%) and sodium phosphate tribasic dodecahydrate (>98%), purchased from Sigma-Aldrich, Germany.

2.2. Preparation of adjuvant gels

Ferric chloride-6-hydrate (1.45 mmol; 390 mg) was dissolved in distilled water (3.5 ml) and diluted with 20 ml of distilled water. Then, a solution of sodium phosphate tribasic dodecahydrate (1.45 mmol; 550 mg) in distilled water (3.5 ml) was added dropwise with stirring (600 rpm) to prepare the FePO_4 dispersion; for preparation of the $\text{Fe}(\text{OH})_3$ dispersion, NaOH (4.35 mmol; 175 mg) was used instead of sodium phosphate. Three different hydroxyphosphates were also prepared with initial Fe/P molar ratio 100/75, 100/50 and 101 100/25 by keeping the total amount of iron equal to 1.45 mmol. The hydroxyphosphates were precipitated from the ferric chloride solution by using a mixed solution of sodium hydroxide and sodium phosphate with amounts of reagents calculated to obtain the expected composition. For example, in order to obtain the composition $\text{FePO}_4 \cdot \text{Fe}(\text{OH})_3$ (Fe/P = 100/50), 87 mg (2.175 mmol) of NaOH and 275 mg (0.725 mmol) of $\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$, dissolved in 3.5 ml of distilled water, were used. The pH of dispersions should not exceed 7. The precipitates formed were stirred for 5 minutes at room temperature and were autoclaved for 30 min (121 °C).

2.3. Physicochemical characterization

The particle morphology and ultra-structure were observed by transmission electron microscope JEM-2100 (JEOL) at acceleration voltage of 200 kV, equipped with a micro-analyzer X-Max 80T (Oxford Instruments). Micron-sized aggregates in the gels were visualized directly in 0.9% NaCl by using an optical microscope (Optika B-180, Italy) with a dark-field condenser.

3. Results and discussion

3.1. Physicochemical properties

The ultrastructural morphology of the obtained ferric phosphates prepared by using different initial Fe/P (iron/phosphate) molar ratios showed a network of nanoparticles of average sizes up to about 20 nm that were aggregated into micro-sized structures (up to about 30 μm), as seen from the transmission electron images shown in Fig. 1.

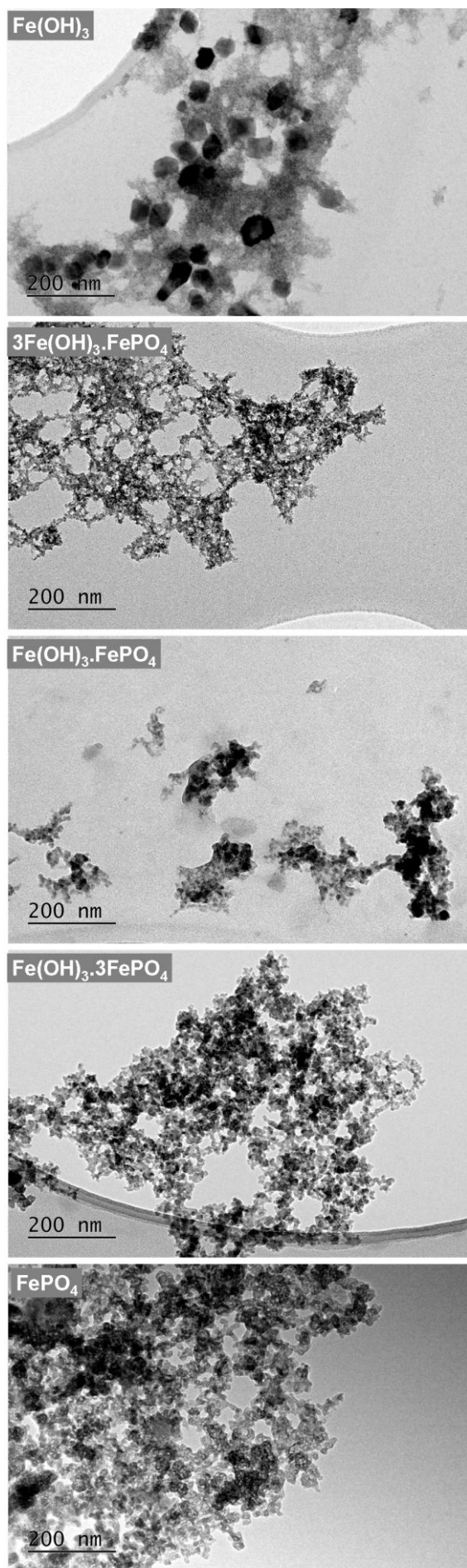


Fig. 1. TEM images at magnification of x25k of Fe(OH)_3 , FePO_4 and different ferric hydroxyphosphates (given in the figure legends).

This morphology was very similar to that of aluminium phosphate currently used in human vaccinations, although the primary nanoparticles of aluminium phosphate are larger, about 20–50 nm in size [12,13]. The increasing hydroxide/phosphate ratio (that corresponds also to increased Fe/P ratio) resulted in the formation of ferric hydroxyphosphates with even smaller primary nanoparticles of sizes <20 nm. These primary nanoparticles were aggregated into clusters via “bridges” of amorphous material.

Analysis by energy dispersive spectrometry (EDS) showed the presence of iron, phosphorous and oxygen. A representative scanning TEM (STEM) image and maps of element (Fe, P and O) distribution in the ferric hydroxyphosphate with an initial molar ratio of Fe/P = 100/50 is shown in Fig. 2. The signals for the elements Fe, P and O are localized in the same areas, indicating the formation of hydroxyphosphate particles (but not separate hydroxide and phosphate particles). Data from quantitative EDS measurements of the Fe/P/O ratio in the obtained materials showed that it was close to that was used in their preparation. However, these values should be interpreted with care, because we found that they may depend on the time for count accumulation probably as a result of changes in the material upon interaction with the electron beam of the microscope. The morphology of the sample can also change upon longer observation times. It should be noted that the interaction with the electron beam can result in heating of the observed sample, dehydration and evaporation of material thus affecting both the morphology and the elemental composition. For that reason, TEM images (Fig. 1) were taken with minimum time of exposure of the material to the electron beam (within less than few minutes).

The electron diffraction analysis showed that the obtained hydroxyphosphates with different hydroxide/phosphate ratio were structurally amorphous. The ultrastructure of the sample formally referred to “ferric hydroxide” or “ Fe(OH)_3 ” (prepared by using sodium hydroxide instead of phosphate) was quite different from that of the ferric hydroxyphosphates prepared at similar conditions. TEM observation revealed that it contained nanocrystals of size up to ~50 nm that were dispersed within an amorphous matrix. Under high-resolution mode (HRTEM) the matrix appeared granular, containing vary small particles, about 3 nm in size. The composition of the sample according to EDS analysis corresponded to Fe/O molar ratio of 1.0/2.4, while the nanocrystalline phase was confirmed to be hematite.

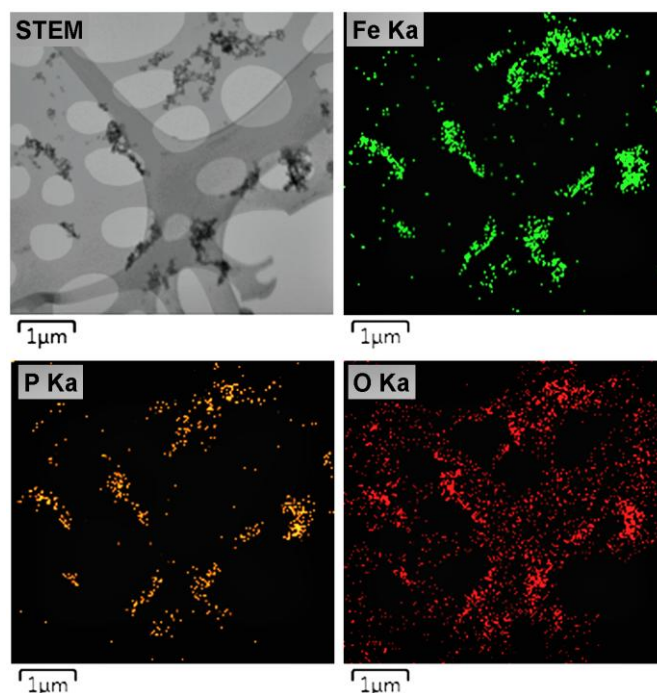


Fig.2. STEM image and maps of element (Fe, P and O) distribution of ferric hydroxyphosphate (Fe/P = 100/50), $\text{Fe(OH)}_3\text{FePO}_4$.

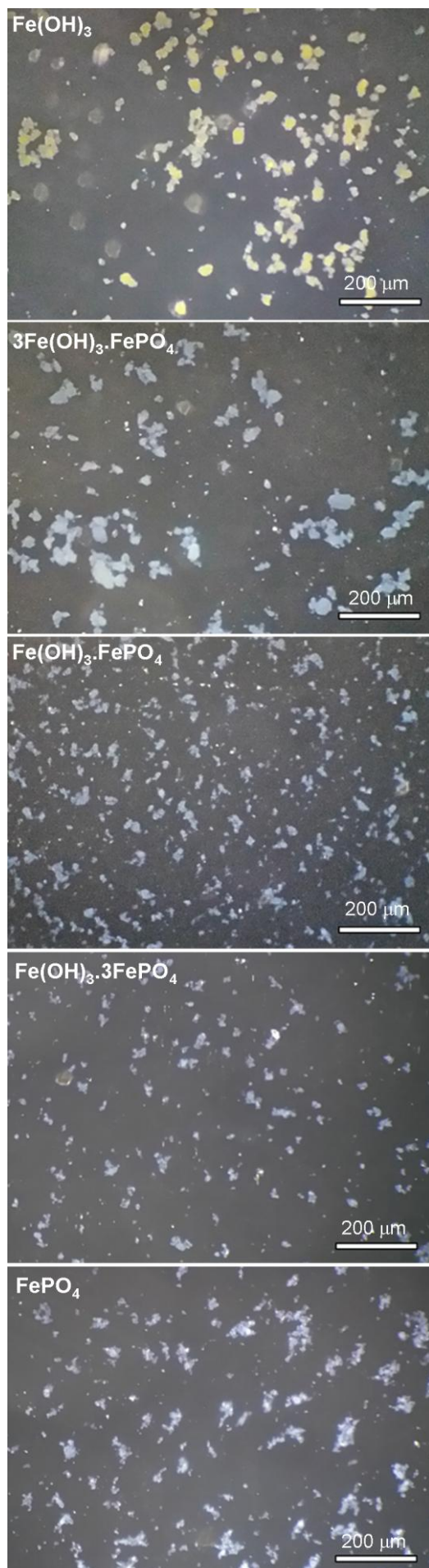


Fig.3. Dark-field optical microscopy images of the micron-sized aggregates of ferric hydroxyphosphates in physiological saline.

Analysis by X-ray powder diffraction (XRD) confirmed the amorphous structure of the obtained materials and the presence of a nanocrystalline hematite phase in the Fe(OH)_3 sample (data not shown). It should be noted that the hematite phase was formed during the autoclaving, since the non-autoclaved Fe(OH)_3 sample was structurally amorphous.

We used a dark-field optical microscope to observe the micron-sized aggregates (secondary particles formed by the aggregated primary nanoparticles) in 0.9% NaCl (Fig. 3). There were different structures – ranging in size from few microns to about 20-30 μm . The ferric hydroxide sample contained the largest particles, which were colored in yellow. These samples were also prone to relatively faster sedimentation forming a fine precipitate upon standing, while all ferric hydroxyphosphates appeared as gel-like suspensions that formed a gel sediment upon mild centrifugation. The aggregation state of adjuvants in vaccines depends also on its concentration and interactions with proteins and other components of the formulation [14]. The size of secondary adjuvant particles (aggregates) appears to be of importance for both the effective adsorption of antigens and phagocytosis of adjuvant particles by antigen-presenting cells [15,16]. The relatively larger particle size in the case of ferric hydroxide may be a reason to expect a lower rate of phagocytosis compared to the hydroxyphosphates although it can be revealed only by detailed future experiments on the intracellular fate of these adjuvant systems.

3.2. Potentials for adjuvant use

Inorganic adjuvants, such as aluminium oxyhydroxide and hydroxyphosphate, which are currently used in many human and veterinary vaccinations, are known to serve as enhancers of antigen phagocytosis and activation of antigen-presenting cells [17], as well as stimulators of inflammatory reactions that appear to play a key role in mediating adjuvanticity and subsequent development of specific immunity [18]. It is currently known that the immune potentiation requires phagocytosis of the adjuvant/antigen by dendritic cells [19]. Similar mechanisms of adjuvanticity can be assumed also for the ferric-based adjuvants, since it is well-established that particulate ferric hydroxide is rapidly phagocytosed by macrophages upon parenteral administration [20,21]. The ferric-based adjuvants can potentially serve as antigen carriers to the phagocytic antigen-presenting cells. In preliminary experiments, we found that all investigated ferric hydroxyphosphate adjuvant gels had isoelectric points between 3.5 and 4.5, and could adsorb albumin (as a model of protein antigen), about 30 mg/mmol Fe(III) at pH 7, which is an important prerequisite for their potential application as protein antigen carriers (details on zeta-potential measurements and protein adsorption will be reported elsewhere).

Among the most important issues in the development of inorganic adjuvants besides efficacy are their safety [22], immunotoxicity [23] and toxicokinetics [24]. High loading of insoluble adjuvant particles in phagocytic cells without immediate cytotoxicity might predispose to their subsequent transport throughout the body, while on the other hand, heightened solubility of adjuvants and potentially the generation of metal ions in the endosomal environment have been positively correlated with an increase in cell mortality *in vitro* [25]. Although it has been demonstrated that ferric phosphate could be dissolved in citrate solutions, similarly to aluminium phosphate [12], the *in vivo* degradation of the ferric-based adjuvants is still unknown. It might be expected that endosomal degradation of ferric phosphates would result in the release of ferric ions inside phagosomes. Phagocytic cells have the ferroportin transmembrane transporter that facilitates transportation of ferric ions out of the cell [21]. Once exported into the extracellular environment, most of the ferric ions are expected to bind with transferrin (ferric-specific transporter protein in blood plasma) and to be included in the normal iron metabolism. Also, adverse effects from the relatively small amount of iron (few milligrams) applied during vaccination are less likely to occur since iron is present in humans in relatively large amounts (35-50 mg iron/kg body weight). However, detailed toxicokinetic experiments

must be performed in order to evaluate the exact safe doses of the different ferric-based adjuvants.

4. Conclusions

Ferric hydroxyphosphates of various Fe/P molar ratios as potential adjuvants have been prepared and characterized. The hydroxyphosphate gels consisted of networks of primary amorphous nanoparticles of average sizes about <20 nm, smaller in size compared to those of aluminum phosphate adjuvants (20–40 nm). The ferric hydroxide obtained at similar conditions consisted of hematite nanocrystals dispersed into amorphous matrix. These primary nanoparticles formed micron-sized aggregates (secondary particles) in physiological solution. Preliminary experiments indicated the ability of the obtained adjuvant gels to adsorb protein substances, which is an important prerequisite for their potential application as vaccine adjuvants and further optimization of the production process.

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APPLICATION OF MODERN TECHNOLOGIES AND DEVELOPMENTS IN THE RECONSTRUCTION OF "GRAF IGNATIEV" BLVD.

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Abstract: In view of the projects, which are being implemented in the second programming period 2014-2020 by the metropolitan municipality, a reconstruction of Graf Ignatiev Blvd was planned. An important part of it is the construction of the railway track. In fulfilment of the requirement for the elaboration of a diploma thesis on this topic, a number of options for implementation of the project, which apart from applied have a cognitive value. They meet the requirements for interoperability of technical infrastructure in relation to Commission Regulation (EU) No 1299/2014 of 18 November 2014 concerning the technical specifications for interoperability relating to the infrastructure subsystem of the rail system in the European Union [3].

Keywords: Interoperability, Regulation No. 1299/2014, Railway track, Tramline

1. Introduction

In view of the projects implemented during the second programming period 2014-2020 by a metropolitan municipality, a reconstruction of the central part of the city was planned, including Graf Ignatiev Blvd., according to the technical requirements and norms of the tramway track [1].

An important part of the reconstruction of the boulevard is the construction of the track. In fulfillment of the requirement for the elaboration of a diploma thesis on the topic, according to [2], a number of project implementation options were considered which besides applied have a cognitive value.

They meet the requirements for interoperability of technical infrastructure in relation to Commission Regulation (EU) No 1299/2014 of 18 November 2014 concerning the technical specifications for interoperability relating to the infrastructure subsystem of the rail system in the European Union in Part [3], which also applies to urban rail transport.

2. Prerequisites and means for solving the problem

2.1. Current situation on "Graf Ignatiev" Blvd.

The current state of the boulevard, which has not been repaired in the first place, is severe: difficult drainage of surface water Fig.1,

missing or broken drainage shafts to which the invisible state of the water supply network has to be added; emergency condition of the road surface and the reinforced concrete panels in which the unsightly tram rails are laid Fig. 2; noise and vibrations caused by the tramway movement, the suspension of the wearing ropes of the contact network to the facades of buildings Fig. 3; the construction of a third metroline and the heavy traffic from construction machines at intersections and adjacent streets [4].

2.2. Possible causes and solutions

The reasons for the state of the boulevard are complex but at this stage stand out: long repaired repairs on the water supply, road cover, tramway, contact network, electrical system, etc. In 2017 a change in Regulation No 2 on planning and designing the communication-transport system of urbanized territories [5] entered into force. The radical change that has been made for many years in tram transport [6] is the transition to a normal track gauge of 1435 mm.

A first step to shift to normal gauge is mounted on the third rail for the simultaneous movement of trams in narrow-gauge (1009 mm) and normal gauge [7]. The verification found that the change is not possible within the gauge of the existing boulevard Fig. 4 [5].



Fig.1 Drainage of surface water



Fig.2 Emergency condition of pavement and concrete panels



Fig.3 Status catenary

3. Solution to the examined problem

3.1. Drainage

The drainage of surface water, its removal and discharge to the urban sewage system, which in turn also undergoes changes in the course of the reconstruction but by a separate project, is a complex task. First of all, the longitudinal slope and the water flow along the longitudinal profile of the tram line are to be traced fig.5 [2].

The drainage of the road crossings is decided according to the drainage of the main boulevards, the existing shafts and drainage facilities, fig.6.

3.2. Noise and vibration

Graf Ignatiev Boulevard is emblematic with the surrounding buildings, most of which are cultural monuments. Noise and vibration start with the traffic and the dynamic impact of the tramway. Tram vibrations are transmitted from the track construction to the ground and from there through the foundations

of the buildings to the main supporting structure. Another way to transmit noise and vibration are carrier ropes catenary [8, 9], which are anchored in the supporting structure of the building.

The output is the interruption of the chain of transmission of the vibration, improvement of the structure of the track in order to reduce the noise source and placing new load-bearing pillars of the catenary to reduce the anchorage of the supporting ropes in the construction of buildings. The design of the track is improved by applying to a rail fastening Pandrol for tramway and applying ballast less structure [7, 10], which is insulated from an underlying concrete with foam rubber.

The structure for the attachment of catenary is exported mainly of steel pillars, with a cantilever fixed slats Fig. 7 [8]. The attachment of the supporting structures of the buildings remains only exceptionally and lighting.

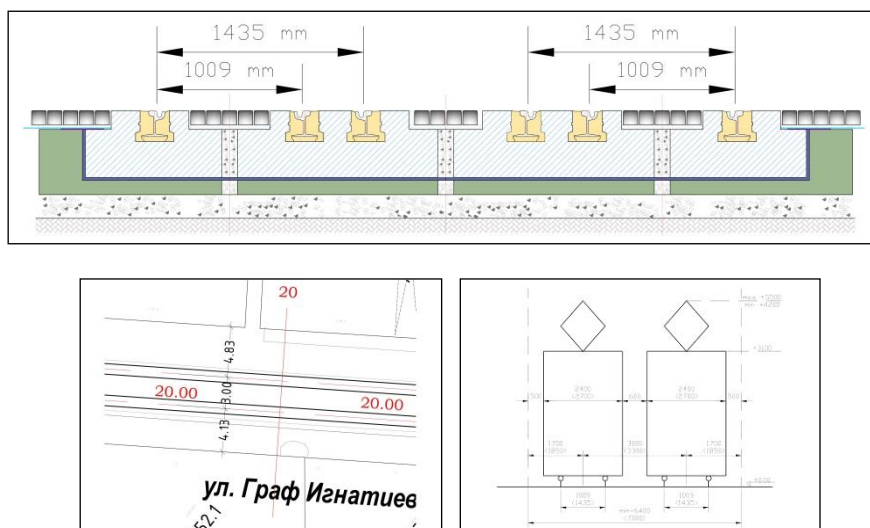


Fig.4 Gauge requirements and options for mounting a third rail

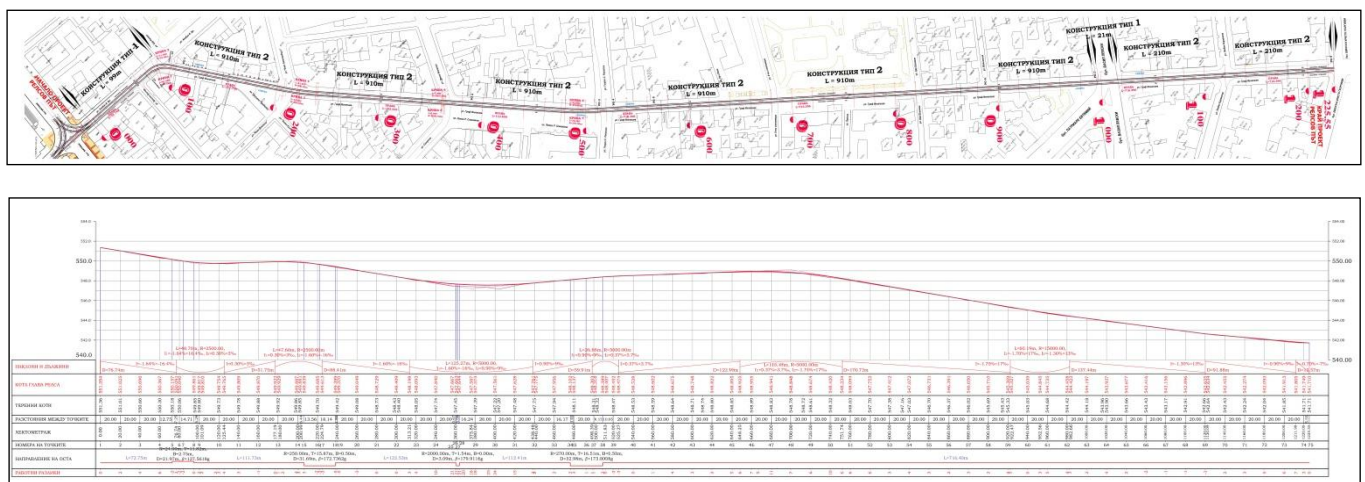


Fig.5 Longitudinal profile of the tram line

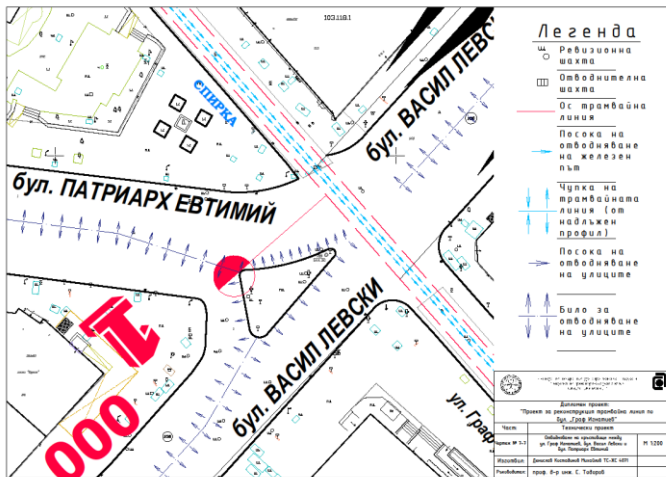
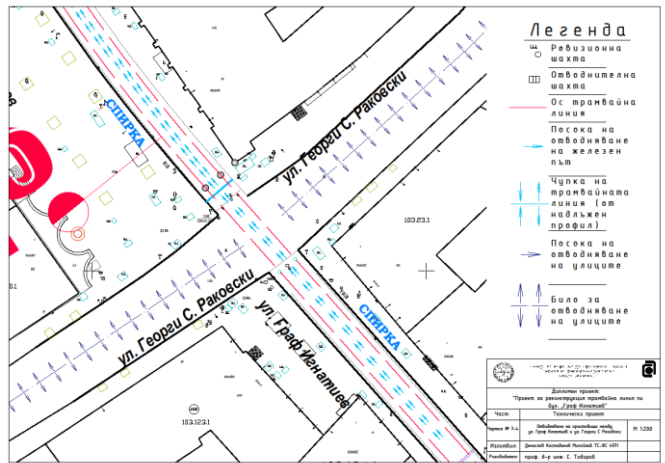
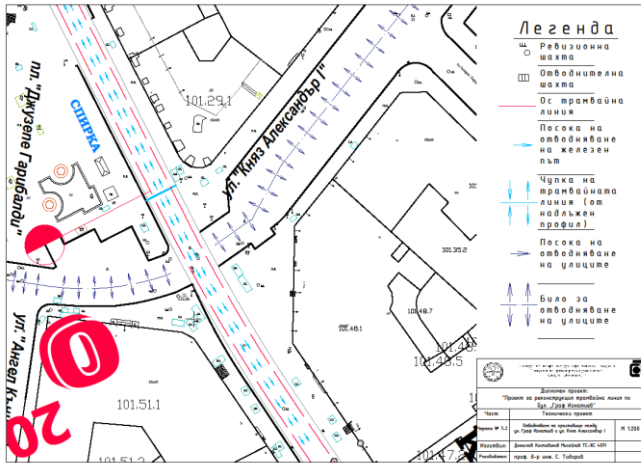


Fig.6 Drainage of main road crossings and drainage ditches

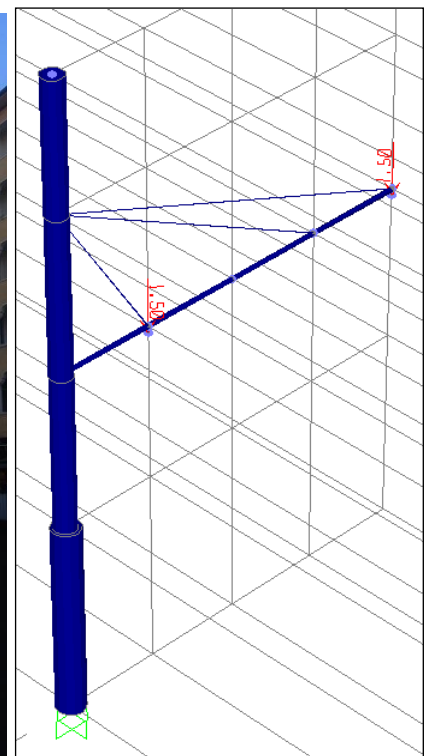
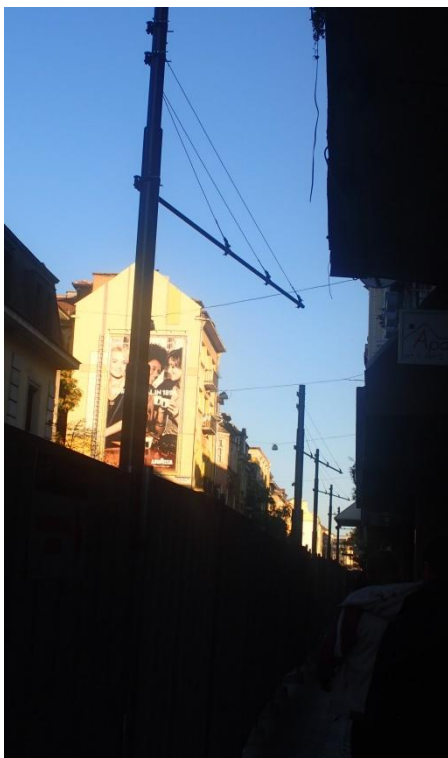


Fig. 7 Support pillars for the catenary

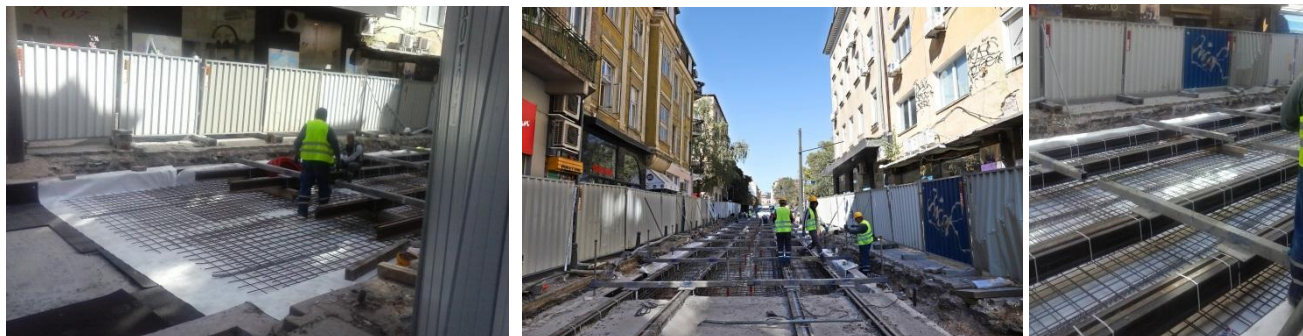
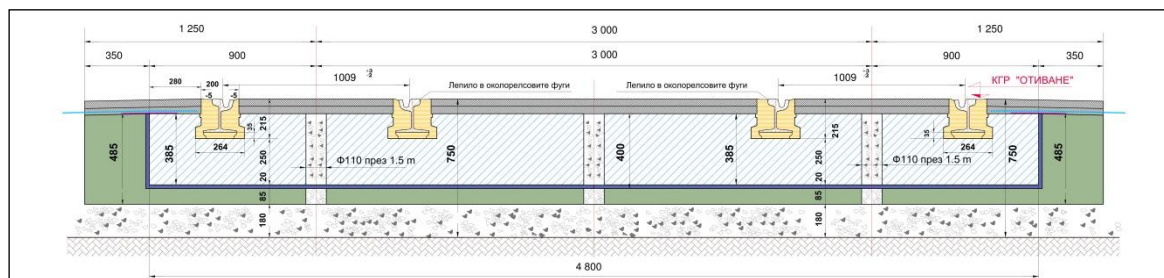


Fig.8 Construction of the tramway track

3.3. Rail Track Solutions

The track construction is improved by adding additional elastic materials (foam rubber):

- a rail tramline Pandrol fastening [10], which covers the rail with a foamed rubber sheath, is applied. This solution reduces vibrations, the rail gets elasticity in the vertical and horizontal plane, adjusts to the wheel load. The noise source is reduced Fig. 8=
- a non-ballast construction of the track is applied which is insulated from the underlaid concrete with a foam rubber, a reinforced concrete "floating" slab, poured in place - the reinforced concrete structure Fig. 8 is interrupted, which is the main conductor of vibrations with insulating and vibration-reducing matter..

4. Results and discussion

The project results are still unclear due to ongoing repairs, performance quality and having started operation. The discussion began in a professional environment, transferred to the public space, including political ground. The actual results will become clear after the start of operations, measurements and comparison of the results with those before and after the repair and with other similar sites in Sofia.

5. Conclusion

The solution to the problems of Sofia's central city district cannot happen suddenly. The way is: finding problems; analysis and study of causes; preparing an assignment and project, providing funding, public discussion and implementation. The investment process is usually 6 or 7 years. There is plenty of time to propose, analyze, and implement a publicly acceptable project.

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EXPERIMENTAL AND SIMULATION DETERMINATION OF FRICTION COEFFICIENT BY USING THE RING COMPRESSION TEST

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Abstract:

One of the main problems in the plastic deformation of materials is the determination of the coefficient of friction as well as the subsequent application of the simulation for comparative analysis. However forecasting process and matching between simulation and experimental data is still a problem. Causes of this are factors such as roughness, mechanical properties of the material, chemical composition, etc. which strongly influence the behavior of the material in the simulation of the process.

In this study, an approach is proposed to determine the changeable coefficient of friction in the deformation process experimentally, taking into account implicitly the influence of surface roughness on the friction curves. For the comparative analysis between experiment and simulation of the process, the experimental data for objective assessment was introduced. Nevertheless, there are differences between experiment and simulation, which is most evident in high loads, using lubricants differing from more than 12 units for graphite lubricant, with more than 6 units with oil and with dry friction with 8 units.

Keywords: FRICTION, RING, COMPRESSION, SIMULATION, PLASTIC DEFORMATION

1. Introduction

Forecasting the coefficient of friction of plastic deformation of metals by means of software products is still a problem [1-4]. As is well known, it depends on a number of factors, such as the type of lubricant used and the roughness of the friction surfaces of the tool and the workpiece [5, 6]. Different software products are used to investigate the problem by introducing a set of experimental data for the purpose of adequate simulation and forecasting. For the majority of software products, the surface roughness parameter is not included as an input parameter, but it is part of a complex friction factor index - friction coefficient μ or friction factor m [7]. Both indicators friction usually introduced as constants in the models to simulate until they change the process of deformation. In such case interpretation of the results may lead to incorrect conclusions and significant deviations of the results of experiment and simulation. To obtain an objective solution to the problem, multiple repetition of simulation with different values of μ and m can be performed.

The aim of the present study is to establish the possibility of simulating the process of deformation of pressure rings (DPR) by applying experimentally established equations for the change of coefficient of friction.

2. Materials for Production of Prototype Parts

Грешка! Източникът на препратката не е намерен.

For the purposes of the experimental study by the process DPR used steel bar material 10 sp. With a chemical composition in% (C - 0.9, Si - 0.26, Mn - 0.43, P - 0.08, S = 0.03). The nominal dimensions of the rings with an outer diameter $D = 16$ mm, the inside diameter $d = 6.5$ mm and height $H = 7$ mm (Figure 1).

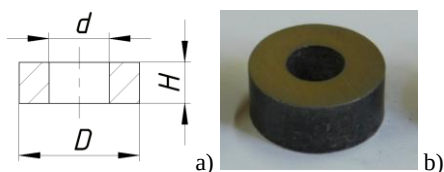


Fig. 1. Test bodies for the experimental determination of the coefficient of friction: (a) the dimensions of the test piece (b) the test piece

The contact surfaces of the test specimens have a roughness $Ra = 2.5 \div 1.25 \mu\text{m}$, and the working surfaces of the tool are of $Ra = 0.63 \mu\text{m}$.

For the flattening of the test bodies was used a hydraulic press MC 2000 with mounted flat parallel boilers (fig.2). The study was performed under three friction conditions - dry, with oil MHL-34 and graphite powder.

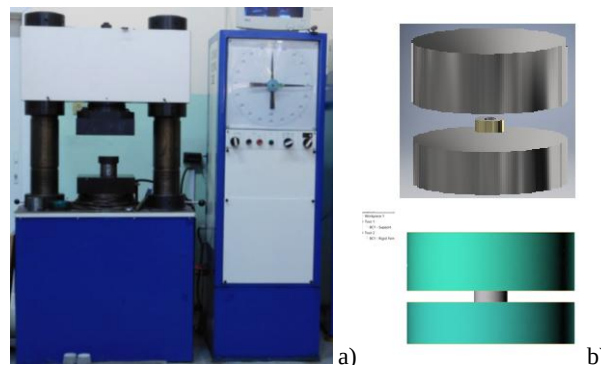


Fig. 2. Used Testing Equipment (a) Testing Machine MS-2000; (b) a digital simulation model

The experimental test rings are flattened into three transitions with a loading force (F) of 100, 200 and 300 kN with a set load speed of 0.5 mm / min at room temperature. Upon reaching the specified load the sample is ejected, wherein using a load cell is recorded the maximum thrust force (T) - the criterion for the maximum friction. Before each deformation, the samples are cleaned, measured, and the test rings are lubricated by their working heads at a specific dose. Prior to each test, the working surfaces of the top and bottom lugs are also cleaned and lubricated with the lubricant for the lubricant tests. The dimensions of the rings before and after deformation are measured with an electronic caliper with an accuracy of 0.01 mm (Table 1, 2 and 3). From the obtained measurement data are calculated: the degree of deflection ε (1), the relative change of the inner diameter $\Delta d / d$, the force of ejection T between the ring sample and the two flat cylinders, the coefficient of friction μ (2) [8] are constructed experimental curves for the change of the coefficient of friction μ' (Fig.3). The calculated μ values for the different strain rates determine the coefficient of variation curve.

$$\varepsilon = (H_0 - H)/H_0 \times 100 \quad (1)$$

$$\mu = (2 \times T)/F \quad (2)$$

For the comparative analysis of the experimental data and simulation, the software product "QForm 3D" v.7.1 was used, in which the necessary data from the experiment was introduced, instead of introducing a constant coefficient of friction using the experimental curve for the change of the coefficient of friction, the presumed recovery curve from the material pressure test, the chemical composition, the type of lubricant, etc.

Data collection from the simulation was performed at a loading step of 100 kN. The study process continues until the maximum force of the hydraulic press 400 kN has been reached. The results of the simulation are presented in tables (tables 4, 5 and 6) and graphical dependencies are built (fig. 4).

3. Results and discussions

Figure 3 illustrates graphically the change of the experimentally established coefficient of friction for the three cases. At the initial deformation stage, the lowest internal diameter variation values are present for the non-lubricated sample. In fact the initial inner diameter under load of 100 kN is not altered (Table 1), while increasing only the outer diameter. Probably this is due to the fact that the roughness of the sample is greater than that of the tool, resulting in friction being associated with breaking the peaks of the roughness during the loading process.

Table 1. No lubrication - Experimental data

Measurement number	Load force	Height	Inner diameter	Strength of pushing	Relative amendment	Relative deformation	Coefficient of friction
	F _n (kN)	H (mm)	d (mm)	T (kN)	Δ d/d ₀ (%)	ε (%)	μ
0	0	7	6.55	0.00	0	0.00	
1	100	6.33	6.55	18.53	0	9.57	0.3705
2	200	4.43	6.4	26.70	2.29	36.71	0.2670
3	300	3.35	5.76	34.60	12.06	52.14	0.2307

Table 2. With Oil - Experimental Data

Measurement number	Load force	Height	Inner diameter	Strength of pushing	Relative amendment	Relative deformation	Coefficient of friction
	F _n (kN)	H (mm)	d (mm)	T (kN)	Δ d/d ₀ (%)	ε (%)	μ
0	0	7	6.55	0.00	0	0.00	
1	100	6.51	6.8	18.58	-3.82	7.00	0.3716
2	200	4.45	6.92	24.58	-5.65	36.43	0.2458
3	300	3.36	6.7	33.92	-2.29	52.00	0.2261

Table 3. With graphite lubricant - Experimental data

Measurement number	Load force	Height	Inner diameter	Strength of pushing	Relative amendment	Relative deformation	Coefficient of friction
	F _n (kN)	H (mm)	d (mm)	T (kN)	Δ d/d ₀ (%)	ε (%)	μ
0	0	7	6.55	0.00	0	0.00	
1	100	6.38	6.6	18.87	-0.76	8.86	0.3774
2	200	4.36	6.87	27.63	-4.89	37.71	0.2763
3	300	3.22	7.22	35.83	-10.23	54.00	0.2388

As a consequence of this effect the neutral surface has a radius less than the inner radius of the sample, which is typical of cases with a lubricant. The increase in load leads to a leveling of the micro-roughness and consequently increase the contact area with which the friction increases, the neutral surface radius increases its r_n to values exceeding the inner radius of the sample ($r < r_n$) and intensive reduction in the inner diameter. The application of lubricant to the other two samples, as well as expected, resulted in the arrangement of the curves in the lower quadrant (Figure 4). Due to reduced friction, the inner diameter (d) increases μ' , as in the case of oil in the initial stage and in comparison with the graphite lubricant is lower. This difference may be explained by the complex influence of the lubricant and roughness in the friction zone.

Due to the fact that the roughness in the initial stage is high, friction occurs with a smaller contact area, which state can be said to correspond approximately to a case of border friction. As a result, the increase in the inner diameter is the greatest in comparison with

the dry friction and the use of a graphite lubricant. With the increase of load d slightly changed until reaching a deformation of 36%, which is associated with the closure of the micro-volumes of oil between the roughness and thereby providing an increased contribution of the oil in the process of friction.

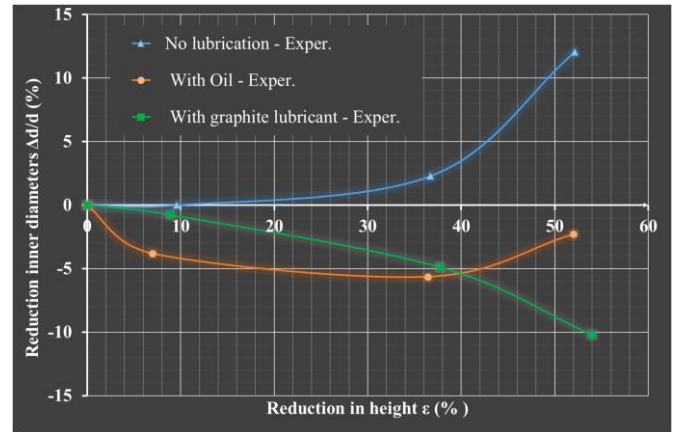


Fig. 3. Friction curves μ' from experimental data

The reduction of d in deformations of more than 38% is in accordance with the known regularity of increasing the coefficient of friction at high loads associated with the increase of the contact area and a significant increase of the inhomogeneity of distribution of the oil, accompanied by its displacement.

Table 4. No lubrication - Simulation data

Measurement number	Load force	Height	Inner diameter	Strength of pushing	Relative amendment	Relative deformation	Coefficient of friction
	F _n (kN)	H (mm)	d (mm)	T (kN)	Δ d/d ₀ (%)	ε (%)	μ
0	0.00	6.80	10.00	0.00	0.00		
1	96.34	6.80	9.88	23.44	1.20	0.00	0.4865
2	122.42	6.30	9.81	25.42	1.90	7.35	0.4152
3	153.38	5.89	9.74	27.52	2.60	13.38	0.3588
4	181.31	5.51	9.68	29.56	3.20	18.97	0.3260
5	210.39	5.15	9.54	31.56	4.60	24.26	0.3000
6	243.26	4.81	9.39	34.08	6.10	29.26	0.2802
7	278.49	4.48	9.18	36.83	8.20	34.12	0.2645
8	316.23	4.18	8.96	39.31	10.40	38.53	0.2486
9	360.26	3.91	8.63	42.11	13.70	42.50	0.2338

Table 5. With Oil - Simulation Data

Measurement number	Load force	Height	Inner diameter	Strength of pushing	Relative amendment	Relative deformation	Coefficient of friction
	F _n (kN)	H (mm)	d (mm)	T (kN)	Δ d/d ₀ (%)	ε (%)	μ
0	0.00	6.80	10.00	0.00	0.00	0.00	
1	88.12	6.80	9.86	23.34	1.40	0.00	0.5298
2	110.49	6.30	10.01	25.36	-0.10	7.35	0.4591
3	142.83	5.80	10.20	28.95	-2.00	14.71	0.4054
4	175.10	5.30	10.38	30.04	-3.80	22.06	0.3431
5	210.92	4.83	10.54	33.04	-5.40	28.97	0.3133
6	250.53	4.40	10.64	36.35	-6.40	35.29	0.2902
7	294.24	4.01	10.92	40.19	-9.20	41.03	0.2732
8	342.07	3.67	10.93	43.59	-9.30	46.03	0.2548
9	395.87	3.38	10.97	47.93	-9.70	50.29	0.2422

Table 6 With graphite lubricant - Simulation data

Measurement number	Load force	Height	Inner diameter	Strength of pushing	Relative amendment	Relative deformation	Coefficient of friction
	F _n (kN)	H (mm)	d (mm)	T (kN)	Δ d/d ₀ (%)	ε (%)	μ
0	0.00	6.80	10.00	0.00	0.00	0.00	
1	92.40	6.80	9.87	23.67	1.30	0.00	0.5124
2	116.52	6.30	9.80	25.46	2.00	7.35	0.4371
3	150.54	5.81	9.90	27.80	1.00	14.56	0.3694
4	181.01	5.37	9.92	30.22	0.80	21.03	0.3339
5	213.05	4.97	9.86	32.69	1.40	26.91	0.3069
6	247.77	4.60	9.88	35.63	1.20	32.35	0.2876
7	286.38	4.25	9.71	38.48	2.90	37.50	0.2687
8	325.62	3.96	9.60	41.46	4.00	41.76	0.2546
9	370.96	3.69	9.48	44.66	5.20	45.74	0.2408

Typical for lubrication with graphite lubricant is the increase of the internal diameter continuous from the beginning of the load. Compared to the effect of the oil, it is obvious that the graphite

grease eliminates the influence of roughness, which can be explained by better adhesion to them. In addition, the results of the experiment once again confirm the well-known fact for the good lubricating effect of graphite at high loads [9].

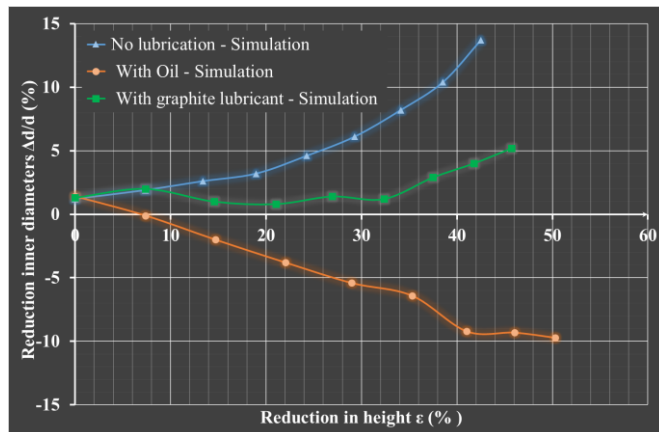


Fig. 4. Friction curves μ'' from simulation data

The comparative analysis of the height variation for the three friction cases shows that for the small deformation rates, the strongest change occurs in dry friction, which can be explained by the influence of the roughness as mentioned above. Furthermore, the dry friction deformation is at the expense only of a change in the outer diameter D , whereas when using a lubricant, deformation occurs at the expense of the outer and inner diameters.

The simulation results show deviations in comparison with the experimental results obtained. The biggest deviation is obtained using a graphite lubricant. The simulation gives a curve to change the friction coefficient (μ'') located above the zero line and up to 32% of the deformation degree, the internal diameter is almost unchanged, indicating that the deformation is largely at the expense of the outer diameter. The character of the curve shows that the software does not take into account the influence of surface roughness, although the input data from the experiment contain implicitly the roughness of the wells and samples. Moreover, in the area of large loads (over 32% deformation), the software provides a change in the direction opposite to the experimentally established. However, the deformation deflection of 46% represents a total of 12 units in the variation of d . These large deviations can not be explained except that graphite in the software is treated as solid particles leading to dry friction when the load is increased.

And when simulating the oil process in the initial stage, the curve of μ'' indicates that the effect of roughness is not taken into account. And when simulating the curve shows that the inner diameter is amended practically linear law until a degree of deformation of 35%. In this range there is some coincidence with experimental curves, then there is a sharp decline in contrast to experiment. This means that the software treats friction at high loads, as if the oil is not thrusting but continues to lubricate, as with low loads.

Regarding dry friction, the simulation gives a comparatively satisfactory result, the curve being similar in character to the experimental but located above it. As the degree of deformation increases, the deviation increases, with 40% of the deformation reaching nearly 8 units. For the difference of lubricant cases, the results of the simulation are more reliable as the lubricant factor is eliminated.

These differences in friction variation also led to a difference in the flattening heights between experiment and simulation, most notably at high deformation rates. Highest values are achieved with dry friction - 9.64%, followed by graphite lubricant - 9% and the smallest with oil reaching 2%.

4. Conclusion

The simulation of the ring flattening process in the case of dry friction gives reliable results regardless of the established deviations. In the presence of a lubricant, the differences between the friction curves from the experiment and the simulation are significant, with the largest change being observed for the graphite lubricant. This is due to the incorrect reading of the influence of lubricants on the changes in roughness in the deformation process. By using oil, it is also accepted that friction continues to decrease with a deformation increase of over 40%, which results in contradiction to experimental data and unrecognized change in contact area. In order to correctly simulate the process of flattening of the underlying rings it is necessary to introduce the change of roughness in the process of deformation.

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ANALYSIS OF THE POINT GROUP OF DIAMOND CRYSTAL

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Abstract: The structure of the diamond is usually represented as two face-centered cubic cell with the same dimensions, which are shifted relative to each other by the value of $\pm \begin{bmatrix} 1 & 1 & 1 \\ 4 & 4 & 4 \end{bmatrix}$. That is eight different ways. However, in this case, there is a possibility of only two enantiomorphous centers, which have the same $\varphi(hkl)_j$. They do not affect on the reciprocal lattice, but allow to explain, for example, the presence of twins. The introduction of the concept of the scattering center of diamond shows that his point group is $Fm\bar{3}m$ with the full symmetry formula $3L_4 4L_3 (4L_3)_i 6L_2 9PC$, whereas the generally accepted model of the diamond structure does not correspond to such symmetry. For example, the L_4 axis is missing, C is not at the origin of coordinates, there is only one L_3 axis along the diagonal along which the sublattices are shifted, etc.
KEYWORD: RECIPROCAL LATTICE (RL), SUPER CELL, DIAMOND, STRUCTURAL UNIT, POINT GROUP $Fm\bar{3}m$.

1. Introduction

The diamond structure is considered as a set of two face-centered cells, one of which is located in the Bravais rapper crystallographic system, and the second cell is shifted relative to the

initial one by the value $\frac{1}{4} \frac{1}{4} \frac{1}{4}$ on the direction $[111]$. Each of the

carbon atoms of the second cell, transferred to a new position, is located in the tetrahedron of the atoms of the first cell. However, all atoms of the first cell are located in the same coordination of the atoms of the second cell.

Diamond spatial group is $Fd\bar{3}m$, hence its point group is $Fm\bar{3}m$. The holohedry of this point group is described by the symmetry formula $6L_2 4L_3 3L_4 9PC$ and does not allow the presence of a single direction that appears when the second cell is shifted.

It is necessary to solve the following tasks:

1. To analyze the point group of diamond, since only its space group $Fd\bar{3}m$ is given in the scientific literature.
2. To consider a diamond structure model in which the structural unit is a carbon tetrahedron.
3. Show that within this model the point group of a diamond has the view $Fm\bar{3}m$.

2. Diamond crystal structure

The cubic face-centered cell is described by the coordinates of homologous points in the crystallographic basis. The cell that is shifted relative to the initial one into a segment $\frac{1}{4} \frac{1}{4} \frac{1}{4}$ will be described by the coordinates given in Table 1 [1].

Table 1. Coordinates of atoms C in the crystal cell and in the cell

shifted by $\frac{1}{4} \frac{1}{4} \frac{1}{4}$

Nº	1	2	3	4
X_1	000	$0 \frac{1}{4} \frac{1}{4}$ $2 \quad 2$	$\frac{1}{4} \frac{1}{4} 0$ $2 \quad 2$	$\frac{1}{4} \frac{1}{4} 0$ $2 \quad 2$
X_2	$\frac{1}{4} \frac{1}{4} \frac{1}{4}$ $4 \quad 4 \quad 4$	$\frac{1}{4} \frac{3}{4} \frac{3}{4}$ $4 \quad 4 \quad 4$	$\frac{3}{4} \frac{1}{4} \frac{3}{4}$ $4 \quad 4 \quad 4$	$\frac{3}{4} \frac{3}{4} \frac{1}{4}$ $4 \quad 4 \quad 4$

That is, the atom of the second cell centers four of the eight octants of the original cell (figure 1). Each atom of the first cell is inside the tetrahedron of the atoms of the second cell and vice versa [2].

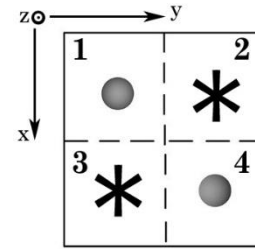


Fig. 1. – Position of atoms from the second cell relative to the original. $(\bullet) - Z = \frac{1}{4}$, $(*) - Z = \frac{3}{4}$ (the numbers are the same as the numbers for x_2 in the table 1)

The set of atoms X_1 and X_2 (table 1) defines the diamond cell. As an example, consider the coordination of an atom of the first cell with coordinates (000). This atom located at the origin of coordinates is located in a tetrahedron of atoms $C(x_2)$ with

coordinates: $\frac{1}{4} \frac{1}{4} \frac{1}{4}$, $\frac{1}{4} \frac{1}{4} \frac{3}{4}$, $\frac{1}{4} \frac{3}{4} \frac{1}{4}$, $\frac{1}{4} \frac{3}{4} \frac{3}{4}$.

Since atoms $C(x_2)$ are homologous to each other, they are all in the same tetrahedral coordination. Naturally, these tetrahedra are formed from atoms of two sublattices. Atom 1 of the second cell, taken as an example, is in a tetrahedron of atoms $C(x_1)$: 000,

$0 \frac{1}{4} \frac{1}{4}$, $0 \frac{1}{4} \frac{3}{4}$, $0 \frac{3}{4} \frac{1}{4}$, $0 \frac{3}{4} \frac{3}{4}$. The sizes of the tetrahedra are the same for

both coordinates. The structural parameters of diamond have the values: $a = 3,57 \text{ \AA}$, $C - C = 1,54 \text{ \AA}$, $Z = 8$. The coefficient of

packaging $k = \frac{4}{3} \pi r^3 8 / a^3 = 0,34$ [3]. The low value of the

coefficient of compactness compared to its value for the densest sphere packing ($k=0,74$) is because the edges of the tetrahedrons exceeds the value of the diameter due to the occurrence in them of the carbon atom [4]. For both sublattices the fewest interatomic bonds to the (111) plane. That is why this plane is the plane on

which take place the twinning, and second, it corresponds to a cleavage plane in diamond crystals. Distance $C - C$ in diamond ($1,54 \text{ \AA}$) coincides with the $C - C$ bonds in aliphatic compounds [5].

Besides carbon like-diamond lattice have a three mono-element crystal: $Ge - 5,66 \text{ \AA}$, $Si - 5,43 \text{ \AA}$, $\alpha\text{-Sn (grey)} - 6,49 \text{ \AA}$.

The generally accepted structure of a diamond is based on the displacement model of the FCC lattice by the direction $[111]$. However, the displacement in three main directions, forming a structural tetrahedron leads to the same lattice. That is, based on a point group $Fm3m$, should consider and other directions of displacement. Direction corresponding to the tetrahedral structure in this case have indices: $[\bar{1}\bar{1}\bar{1}]$, $[1\bar{1}\bar{1}]$, $[\bar{1}1\bar{1}]$, $[1\bar{1}1]$. In case of displacement in these directions the diamond cell remains invariant. Figure 2 shows the projection of the sublattice of atoms on a plane XY .

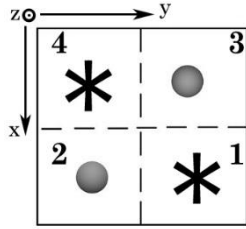


Fig. 2. – The position of the atoms C in the diamonds sublattice which is displaced from the crystal lattice. The Z coordinate of the

points $(*) - \frac{3}{4}$, $(\bullet) - \frac{1}{4}$

3. The diamond reciprocal lattice at different installation of the crystallographic system

Reciprocal lattice of any crystal is described by a crystallographic basis $\vec{a}^*, \vec{b}^*, \vec{c}^* = \vec{a}_i^* (i = 1, 2, 3)$, which associated with the basis cell of the crystal $\vec{a}, \vec{b}, \vec{c} = \vec{a}_j (j = 1, 2, 3)$ by the condition:

$$(\vec{a}_i^* \cdot \vec{a}_j) = (\vec{a}_j \cdot \vec{a}_i^*) = \delta_{ij}, \quad (1)$$

Of all the possible cases of location of the start of the crystallographic coordinate system we will consider three: 1) the origin of coordinates coincides with the atom at the vertex of the F -cell, described by a right-hand coordinate system. Another cell is the F -type, homologous to the initial offset value $\frac{1}{4} \frac{1}{4} \frac{1}{4}$ (in units of parameter a); 2) the second cell is offset from the first by the value $-\frac{1}{4} - \frac{1}{4} - \frac{1}{4}$ (in units of parameter a); 3) the origin of coordinates coincides with the center of symmetry which is the closest to the node (000) of the original cell, that is, the origin offset value $\frac{1}{8} \frac{1}{8} \frac{1}{8}$ (in units of parameter a).

Of the three considered options the position of the center of symmetry corresponds to the point $\pm \left(\frac{1}{8} \frac{1}{8} \frac{1}{8} \right)$ with the two graphical solutions of enantiomorphous lattices.

Strictly speaking, in the diamond structure, for any displacements of the sublattices, there is no axis 4 (L_4) and only one of the four axes 3 (L_3) remains that coincides with the direction of displacement of the two sublattices.

If in the transformations of the second sublattice replace $\frac{1}{4}$ by

$\frac{3}{4}$, and $\frac{3}{4}$ by $\frac{1}{4}$, then the resulting distribution is corresponding

to the transferring by $-\frac{1}{4} - \frac{1}{4} - \frac{1}{4}$. That is, the point

symmetry of these two structures is the same. However, both of these structures are incorrectly described from the point of view of their crystallographic analysis, since the origin of coordinates must coincide with the center of symmetry. Completed additional analysis is illustrated in table 2.

Table 2. Analysis of the effect of point-symmetry operations on the diamond structure when the origin of coordinates is located at

$\left[\frac{1}{8} \frac{1}{8} \frac{1}{8} \right] \equiv \bar{1}(x_0)$. (After the line $\bar{1}$ for describing the coordinates, only the numerator is indicated, since the denominator of all coordinates is 8)

sublattice		I			
№		1	2	3	4
$(xyz)_0$		$\frac{7}{8} \frac{7}{8} \frac{7}{8}$	$\frac{3}{8} \frac{3}{8} \frac{7}{8}$	$\frac{3}{8} \frac{7}{8} \frac{3}{8}$	$\frac{7}{8} \frac{3}{8} \frac{3}{8}$
– 1	$(xyz)_s$	111 (8)	551 (5)	515 (6)	155 (7)
2_x	$(x)_s$	117	557	513	153
$3[111]$	$(xyz)_s$	777 (1)	733 (4)	337 (2)	373 (3)
$3[1\bar{1}\bar{1}]$	$(xyz)_s^0$	171	135	531	575
4_z	$(xyz)_s^0$	177	537	133	573
$\bar{4}_z$	$(xyz)_s^0$	717	531	135	575
P_z	$(xyz)_s^0$	771	331	375	735
P_{xy}	$(xyz)_s^0$	777 (1)	337 (2)	733 (4)	373 (3)
$P_{x\bar{y}}$	$(xyz)_s^0$	117	557	153	513
sublattice		II			
№		5	6	7	8
$(xyz)_0$		$\frac{5}{8} \frac{5}{8} \frac{1}{8}$	$\frac{5}{8} \frac{1}{8} \frac{5}{8}$	$\frac{1}{8} \frac{5}{8} \frac{5}{8}$	$\frac{1}{8} \frac{1}{8} \frac{1}{8}$
– 1	$(xyz)_s$	337 (2)	373 (3)	733 (4)	777 (1)
2_x	$(x)_s$	331	375	735	771
$3[111]$	$(xyz)_s$	155 (7)	551 (5)	515 (6)	111 (8)
$3[1\bar{1}\bar{1}]$	$(xyz)_s^0$	753	357	313	717
4_z	$(xyz)_s^0$	351	755	315	717
$\bar{4}_z$	$(xyz)_s^0$	357	753	313	711
P_z	$(xyz)_s^0$	557	513	153	117
P_{xy}	$(xyz)_s^0$	551 (5)	155 (7)	515 (6)	111 (8)
$P_{x\bar{y}}$	$(xyz)_s^0$	331	735	375	771

Since the coordinates of carbon atoms in diamond at the specified setting the origin of coordinates have the form $\frac{n}{8}$, where n is an integer, only these values are indicated in the table. Table 2 shows the results of the action on the diamond structure of the elements of the point group $m\bar{3}m$. In the upper coordinate line of the table, the coordinates of the C (x_0) atoms are given when the origin of coordinates is transferred to the center of symmetry, that is, to the point $\left[\begin{smallmatrix} 1 & 1 & 1 \\ 8 & 8 & 8 \end{smallmatrix}\right]$. After the action of the specified symmetry operation, the coordinates of the atoms are represented in terms of the crystal cell (x)_s. If the conversion is invariant, then the number of the atom in the crystal cell is specified in the bracket.

In table 2, along with the plane passing through the axis 3 [111], the plane passing through the angle bisector ($x \wedge \bar{y}$) and through the axis z is considered. This plane is absent in a diamond at the considered coordinate system.

4. Specific features of the crystal structure of diamond

It should be noted that when analyzing the reciprocal lattice of a diamond crystal, it is necessary to consider not only the positions of its nodes, but also their "weight". The "weight" of the reciprocal lattice nodes is determined by the magnitude of the structural amplitude

$$F(hkl) = \sum_{j=1}^N f_j \exp 2\pi i(hx_j + ky_j + lz_j), \quad (2)$$

Additionally consider the case when the point [[000]] is located at the center of symmetry. Let us analyze one of the eight invariant positions of the centers of symmetry. Exactly $\left[\begin{smallmatrix} 1 & 1 & 1 \\ 8 & 8 & 8 \end{smallmatrix}\right]$. It is expected that in all cases the structural factors will be the same and the structural amplitudes may be different phases. Let's check these assertions. In the general case:

$$F(hkl) = \sum_{j=1}^N f_j \exp 2\pi i(hx_j + ky_j + lz_j), \quad (3)$$

where f_j is the atomic amplitude of scattering (table value); h, k, l – indices of the crystallographic plane from which the diffraction maximum is obtained; $(x, y, z)_j$ – crystallographic coordinates of j -th atom; N – number of atoms in the cell.

1st case:

$$F(hkl) = [1 + \exp \pi i(h+k) + \exp \pi i(h+l) + \exp \pi i(k+l)] \cdot$$

$$\cdot \left[1 + \exp \pi i \frac{h+k+l}{2} \right] = B \cdot \left[1 + \exp \pi i \frac{h+k+l}{2} \right],$$

where B is the left bracket.

2nd case:

$$F(hkl) = B \cdot \left[1 + \exp \pi i \left(-\frac{h+k+l}{2} \right) \right], \quad (4)$$

3rd case:

$$F(hkl) = B \cdot \left[\exp \pi i \frac{h+k+l}{4} + \exp \pi i \left(-\frac{h+k+l}{4} \right) \right] = \\ = B \cdot 2 \cos \pi \frac{h+k+l}{4}, \quad (5)$$

Square bracket in formulas (3-5) $S \neq 0$ only when h, k, l are either all even, or all odd, i.e. $(h+k+l) = 2n$, where n is an integer.

The second multiplier in (3-4) can have two values. If $(h+k+l) = 4n$, then the second bracket equals 2, while $(h+k+l) = 4n + 2$ is equal to zero, because $e^{(\pi 2n+1)} = -1$.

The right bracket in condition 3 imposes absolutely the same restrictions on the "weight" of the reciprocal lattice nodes with even indices. It follows that from the reciprocal cell with parameters

$$a_j^* = \frac{1}{a_j}, j = 1, 2, 3 \text{ it is necessary to go to the super cell with}$$

parameters $a_s^* = 4a^*$, because $F(1)=F(2)$, the structural factors $|F(1)|^2 = |F(2)|^2$. Wherein

$$F^2(1) = F^2(2) = \left[1 + e^{\pi i \frac{h+k+l}{2}} \right] \left[1 + e^{-\pi i \frac{h+k+l}{2}} \right] = \\ = 2 \left[1 + \cos \pi i \frac{H}{2} \right] = 4 \cos^2 \pi \frac{H}{4}, \quad (6)$$

where $H=h+k+l$.

Consequently, the reciprocal lattice of diamond does not depend on the choice of the origin of the coordinates of the crystal lattice. In the reciprocal diamond lattice, the cell has parameters $a_s^* = 4a^* = 4/a$, where a is the diamond lattice period. Lattice nodes can have indices $(h+k+l)=4n$, if h, k, l are all even, and odd restrictions are not imposed on all h, k, l . The reciprocal super cell of a diamond includes the following nodes of the reciprocal lattice: 000, 111, 220, 202, 022, 113, 131, 311, 331, 313, 133, 333. Therefore, the diamond's reciprocal lattice is described by a face-centered super cell with basis vectors $\vec{a}_s^* = 4\vec{a}_0^* = 4/\vec{a}$ in which the nodes 111, 131, 311, 331, 113, 133, 313, 333 are located. Thus, the super cell of the reciprocal diamond lattice is a face-centered cube with an edge $a_s^* = 4/a$ in which a primitive cube with an edge $a_2^* = 2/a$ is located, where a is the period of the diamond lattice. The centers of these cubes coincide (Figure 3).

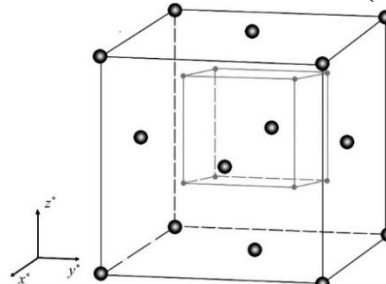


Fig. 3. - Super cell of the reciprocal diamond lattice: 1 - face-centered cube with an edge $a_s^* = 4/a$; 2 - primitive cube with edge $a_2^* = 2/a$; a - the period of the diamond lattice

The diamond's reciprocal lattice is characterized by a super cell, which can only partially be considered as face-centered. Since the reciprocal lattice of F -type crystals corresponds to a super cell of the I -type, it is not necessary to refer the diamond lattice cell to a face-centered lattice. The standard term "like-diamond cell" should be used. The Bravais cells are in good agreement with the lattices of either mono-element crystals or with crystals of complex composition, but the molecule is considered as a single structural element. In diamond, the second sub-cell is offset from the first by a distance $\frac{1}{4} \frac{1}{4} \frac{1}{4}$ (in units of parameter a).

It is necessary to proceed from the fact that the single scattering center of a diamond is not a single carbon atom, but a structural carbon grid of five atoms, one of which is in the center of a tetrahedron of four other atoms C . Which model of orientation of this structural unit is chosen does not matter, since their dissipative abilities are the same. Eight variants of the location of these centers form two groups of lattices that are enantiomorphic each to other.

This leads to the formation of twins, which explains the fragility of diamond crystals. Since the arrangement of carbon tetrahedra is equiprobable over eight octants of the coordinate system, and the bond covalency determines a stable electronic frame, which is described by the formula $\rho(\vec{r})$ and the electron density in it is comparable to the electron density of carbon atoms, we can assume that the averaged (effective) scattering center has the following properties:

1. Its form is the sphere;
2. These spheres form in a crystal the most dense three-layer sphere packing;
3. The radius of this structural unit is equal to $1,263\text{\AA}$;
4. The scattering ability of the "effective" scattering center of the diamond is equal to:

$$\varphi_{ef}(S) = 2f(c) \cos \pi(h+k+l)/4, \quad (7)$$

That is, the effective scattering ability does not change monotonic as the amplitude of the atomic scattering ability $f(c)$, but has the type of comb function;

5. The structural amplitude for this model has the view:

$$F(hkl) = 2 \cos \pi \frac{h+k+l}{4} \left[1 + e^{\pi i(h+k)} + e^{\pi i(h+l)} + e^{\pi i(k+l)} \right], \quad (8)$$

that coincides with formulas (3-5).

The scheme of effective scattering center is shown in Figure 4, which shows not compensated inter-atomic bonds which are forming crystal.

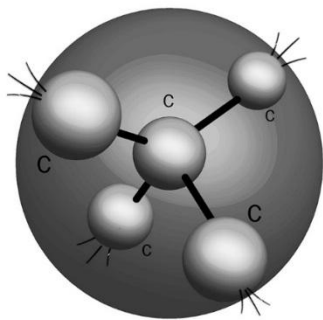


Fig. 4. – The scheme of effective scattering center

The radius of the effective scattering center is equal to the edge of the tetrahedron of 5 atoms C. The coefficient of compactness in this model corresponds to 74%. The traditional model assumes that the radii of carbon ions are equal to the shortest C – C distance of $1,54\text{\AA}$. It creates a generally accepted idea of the structure of diamond as the same arrangement of ions C^{++} . But the valence electrons can be removed from consideration, they create a single frame for the entire volume of the crystal. Separation of even a single carbon ion as in the case when the ion is displaced from its equilibrium position is changing in the e-frame and in accordance with the principle of Curie-von Neumann-Shubnikov creates tension in the volume of the whole crystal, which explains its high hardness.

Like-diamond structure is characteristic of other substances, which are characterized by a larger super cell. However, for these substances, due to the increase in the serial numbers in the Periodic Table, the share of electrons in the electronic frame decreases, which leads to a decrease in hardness compared to diamond.

5. Conclusion

The single scattering center of a diamond is not a point object, since it has a well-defined volume. But most importantly, this center is structured, since carbon ions are distributed in it. This structure affects the distribution of sites of the reciprocal lattice and leads to modulation of the scattering factor. Within this model, the concept of the densest sphere packing of FCC type, that is, with the point group $Fm\bar{3}m$, is valid. This explains the symmetry of the tensor physical properties of diamond.

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SMART MANUFACTURING AND CLOUD COMPUTING: VISION AND STATE-OF-THE-ART

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Abstract: Industry analysts are predicting that the next decade of innovation, productivity and growth in manufacturing will be driven by the demand for mass customization and the convergence of technologies that will enable a new generation manufacturing IT platform for “smart manufacturing” which includes advances in connected factory automation, robotics, additive manufacturing, mobile, cloud, social, and digital 3D product definition. The new generation of smart machines for manufacturing will have on board computers that will directly support internet protocols and direct communication with enterprise applications. Cloud computing is one of the technology stacks of Smart manufacturing and a service delivery model that is opening new opportunities for manufacturers. This paper describes what is “Smart manufacturing” that goes beyond smart machines, Industrial Internet of Things (IIoT) and Industry 4.0 and explores how cloud computing can help achieve Smart Manufacturing goals to optimize processes inside the factory.

Keywords: SMART MANUFACTURING, CLOUD COMPUTING, STATE-OF-THE-ART

1. Foreword

Emerging capabilities in additive manufacturing, advanced robotics, sensor-enabled equipment and other new approaches to fabrication, open new process improvement opportunities both in the plant and across the supply chain. Sophisticated computer modeling and simulation tools are evolving to give engineers far greater scope in designing a manufacturing process before building the production lines. These new technologies and capabilities are dramatically changing the management of manufacturing operations.

The next-generation Smart Factory feeds real-time information to a more empowered workforce through a combination of smart facilities, machines and equipment with built-in sensors, self-diagnostics and connection to other smart systems. Production processes in the Smart Factory can be optimized for best use of manpower, equipment and energy resources through simulation with digital representations and models. Smart Manufacturing encompasses and goes beyond smart machines, Industrial Internet of Things (IIoT) and the Smart Factory, recognizing that manufacturing processes in the 21st century go beyond the plant floor and must integrate the entire value chain that creates the final product. Smarter Digital Threads of product and process definitions and smarter connected manufacturing machines will come together with smarter manufacturing business processes to achieve the Smart Manufacturing enterprise [5] [2] [12].

This paper describes what is “Smart manufacturing” that goes beyond smart machines, IIoT and Industry 4.0 and explores how cloud computing can help achieve Smart Manufacturing goals to optimize processes inside the factory.

2. The Goals of Smart Manufacturing

Smart Manufacturing is the endeavor to design, deploy and manage enterprise manufacturing operations and systems that enable proactive management of the manufacturing enterprise through informed, timely (as close to real-time as possible), in-depth decision execution. Systems with Smart Manufacturing capabilities are realized through the application of advanced information, communication and manufacturing process technologies to create new and/or extend existing manufacturing system components that are then synergistically integrated to create new or extend existing manufacturing systems that possess the desired advanced automation, analysis and integration capabilities. To reach the goals of Smart Manufacturing, manufacturing resources (machines, equipment, people and factories) and the processes they carry out must be better when automated, integrated, monitored and continuously evaluated to enable people to work smarter, make timely informed decisions and run operations that are more efficient.

Smart Manufacturing can be applied more broadly and less costly if implemented on top of enhanced manufacturing-IT platforms with capabilities such as the ability to receive published

data from equipment using secure open standards, analyze and aggregate the data, and trigger process controls to record the history and implementation of workflows.

The ultimate outcome of applying the Smart Manufacturing concept can be: [6]

- Efficient distributed production systems that connect any number of global plants and suppliers into an integrated value chain for each product line.
- Autonomous and distributed decision support at the device, machine and factory level.
- New levels of efficiency to support new business models, including mass customization and product-as-a-service.
- Efficient flexibility for plants that can build products in small batches or even build one product at a time as ordered and configured by each customer.
- Design anywhere and build anywhere strategies with robust change management practices that guarantee fidelity to product design specifications.
- Enhanced information-based decision-making and analytics based on large amounts of raw data gathered from the Smart Manufacturing equipment and processes.
- Enhanced product genealogy traceability for critical materials and components into higher levels of components, all the way to the final product.

3. Introduction to cloud computing and cloud services

A common misconception about the cloud is that “There is no such thing as cloud; it is just someone else’s computer.” While there is some truth to this statement, it is also misleading. Thanks to internet connectivity, organizations can leverage many services provided by service providers on their cloud computing frameworks within their own internal IT systems architecture. The National Institute of Standards and Technology (NIST) offers the following characteristics of the cloud: [7]

- On-demand self-service: An end user can sign up and receive services without the long delays that have characterized traditional IT;
- Broad network access: The service is accessible via standard platforms (desktop, laptop, mobile, etc.);
- Resource pooling: Resources are pooled across multiple user organizations;
- Rapid elasticity: Capability can scale to cope with demand peaks;
- Measured service: Billing is metered and delivered as a utility service.

The cloud is much more than someone else's computer. It is a collection of tools and techniques to thread together internal and external hardware and software technologies to create an enhanced IT infrastructure for the organization at a reduced cost of ownership.

Many new machines come ready to integrate via APIs. New Industrial Internet of Things (IIoT) and edge devices are creating bridges to enterprise systems and cloud services for older equipment. These new capabilities help render the old division between Operational Technology (OT) and IT Enterprise Systems obsolete. The question is not whether a manufacturing system will be on the cloud, but instead how much of the manufacturing system will be on the cloud to maximize the benefits to each organization and its customers.

Cloud computing is changing the landscape of enterprise IT architecture. Organizations of all sizes are adopting SaaS solutions to simplify their need for internal IT resources while accelerating the pace of enterprise systems adoption. Possible first steps to adopting cloud computing is to move one or more enterprise systems to the cloud: [8]

- ✓ Customer relationship management (CRM): CRM is how a sales team manages its market and customer data, and the engagement of the sales process. CRM solutions promote the SaaS model with low risk adoption. This application offers easy worldwide remote access through a central company system via the internet. For this reason, SaaS solutions have become the default in this arena;
- ✓ Product Lifecycle Management (PLM): PLM solutions allow manufacturers to create and manage product structures and product family, and successfully implement change control processes for their products. Because many manufacturers need to work closely with their supply chain partners in the collaborative design of products, PLM has become another target for movement to the cloud in order to provide easy access to suppliers and customers for collaboration in engineering processes;
- ✓ Advanced planning systems: Advanced planning systems are solutions used to effectively plan and schedule parts and materials in the supply chain. By integrating these solutions into supply chain “control tower” software offered in the cloud, suppliers link into a demand-driven supply chain and distribution network;
- ✓ Enterprise Resource Planning (ERP): ERP is the heart of most manufacturers’ transaction management for financials, order entry, purchasing, work order management and scheduling. Organizations have been slow to trust the security of their financials and contract details to cloud solutions, but adoption is increasing. ERP procurement and inventory management functions can benefit from easier supplier and multiple location connectivity via a cloud solution;
- ✓ Manufacturing Execution Systems (MES): MES is the last enterprise system considered for a move to the cloud. Small and medium manufacturers interested in the low risk and quick startup proposition are adopting MES cloud solutions. Cloud-based MES solutions make it easier to rollup metrics across a network of distributed manufacturing plants.

4. Impact of smart manufacturing to the IT architecture under the fourth industrial revolution

The era of “one-size-fits-all” mass production is behind us. We are looking ahead at a new era of manufacturing that supports mass customization and products sold as a service. Industry analysts and visionaries have identified this era as a next Industrial Revolution. Here is historical context for the Fourth Industrial Revolution [11].

The Fourth Industrial Revolution, dubbed the Digital or Cyber-physical Revolution, is starting now in the 21st century. In 2015, the expected investment is an estimated \$120 billion to connect operations, building systems, mobile equipment in the field and more to the IoT, up 18 percent from 2014, according to IDC, a technology market consultancy. In 2014, 278 million factory machines, construction vehicles and other pieces of industrial equipment connected to the IoT, 10.2 percent more than in 2013,

according to technology research consultant Gartner Inc. By 2020, Gartner [3] expects 526 million pieces of equipment to be connected. According to McKinsey [12], the IoT will unleash \$6.2 trillion in new global economic value annually by 2025, with \$2.3 trillion coming from the global manufacturing industry alone. To put this into perspective, the total global gross domestic product for 2013 was approximately \$75 trillion. Companies that quickly leverage the full opportunity presented by the IoT will seize the greatest value, and assume market-leader status in the next decade.

It is difficult to manage the Manufacturing Operations department as an island, isolated from other enterprise departments like Engineering, Supplier Management, Quality Management, Human Resources, Facilities Management and Financial Management. Effective ways are needed to create information threads for business processes across departments that do not depend on manual translation of information. Currently, many interdepartmental business processes operate via email and with frequent manual interpretations and translations of data inputs to outputs along the way. These manual interdepartmental business processes are prone to error and cannot scale to handle a higher volume of transactions. [9]

An ideal Smart Manufacturing system platform would facilitate (a) a Smart Factory where there is integration throughout different data and functional layers, providing insights to improve safety, quality, cost and schedule, (b) Digital Thread where engineering design follows the entire product lifecycle, (c) Value Chain Management where a fully connected supply chain and customer management combine seamlessly.

Part of Smart Manufacturing is the IIoT (Industrial Internet of Things). IIoT leads to the proliferation of connected smart machines, devices and sensors that result in an explosion of data. The Internet of Things (IoT) is a term coined in 1999 by Kevin Ashton [1] to refer to networks of physical objects, or “things,” embedded with electronics, software, sensors and connectivity to exchange data in support of business processes. All IIoT- and Smart Manufacturing-related efforts have a similar vision: to improve manufacturing operations and collaboration between partners in the manufacturing value chain. In order to achieve this, manufacturers want to see industrial automation use standards and mechanisms similar to home and office equipment integration. Manufacturers would like to see applications (aka apps) on their phones giving them the ability to view, interact and control the shop like the apps they have today to control their home or car.

For existing manufacturing environments, especially in highly-automated, process-intensive industries (e.g. chemicals, food processing), much of the data one would consider “IoT” data is already being captured today by existing SCADA (Supervisory Control and Data Acquisition) and DCS (distributed control system) software, so sensor integration is a smaller challenge in those types of environments. A bigger challenge is switching those integration methods to open industry standards, and modeling those industrial “things” as cyber physical systems that knit together the information about existing assets with service layers and analytics engines that really bring the “smart” into Smart Manufacturing.

However, Smart Manufacturing is more than optimizing specific machine processes or each manufacturing plant in the enterprise. That might be a good start, but to realize the vision means a need to connect and optimize the processes across the entire value. There is a need to look at plant systems in each node of the multi-tier value chain to understand how they connect and interact across the entire value chain with systems, including customer and supply chain management across different companies to deliver the final products and services to the end-user customer.

A 2017 Gartner survey [4] discovered that 70 percent of manufacturers are working Smart Manufacturing efforts in parallel and not integrated with their digital supply chain endeavors. This needs to change to achieve the revolutionary productivity gains required for a fourth industrial revolution.

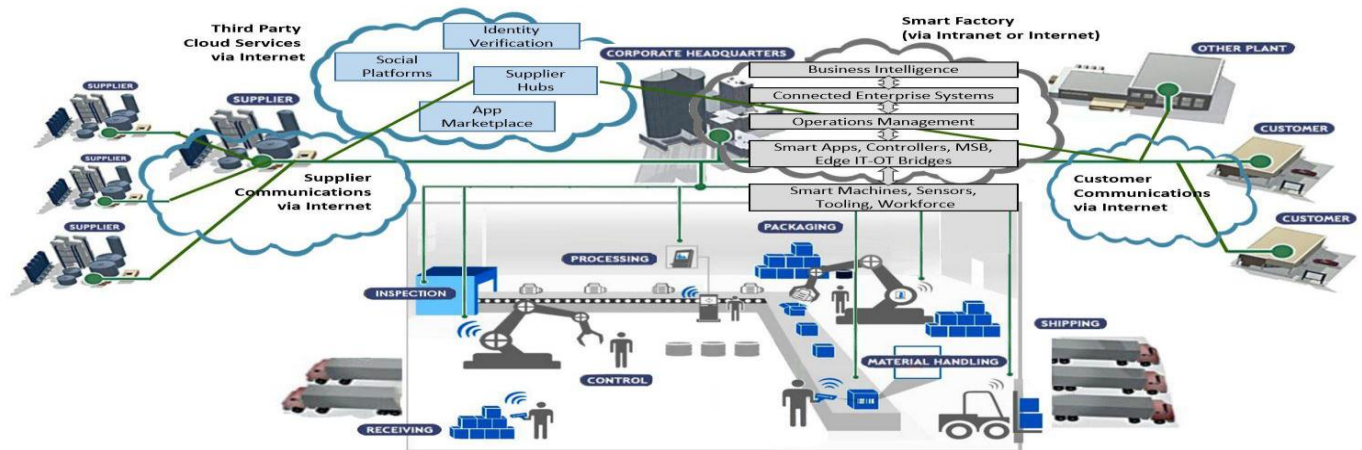


Fig. 1 Smart Manufacturing systems connect multiple clouds and cloud services to realize the connected value chain [10]

Figure 1 illustrates how internal and external systems in the cloud help connect the multi-tier network of multiple plants, suppliers and customers in the new Smart Manufacturing ecosystem. Connecting these new ecosystems is how to realize the most value from cloud computing to Smart Manufacturing endeavors.

Conclusion

Change is a constant in life and manufacturing is no exception. The manufacturing industry is at an inflection point with major advances in enabling innovations and a proliferation of smarter end points that are both valuable and vulnerable. Smart Manufacturing includes the Internet of Things (IoT), cyber security, network convergence, cloud computing, data and analytics, virtualization and mobility.

It is clear that manufacturing will serve as a key driver of research, innovation, productivity, job creation and export growth. The Smart Manufacturing future ties inextricably to the rise of Internet Protocol (IP) technology.

Smart Manufacturing will address some of the challenges facing the world today such as resource and energy efficiency, urban production and demographic change. Smart Manufacturing delivers continuous resource productivity and efficiency gains across the entire value network. It organizes work in a way that takes demographic change and social responsibility into account.

Both Smart Manufacturing and cloud computing are here to stay. Cloud computing is opening new infrastructure, systems and connectivity opportunities for manufacturers to help realize a Smart Manufacturing vision. This is especially important because Smart Manufacturing does not stop at the factory walls; it connects and optimizes the entire value chain.

Each manufacturer will draw the line differently between on premise and on-cloud services, depending on their unique needs. For some organizations, the choice will be to shift IT systems completely to the cloud; for others, hybrid scenarios might be a better path forward.

Whether the organization is contemplating a complete rip and replace of systems or simply wants to strategically leverage cloud services in some specific areas, it is clear the organization should consider cloud computing as it puts together the roadmap for evolving IT infrastructure and achieving the goals established for its Smart Manufacturing vision.

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THE ROLE OF RFID TECHNOLOGY IN THE INTELLIGENT MANUFACTURING

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Abstract: The manufacturing industry is facing high competitiveness from rivals and high demands from customers. Industry 4.0, as a new manufacturing paradigm, also imposes its demands. The main driver of Industry 4.0 is the development of new innovative technologies including information and communication technologies whose rapid development has given impetus to the development of automated data acquisition systems. The RFID technology is one of the key technologies for intelligent manufacturing that encompasses advanced information and manufacturing technologies. Although the RFID technology is used in Croatia (mostly for identifying persons, access control, payment control, etc.), there is no wider use of the RFID technology in the industry where the main problem of low competitiveness is caused by low levels of innovative capabilities and obsolete technological equipment. The EU strategic documents (e.g. Europe 2020, Digitising European Industry initiative) encourage the digital transformation of industry (with an emphasis on investment in technology and innovation). One of the goals of the Industrial Strategy of the Republic of Croatia 2014-2020 is to increase productivity. To achieve this goal and improve competitiveness it is necessary to increase the use of the RFID technology in industry as the basis for digital transformation.

The goal of this paper is twofold: to present bibliometric literature review on the RFID technology, and to present advantages of the RFID technology in the context of intelligent manufacturing with reference to the case of Croatian economy.

Keywords: RFID, INTELLIGENT MANUFACTURING, INDUSTRY 4.0, INNOVATIVE TECHNOLOGIES

1. Introduction

Currently, the increased customer demands for high-quality customized and personalized products, with short delivery times, manufacturing companies need to respond quickly to these requirements, increase product efficiency and quality. Traditional production systems cannot respond to such requirements. In order to survive in the market and in view of the requirements of Industry 4.0, manufacturing companies must be digitally transformed and turn to a new paradigm, intelligent manufacturing.

Intelligent manufacturing with features such as learning, reasoning, and acting is closely related to Industry 4.0, as it is called the fourth industrial revolution [1]. Intelligent manufacturing depends on timely data acquisition, distribution and use of different types of data from production resources, products and production processes. The connection of all these elements enables manufacturing systems to become more agile, making decisions based on real-time information and being more adaptable to changing market demands. Technologies of manufacturing intelligence that can be linked to different enterprise information systems (e.g. Enterprise Resource Planning system (ERP), Supply Chain Management system (SCM) etc.) are being rapidly developed and facilitate improving timely decision-making based on real-time information of the actual state of manufacturing and supply chain processes. New innovative technologies that enable such transformation and intelligent manufacturing include: Information and Communication Technologies (ICT), Cloud Computing, Big Data Analysis, Artificial Intelligence. According to [2] there are the four key components of Industry 4.0 (based on literature review): Cyber-Physical Systems (CPS), Internet of Things (IoT), Internet of Services (IoS) and Smart Factory. The development of new, innovative technologies that support these components, especially IoT, leads to that a manufacturing in the context of Industry 4.0 will more and more intelligent [3]. One of the key technologies on which the Internet of Things is based is Radio Frequency Identification (RFID) technology.

Today, technologies of manufacturing intelligence that can be linked to different enterprise information systems are being rapidly developed and enable improving timely decision-making based on real time information of the actual state of manufacturing and supply chain processes.

2. RFID technology in manufacturing

The RFID technology for automatic identification and tracking facilities enables data acquisition in real time, which can significantly improve planning, scheduling and production monitoring. Using RFID technology, sensors and actuators, resources of an enterprise become smart objects. The RFID technology has a significant role in digital and intelligent manufacturing because it enables all production resources (machines, people, products, etc.) to communicate with the manufacturing system in real time, wirelessly using radio waves. Using RFID technology, real-time and accurate production data such as material consumption, data on workers, the status of machines, order progress, data on scheduling, product location, data on materials and tools monitoring are gathered [4]. The collected data is transformed into information and knowledge that makes manufacturing intelligent. The RFID technology enables automatic identification and monitoring of all resources in production and products in all phases of its lifecycle.

The RFID technology is already widely used in manufacturing, to assembly lines, in maintenance, warehousing, transportation etc. [5-9].

RFID systems consist of three basic components: a transponder consisting of a chip connected to the antenna, a reader that transmits radio signals and collects data from the transponders and enterprise applications (Fig. 1). By attaching transponders to objects (all resources in manufacturing), they become smart objects that are capable of communicating with the environment.

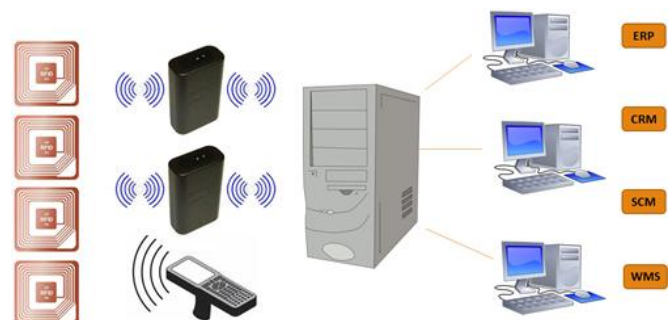


Fig. 1 Simplified working principle of RFID system

2.1 Literature review

There are many published papers on the RFID technology. Within the databases of the Web of Science (WoS) platform, the first indexed article was published in 1985. The authors of article [Ngai, 2008] provided an extensive overview of published journal articles and conference papers on RFID technology for the 1995-2005 period. The classification of RFID technology applied in manufacturing, according to the author's literature review, is presented in the article [9], the main application fields are: process management, tool management, warehouse management, supply chain management and life cycle management. The authors of the article [11] proposed a RFID-enabled real-time manufacturing model that would provide support to management to make the right decisions based on real time information. RFID, as one of the most significant technologies that enables mass personalized production in relation to mass customized production, is described in the article [12]. For the application of RFID technology in logistics, the Big Data Analysis methodology is suggested in the article [13]. The article [14] deals with RFID technology in terms of supply chain management. The opportunities for implementing the Just in Time principle in logistics using RFID technology are presented in the article [15]. Intelligent and integrated RFID (II-RFID) system that enhances traceability and visibility of products is presented in article [16]. The article [17] emphasizes the advantages of using RFID technology in manufacturing that have been reported in the literature: reducing WIP, increasing utilization of machines, real-time information, improved scheduling and monitoring production, reducing errors in data entries compared to other methods (especially manual), shortened production cycle, improved satisfaction of customer.

A review of the literature shows that the RFID technology in production is dealt with from various aspects, proposals of technical solutions, models, production management, and supply chain management. Therefore, bibliometric literature analysis was conducted in order to gain a clearer insight into the trends in the research and development of the RFID technology in manufacturing, especially in the context of intelligent manufacturing and Industry 4.0.

3. Bibliometric Literature Analysis

The research methodology included searching the citation and index databases of the Web of Science (WoS) platform for the 1955-2017 period. The research involved only journal articles and proceeding papers, while other types of publications were excluded from the research. The first, search by keywords was conducted as:

- ("radio frequency identification" or RFID)
- ("intelligent manufacturing" or "smart manufacturing")
- "Industry 4.0".

Then, the databases of the WoS platform were searched to find overlappings of the main keywords in the articles, as stated below:

- The results derived from the keyword ("radio frequency identification" or RFID) were refined by the keywords: ("intelligent manufacturing" or "smart manufacturing") delivered 31 results.
- The results derived from the keyword ("radio frequency identification" or RFID) were refined by the keywords: "Industry 4.0" delivered 32 results.
- The results obtained by keyword search ("intelligent manufacturing" or "smart manufacturing") refined by the keyword: "Industry 4.0" yielded 112 results.
- The results obtained by keyword search ("radio frequency identification" or RFID) is refined by the keywords ("intelligent manufacturing" or "smart manufacturing") and "Industry 4.0" yielded 7 results.

Figure 2 shows the number of journal articles and proceedings papers found in the databases of WoS platform according to the defined keywords.

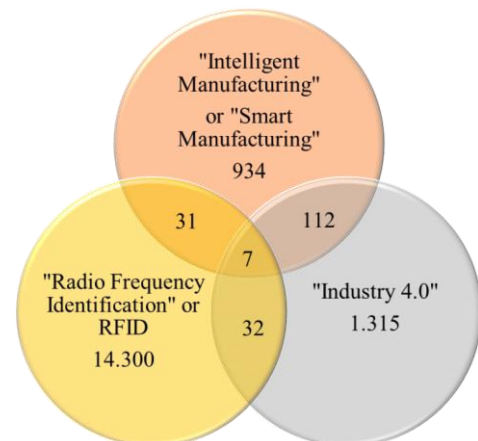


Fig. 2 Number of articles and conference papers found within the WoS platform in accordance with the defined keyword.

4. Case of Croatia – PEST analysis

The implementation of innovative technologies that enable intelligent manufacturing and Industry 4.0 in Croatia, with a special focus on RFID technology, depends on the impacts of the political, economic, social and technological environment. In order to determine which impacts were carried out, the PEST analysis was performed. Table 1 shows PEST indicators by categories (political, economic, social, technological).

Table 1: PEST indicators

	Indicators
Political	As an EU member Croatia complies with the governmental strategies: Industrial Strategy of the Republic of Croatia 2014-2020, Smart Specialization Strategy of the Republic of Croatia 2016-2020, Strategy of Fostering the Innovation of the Republic of Croatia 2014-2020. However, there is a discrepancy between the strategies and the real-life situations; and investments in research, development and innovation are already becoming insufficient, although they have been additionally reduced, high VAT.
Economic	Opportunities for benefiting from the use of EU funds; GDP is stagnating or growing slowly; reduced foreign direct investment, foreign debt has been growing steadily; there is a risk that a strong entrepreneurial culture in Croatia will lose out if there is no basis for sustainable economic development (digital infrastructure, digitally skilled professionals and access to finance); according to EU Digital Transformation Enablers' Index Croatia is very low (Croatia is only followed by Latvia and Romania).
Social	High unemployment; poverty; negative demographic trends and emigration; less and less skilled workforce; fewer students due to the emigration of young people; mismatch between education and labor market needs; low participation of population in lifelong learning; Croatia is among the most digitally aware countries in EU.
Technological	Obsolete technical equipment of the enterprises; lack of necessary knowledge and skills; level of innovation of the Croatian economy is low compared to the EU average; low level of business sector participation in research and development activities; slow progress on the integration of digital technology by businesses; low level of participation of researchers in the business sector; strong ICT industry; enterprises are above average users of cloud technologies.

According to the Eurostat data, the application of the RFID technology in the EU enterprises is on a steady rise. Compared to 2011, when the average RFID technology use for product identification in enterprises was 1.62% of enterprises, in 2017 it was 3.75% of enterprises. In Croatia, in 2017, or 4.54% of companies used RFID technology in product identification, compared to 2011 when only 2.49 % of enterprises used RFID for the same purpose.

In Bulgaria, the RFID technology was used for product identification in 9.18% of enterprises, more than in other EU member countries.

Figure 3 shows percentages of enterprises per EU member country that use Radio Frequency Identification (RFID) technology in 2018 as part of the production and service delivery or for the purpose of after sales product identification (data source: Eurostat). There are 4.5 % of enterprises that use RFID technology for these purposes in Croatia compared to the EU average of 28 countries (4.2 %).

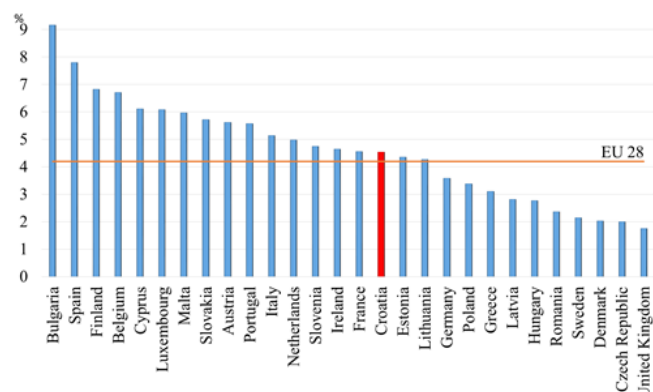


Fig. 3 Percentage of enterprises per EU member, that use RFID technology in 2018 (as part of the production and service delivery or for purpose of after sales product identification).

5. Results and discussion

According to the results of the bibliometric literature analysis on WoS platform, term ("intelligent manufacturing" or "smart manufacturing") first appeared in relevant literature in 1989. Since then researchers have shown continued interest in this topic, which grew rapidly after 2011 (see Fig. 4), which coincides with the emergence of the concept of Industry 4.0. There has been a significant increase in the number of relevant published articles and proceedings papers indexed in databases of the WoS platform.

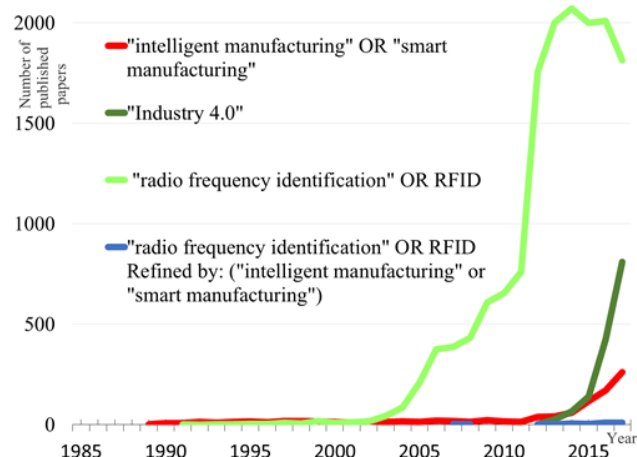


Fig. 4 Number of articles and proceedings papers published per year (indexed within Web of Science platform).

The number of publications on intelligent / smart manufacturing is the largest in the research areas: Engineering, Computer Science and Automation Control Systems.

There are many published papers on the RFID technology. The first article that was indexed in citation and index databases of the WoS platform was published in 1985, although the technology itself was developed during World War II. The rapid rise in the number of published articles and proceedings papers on RFID technology emerged at the beginning of 2000, after the Internet of Things was developed. A new, even greater, hike in the number of published articles and papers came after the emergence of the new Industry 4.0 paradigm. The bibliometric literature analysis within the WoS

platform shows that RFID researches are represented in many areas such as engineering, computer science, telecommunications, oceanography, biodiversity conservation and many others. The number of articles and conference papers on RFID topic according to research areas with the greatest number of journal articles and proceedings papers is presented on Fig. 5. Most of the research on the RFID technology is in the field of engineering, followed by computer science, telecommunication, automation control systems and other areas that are important for intelligent manufacturing.

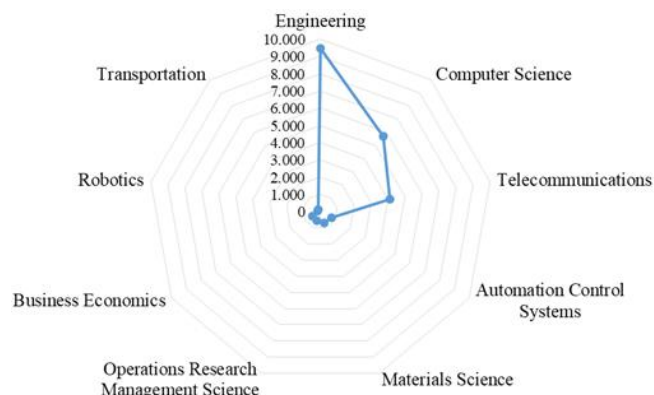


Fig. 5 Number of articles and conference papers on RFID topic by research areas.

After filtering the results on the RFID technology according to the "Countries/Regions" field in the WoS platform and only for the EU member states, the largest number of published articles and proceedings papers on RFID have Italy, Germany, United Kingdom, France and Spain (Fig. 6).

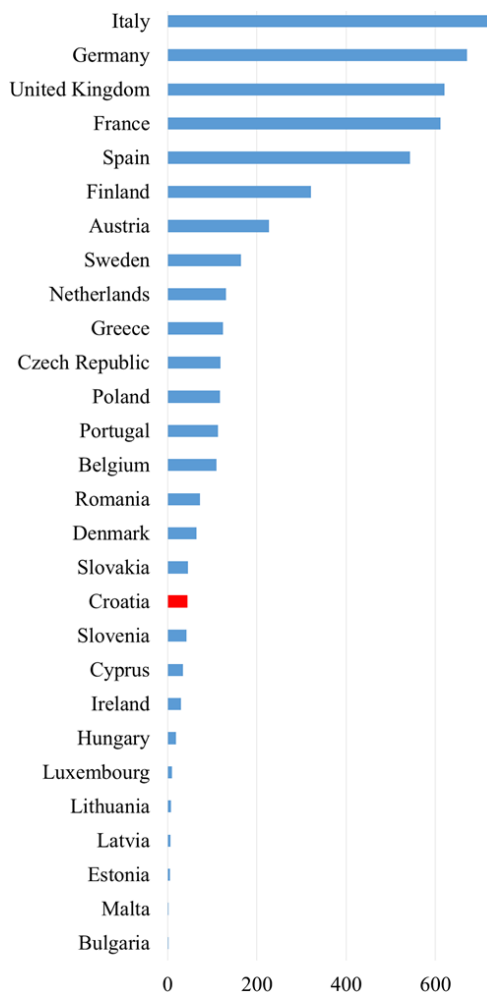


Fig. 6 Number of articles and conference papers on RFID topic by countries – EU members (according to WoS platform).

The analysis of the journal articles and conference papers indexed in the databases of WoS platforms, according to keywords

("radio frequency identification" or RFID) on the "Topic" field and according to the "Countries/Regions" field, it was found that most publications in the world were published by researchers from Peoples Republic of China (22.6%), the United States 16.0%, South Korea 6,6 %, Taiwan 6,5 %, , South Korea 6.6%, Taiwan 6.5%, followed by Italy with 5.1% of publications, as the most prolific EU member country with the most published articles and proceedings papers. The total number of research papers published in the EU member countries accounts for 35.8% of the total number of papers on RFID indexed in the WoS platform (Fig 7).

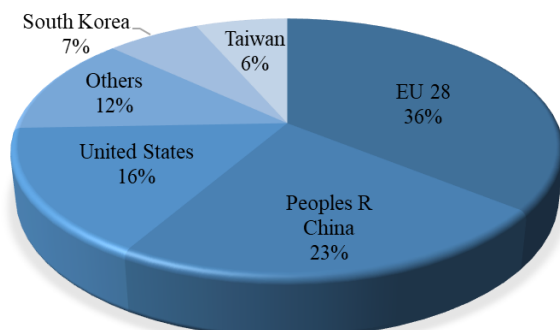


Fig. 7 Number of articles and conference papers on RFID by Countries/Regions (according to WoS platform).

The number of articles and proceedings papers, in which keywords ("radio frequency identification" or RFID), ("intelligent manufacturing" or "smart manufacturing") and "Industry 4.0" appear simultaneously, are small and appeared only in the past few years. This is understandable because it is a recent field of research. Certainly, an increase in the number of published papers in the context of Industry 4.0 and intelligent production is expected.

Table 2 lists the journals (within WOS platform) articles on topic: (RFID or "radio frequency identification") refined by: (manufacturing) and (intelligent or smart), with at least three articles on subject with their 5-year Impact Factor (IF).

Table 2: Journals publishing articles on RFID in manufacturing

Journal name	No. of articles	Impact factor
Journal of Intelligent Manufacturing	6	3.383
International Journal of Production Research	5	2.78
International Journal of Advanced Manufacturing Technology	3	2.748
International Journal of Production Economics	3	4.976
Journal of Cleaner Production	3	6.352
Robotics and Computer Integrated Manufacturing	3	4.031

The results of the analyses of journal articles and proceedings papers indexed in citation databases within the WoS platform on RFID, intelligent manufacturing and Industry 4.0 indicate that researchers in countries with stronger economies have better results in terms of number and quality of publication. It can be concluded that Croatia significantly lags behind the countries with stronger economies in terms of research and number of publications on the topics discussed in this paper. This is in line with the PEST analysis results: one of the identified indicators, which is at the same time the most important, is the low level of investment in research, innovation and development. The results of the bibliometric literature analysis also indicates that RFID is a research area of high interest, especially after the appearance of the concept of the Internet of Things and the development of intelligent manufacturing. It can be expected that the number of publications, as a result of great interest to the research area, will continue to increase.

6. Conclusion

Our research has highlighted the importance of the role of the RFID technology in manufacturing, which together with other new innovative technologies will facilitate the transformation of manufacturing into intelligent manufacturing.

The industrial sector makes an important share in GDP in Croatia (21.76 % in 2017, according to the World Bank). Therefore, it is important to invest in new innovative technologies in order to enable the Croatian enterprises to meet the requirements of Industry 4.0 and become competitive.

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MARKET ORIENTATION AND BUSINESS PERFORMANCE FROM BEHAVIOURAL PERSPECTIVE - THE CASE OF SLOVAKIA

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Abstract: In the context of highly competitive global markets, challenging customer needs and increasing dynamics of business environment, businesses try to identify and apply the most effective practices whose enforcement will lead to superior performance. It becomes necessary for businesses operating in competitive environment to efficiently generate, disseminate and respond to market information. Market orientation is a concept that has appeared as a significant predictor of business performance. The main aim of the paper is to examine market orientation of businesses operating in Slovakia through MARKOR measurement method with the respect to business performance measured through the financial and non-financial indicators. The MARKOR method enables to gain information about specific behavioural reactions of business on critical aspects of a market such as competition, customers, regulation, social and macroeconomic forces. Research findings may help businesses to identify the most relevant elements that subsequently could be implemented with the intention of reaching better position on the market.

Keywords: MARKET ORIENTATION, BUSINESS PERFORMANCE, BEHAVIOURAL PERSPECTIVE, MARKOR, FINANCIAL AND NON-FINANCIAL INDICATORS

1. Introduction

Market orientation became a center of studies for more than 30 years (Parasuraman, 1983; Greenley and Matcham, 1986; Naidu and Narayana, 1991). In marketing literature (Narver and Slater, 1990; Ngai and Ellis, 1998) the importance of market orientation is emphasized mainly as the key aspect for increasing businesses profitability. Implementation of marketing activities results in outperforming of businesses performance (Day and Nedungadi, 1994). McCarthy and Perreault (1990) understand market orientation as implementation of marketing concept. Deshpandé and Farley (1999) consider market orientation as a significant predictor of business performance whose implementation lead to achievement of long-term profitability.

Market orientation could be understood from both *behavioural* and *cultural perspective* (Kirca et al., 2005). Behavioural perspective is presented by the works of scholars Kohli and Jaworski. Narver and Slater are scholars who have developed cultural perspective. Researches of these authors are considered as a key in developing the market orientation issue. Their different definitions of market orientation have become cited by many authors up to these days (Rojas-Méndez and Rod, 2012; Shin, 2012; Guo and Wang, 2013; Eslahnia, 2014; Kajalo and Lindblom, 2015; Long, 2015; Widana et al. 2015).

A. K. Kohli and B. J. Jaworski (1990), the main representatives of *behavioural perspective*, in one of the first research found that market orientation entails more precise and detailed view on customer focus and coordination. Firstly, it involves one or more departments engaging in activities concentrated on the development of understanding of current and future customer needs and recognizing the factors that affecting them. Secondly, the market orientation is characterized by sharing the understanding of customer needs and wants across all departments in business unit. Thirdly, the various departments are involved in realizing activities devised to come across select customer needs. Authors synthesized their findings into the formal definition of market orientation as an “organization-wide generation of market intelligence, pertaining to current and future customer needs, dissemination of the intelligence across departments, and organization-wide responsiveness to it” (Kohli, Jaworski, 1990, p. 6). Understanding of these three dimensions requires more detailed description of operations performed within the business as follow (Varela, Río, 2003):

Generation of market information refers to the degree to which business systematically collects and processes information about current and future needs of consumers and industrial end-users, as well as external factors, such as competition, technological and environmental changes, etc. Into this task should be involved all departments because of their special relationships with the market

agents. The speed dimension of market information generation is crucial; *Dissemination of market information* is accomplished through the three operations within the business. Firstly, through the interdepartmental meetings or informal chats about the tendencies of the market and its changes; secondly, through the generalized discussion about customers and competition, and thirdly, through the interactions and communications of marketing department members with the other departments in order to examine future needs of customers. Quick distribution of information and involvement of all member of business unit is the way how to maximize the value of generated information; *Responsiveness* to market information means to implement marketing activities consistent with the accumulated market information about customer, competition and environmental factors, and planning the supply according to the customers’ preferences and wants. The changes detected in customers’ and competitors’ behaviour should be implemented into business decisions.

In our paper we occupy with the impact of market orientation on business performance, which can be expressed through financial or non-financial indicators. Performance measurement is a key activity of gauging the set objectives. Outputs obtained by measuring the performance of the business provide a picture about overall situation of business to owners and potential investors and also allow managers to take different actions. Lesáková (2004) defines the performance as the business ability to achieve the desired effects or outcomes, and possibly in measurable units. Business performance can be measured through the key performance indicators that serve to evaluation of actual development of the business in comparison with objectives and targets that it has set (Kabát, et al., 2013). Several authors (Rajnoha et al., 2013; Marinič, 2008) agree that the performance evaluation approaches are essentially based on two groups of indicators: financial performance indicators and non-financial performance indicators. Thus, performance criteria can be set for both financial and non-financial area.

Kirca and Hult (2009) refer that expansion in market orientation research has accelerated in the last two decades. Especially, there are three groups of models proposed and tested by researchers. There are models focused on conceptualization and measuring the market orientation of business (Kohli and Jaworski, 1990; Narver and Slater, 1990), models directed on identifying of antecedents and consequences of market orientation (Matsuno et al., 2002) and models investigating the mediators and moderators that influence relationship between market orientation and business performance (Slater and Narver, 1994). For the purpose of our research we will dedicate with models measuring market orientation of business and models investigating *relationship between market orientation and business performance*.

2. Methodology

The main aim of the paper was to examine market orientation of businesses operating in Slovakia through MARKOR measurement method with the respect to business performance represented by financial and non-financial indicators. We assumed that the relationship between market orientation and business performance indicators will be confirmed. Our research sample involved 230 completed questionnaires from businesses operating in Slovakia (realized in 2017). These businesses had to meet the conditions of profit-orientation and number of employees (10 employees and more). Our research sample copy the structure of population in the terms of legal form, number of employees, and region. We can generalize statistically verified result on whole population due to representative character of research sample. The topic is part of the research project VEGA 1/0686/16 Marketing orientation of businesses as a tool of increasing business competitiveness and performance, 2016-2018

Kohli and Jaworski (1993) developed MARKOR method as a tool for measuring market orientation from behavioural perspective. It includes three components – *generation of market information, dissemination of information and responsiveness capacity* with 20 items (detailed statements can be seen in Results). The MARKOR method appears to be able to gain information about specific behavioural reactions of business on critical aspects of a market such as competition, customers, regulation, social and macroeconomic forces (Day and Wensley, 1988; Jaworski and Kohli, 1993; Kohli, Jaworski, Kumar, 1993). Questionnaire contains Likert-scales items which have positive or negative character. Negative formulation is used as a control tool for sustaining attention of respondent. We used 7-point Likert-scale items and followed the studies of several authors (Narver, Slater, 1990; Pitt a kol., 1996; Puledran a kol., 2003; Hooley a kol., 2003). Moreover, we slightly modified some items on the basis of qualitative pre-research realized with marketing managers of businesses.

In our research we investigated business performance measured through the financial and non-financial indicators. Business performance is more frequently measured through the *financial indicators* (Table 1). In our questionnaire we investigated the impact of market orientation on traditional indicators, such as profit, sales, return on sales, return on assets, return on investment or return on equity and so on. Moreover, we extended our measuring methods through the modern indicators. We have decided to get involved net present value, economic value added, cash flow return on investment, market value added, and Balanced Scorecard (involved on the basis of qualitative pre-research).

Table 1 Financial Indicators of Business Performance

I.	Business Performance
1.	Our overall financial performance has increased over the last three years.
2.	Our market share has increased over the last three years.
3.	Our profit has increased over the last three years.
4.	Our sales have increased over the last three years.
5.	Sales generated by new products have increased over the last three years.
6.	Return on sales (ROS) has increased over the last three years.
7.	Return on assets (ROA) has increased over the last three years.
8.	Return on investments (ROI) has increased over the last three years.
9.	Return on equity (ROE) has increased over the last three years.
10.	Return on marketing investments (ROMI) has increased over the last three years.
11.	Net present value (NPV) has increased over the last three years.
12.	Economic value added (EVA) has increased over the last three years.
13.	Cash flow return on investments (CFROI) has increased over the last three years.
14.	Market value added (MVA) has increased over the last three years.
15.	Based on method Balanced Scorecard our performance has increased over the last three years.

Source: Modified according to Kohli and Jaworski. 1990.

Non-financial indicators defined by Kohli and Jaworski (1993) created the statements for measuring outcomes of market orientation within the organizational commitment, esprit de corps, and customer satisfaction. We added to these groups several statements which we consider as important (according to the pre-

research results). They are highlighted by dark grey colour in table 2.

Table 2 Non-financial Indicators of Business Performance

I.	Organizational Commitment
1.	Employees feel as though their future is intimately linked to that of this organization.
2.	Employees would be happy to make personal sacrifices if it were important for the business unit's well-being.
3.	The bonds between this organization and its employees are weak.
4.	In general, employees are proud to work for this business unit.
5.	Employees often go above and beyond the call of duty to ensure this business unit's well-being.
6.	Our people have little or no commitment to this business unit
7.	It is clear that employees are fond of this business unit.
8.	In our business unit there is low fluctuation of employees.
9.	Based on the assessment of individual statements we can say that our employees are generally satisfied.
I.	Esprit de Corps
1.	People in this business unit are genuinely concerned about the needs and problems of each other.
2.	A team spirit pervades all ranks in this business unit.
3.	Working for this business unit is like being a part of a big family
4.	People in this business unit feel emotionally attached to each other.
5.	People in this organization feel like they are "in it together."
6.	This business unit lacks an "esprit de corps."
7.	People in this business unit view themselves as independent individuals who have to tolerate others around them
8.	Based on the assessment of individual statements we can say that our employees are loyal to our business.
I.	Customer Satisfaction
1.	Customers are satisfied with the quality of our products.
2.	Customers are satisfied with the prices of our products.
3.	We rarely receive complaints from our customers.
4.	We are easily getting new customers.
5.	We serve many of the same customers we have served in the past.
6.	Our customers are often returning to us.
7.	We have more loyal customers than our competitors.
8.	Based on the assessment of individual statements we can say that our customers are generally satisfied.

Source: Modified according to Kohli and Jaworski. 1990.

3. Results and Discussion

We measured market orientation through 20-item MARKOR method. These items were thematically divided into three groups – intelligence generation, intelligence dissemination, and responsiveness. In table 3 are presented mean values of respondents' answers to individual items which measure *intelligence generation*. Respondents achieved the highest values in items number 1 (i.e. 5.74) and number 4 (i.e. 5.54). It means that businesses from our sample use mainly the assessment of quality of products and services from end-users as the activity in order to gain market information and consequently they meet with customers to find out their future needs. Contrary, the lowest mean value was reached in item number 6 (i.e. 4.53). Thus, the respondents give smaller attention to periodic review of effect of changes in business environment on consumers.

Table 3 Mean Values of Items Connected to the Intelligence Generation

I.	Intelligence Generation	Mean
1.	In this business unit, we meet with customers at least once a year to find out what products or services they will need in the future.	5.74
2.	In this business unit, we do a lot of in-house market research.	4.69
3.	We are slow to detect changes in our customers' product preferences.	4.62
4.	We poll end users at least once a year to assess the quality of our products and services.	5.54
5.	We are slow to detect fundamental shifts in our industry (e.g., competition, technology).	4.87
6.	We periodically review the likely effect of changes in our business environment (e.g. regulation) on customers.	4.53
	Mean value of group	5.00

The second group of items referred to the *market intelligence dissemination*. We can see from the table 4 that respondents reached highest mean values in items number 9 (i.e. 5.21) and number 10 (i.e. 5.09). These two items are connected to the dissemination of information about customers. The lowest mean value reached respondents in item number 8 (i.e. 4.35) which was focused on the effort of marketing personnel to discuss about future needs of customer with the other departments.

Table 4 Mean Values of Items Connected to the Intelligence Dissemination

I.	Intelligence Dissemination	Mean
7.	We have interdepartmental meetings at least once a quarter to discuss market trends and developments.	4.72
8.	Marketing personnel in our business unit spend time discussing customers' future needs with other functional departments.	4.35
9.	When something important happens to a major customer of market, the whole business unit knows about it within a short period.	5.21
10.	Data on customer satisfaction are disseminated at all levels in this business on a regular basis.	5.09
11.	When one department finds out something important about competitors, it is slow to alert other departments.	4.39
	Mean value of group	4.75

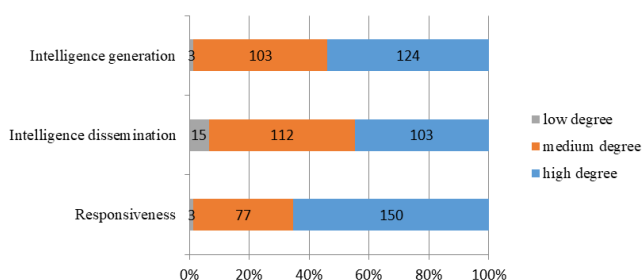
The third group of items referred to the *responsiveness to market information* (see Table 5). These items assess the speed and quality of reaction to achieved information about customers, competitors, and market. Two highest mean values were reached by respondents in item number 13 (i.e. 5.89) and item number 18 (i.e. 5.77). High mean values of both items speak about the fact that respondents definitely do not ignore customer complaints and the changes in their needs.

Table 5 Mean Values of Items Connected to the Responsiveness

I.	Responsiveness	Mean
12.	It takes us forever to decide how to respond to our competitor's price changes.	5.15
13.	For one reason or another we tend to ignore changes in customer's product or service needs.	5.89
14.	We periodically review our product development efforts to ensure that they are in line with what customers want.	5.06
15.	Several departments get together periodically to plan a response to changes taking place in our business environment.	4.66
16.	If a major competitor were to launch an intensive campaign targeted at our customers, we would implement a response immediately.	5.32
17.	The activities of the different departments in this business unit are well coordinated.	5.17
18.	Customer complaints fall on deaf ears in this business unit.	5.77
19.	Even if we came up with a great marketing plan, we probably would not be able to implement it in a timely fashion.	4.65
20.	When we find that customers would like us to modify a product of service, the departments involved make concerted efforts to do so.	5.03
	Mean value of group	5.19

Graph 1 presents the results of three elements of market orientation from behavioural perspective.

Graph 1 Values of Market Orientation from Behavioural Perspective



According to the achieved value we divided businesses into 3 groups: 1.00 to 2.99 – low market orientation; 3.00 to 4.99 – medium market orientation; 5.00 to 7.00 – high market orientation. Respondents achieved highest mean values in responsiveness to the market information, because 65.22 % of respondents reached high market orientation and 33.48 % of respondents reached medium market orientation. 53.91 % of respondents reached high market orientation in the items connected to the intelligence generation and 44.78 % of respondents reached medium market orientation. The lowest mean values of market orientation achieved respondents in intelligence dissemination (6.51 % of respondents achieved low market orientation, 48.70 % of respondents achieved medium market orientation, and 44.78 % of respondents achieved the high market orientation).

The next step in our research was to test statistically correlation between market orientation and all indicators of business performance (Table 6). As we can see in this table, there is statistically significant middle-strong positive dependence between market orientation and almost all financial indicators and also non-financial indicators.

Table 6 The Effect of Market Orientation on Non-financial and Financial Indicators of Business Performance

	MARKOR	
	p-value	Spearman's rho
Employees Commitment	0.000	0.476
Esprit de Corps	0.000	0.418
Customer Satisfaction	0.000	0.369
Overall Performance	0.000	0.359
Market Share	0.000	0.282
Profit	0.000	0.313
Sales	0.000	0.386
Sales Generated by New Products	0.000	0.291
Return on Sales (ROS)	0.000	0.386
Return on Assets (ROA)	0.000	0.285
Return on Investment (ROI)	0.000	0.293
Return on Equity (ROE)	0.001	0.231
Return on Marketing Investment (ROMI)	0.017	0.197
Net Present Value (NPV)	0.000	0.421
Economic Value Added (EVA)	0.000	0.399
Cash Flow Return on Investment (CFROI)	0.000	0.282
Market Value Added (MVA)	0.000	0.340
Balanced Scorecard	0.000	0.391

Finally, we were interested in more detailed analysis regarding market orientation dimensions. We tested the dependence between all three dimensions of behavioural market orientation perspective and business performance indicators. Dependence between intelligence generation and business performance was confirmed in linkage to all financial and non-financial indicators. Then, we focused our interest on intelligence dissemination. Correlation was not confirmed in linkage to return on assets (Sig.=0.239), return on equity (Sig.=0.095), cash flow return on investment (Sig.=0.196), and market value added (Sig.=0.140). Only one financial indicator – return on marketing investments (Sig.=0.437) – is not correlated to the third element – responsiveness. In all other cases the dependence was confirmed. More thorough analysis of the effect of components of market orientation from behavioural perspective on business performance indicators is introduced in table 7.

In the following text we proceed to the comparison of results of our primary research to the results of researches realized abroad. From the geographical, historical, and sociological point of view is Slovak market the most similar to the market of Czech Republic. Tomášková (2009) in her research investigated the relationship between market orientation, customer orientation, employees' orientation, and business performance of hi-tech businesses in Czech Republic confirmed the positive correlation between market orientation and business performance of hi-tech businesses. Market orientation has the positive influence on business performance in the terms of market and finance performance. The results of this research are in accordance with the results of our primary research in which we also confirmed the positive influence of market orientation on business performance measured through the financial and non-financial indicators. The increasing of business performance contributes to the achieving or sustaining the competitive advantage and thus affects the overall competitiveness of business. Nožička and Grosová (2012) who used the New method developed especially for the conditions of Czech businesses, examined the market orientation in the context of innovative small and medium businesses. The results of correlation analysis in this research proved very strong correlation between market orientation and business performance.

There were processed several meta-analyses reflecting the overview of research finding all over the world (Kirca et al., 2005; Jaramillo et al., 2007; Vieira, 2010). For example, Vieira (2010) conducted the Brazilian meta-analysis of 27 papers which aggregate the sample size of 4537 businesses. The results proved the positive and strong relationship between market orientation and business performance. Moreover, they realized the international mega-analysis consists of seven meta-analyses on market orientation and the results showed that there exists strong, positive and consistent relationship between market orientation and business performance across countries. Majority of analyzed researches confirmed the positive relationship between market orientation and business performance (e.g. Talaja et al., 2017; Hussain et al., 2016; Dubihlela and Dhurup, 2013; Alizadeh et al., 2013; Nožička and Grosová, 2012; Tomášková, 2009; Kara et al., 2005; Avlonitis and Gounaris, 1997; Šályová and Táborecká-Petrovičová (2016), Šályová and Táborecká-Petrovičová (2017b)).

Table 7 The Effect of Behavioural Components of Market Orientation on Business Performance Indicators

	MARKOR					
	Intelligence Generation		Intelligence Dissemination		Responsiveness	
	p-value	Spearman's rho	p-value	Spearman's rho	p-value	Spearman's rho
Employees Commitment	0.000	0.369	0.000	0.320	0.000	0.373
Esprit de Corps	0.000	0.335	0.000	0.325	0.000	0.336
Customer Satisfaction	0.000	0.397	0.023	0.150	0.000	0.315
Overall Performance	0.000	0.289	0.006	0.189	0.000	0.330
Market Share	0.003	0.208	0.012	0.176	0.000	0.244
Profit	0.013	0.169	0.033	0.146	0.000	0.289
Sales	0.000	0.263	0.002	0.216	0.000	0.358
Sales Generated by New Products	0.015	0.170	0.001	0.222	0.000	0.248
Return on Sales (ROS)	0.000	0.292	0.011	0.182	0.000	0.335
Return on Assets (ROA)	0.000	0.288	0.239	-	0.002	0.217
Return on Investment (ROI)	0.001	0.225	0.045	0.144	0.000	0.257
Return on Equity (ROE)	0.004	0.206	0.095	-	0.009	0.187
Return on Marketing Investment (ROMI)	0.041	0.168	0.047	0.163	0.437	-
Net Present Value (NPV)	0.000	0.317	0.017	0.203	0.000	0.365
Economic Value Added (EVA)	0.001	0.280	0.009	0.217	0.000	0.327
Cash Flow Return on Investment (CFROI)	0.001	0.269	0.196	-	0.008	0.209
Market Value Added (MVA)	0.000	0.371	0.140	-	0.003	0.243
Balanced Scorecard	0.001	0.309	0.005	0.264	0.004	0.272

Source: Own elaboration according to SPSS output.

Our research results contributed to the current knowledge and are in line with the findings present across a wide variety of countries and contexts.

4. Conclusions and Managerial Implications

According to the research results we conclude that the relationship between the market orientation of businesses in Slovakia and their performance expressed through financial and non-financial indicators was confirmed. The existence of this relationship is proved for the decades by results of enormous number of researches implemented in different countries all around the world, on the sample of businesses of different sizes and operating in various sectors of economy Based on our findings, we formulate proposals for businesses operating in Slovakia which go evidently beyond the borders of marketing. Market orientation has interdisciplinary character therefore our suggestions touch upon management, human resources or corporate culture. In terms of implementation of the marketing concept in the whole business and irreplaceable role of inter-function coordination within the market orientation, the application of the proposals across all functions and departments of business is directly induced.

From the behavioural perspective, in the phase of generation market intelligence the businesses with the best results meet with customers at least once a year to find out what products or services they will need in the future. The next activity is polling end users at least once a year to assess the quality of our products and services. Regarding this, the most important for market-oriented business is to meet with customers regularly in order to find out their opinion about products. In the phase of dissemination market intelligence the best market-oriented businesses focus on organizing interdepartmental meetings at least once a quarter to discuss market trends and developments. In connection to this, marketing personnel in these businesses spend time discussing customers' future needs with other functional departments. Thus, we can state that it is important to communicate about market information within the all departments of business. In the phase of responsiveness to market intelligence the best businesses focus on several activities. They definitely do not ignore changes in customers' product or service needs and periodically review product development efforts to ensure that they are in line with what customers want. In the connection to the customers, the businesses react and solve the complaints of customers. In the field of competition, these business immediately implement the response to the intensive campaign targeted at their customers launched by major competitor. They are also very flexible and quick in implementing the marketing plans. Response to changes taking place in business environment are periodically planned by several departments.

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THE SHADOW ASPECTS OF CRITICAL THINKING FOR LEADERSHIP, SOCIETY AND INDUSTRY 4.0

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Abstract - The text focuses on selected aspects of critical thinking in the context of leadership in a modern security environment, from the point of view of selecting and preparing professionals and leaders. It discusses, in particular, the changes in the professional quality requirements related to the development of industry and society 4.0 as well as selected situational and systemic contexts in which the critical thinking applies in the process of cognition, decision making, and action of professional leaders.

Keywords - INDUSTRY AND ENVIRONMENT 4.0, COGNITIVE CONTINUUM, COGNITION, RATIONALITY, INTUITION, CRITICAL, SITUATIONAL AND SYSTEMIC THINKING.

1. Introduction

The article discusses the area of critical thinking and selected personality aspects in relation to the characteristics and expectations of the development of a modern environment in the form of society or industry 4.0. It presents partial aspects of the complex analysis carried out for the preparation of a pilot project focused on the selection and preparation of professionals and leaders for the pursuit of activities and functions of security character in conditions of a modern environment. The first part deals with the characteristics of modern environment, in the second part we discuss the requirements for professionals and leaders, in relation to critical thinking. In the third part, we highlight the specific aspects related to the selection and preparation of professionals.

The purpose of the analysis and the research was to create background documentation for a pilot project aimed at the complex identification of the level of natural potential of human competences and the natural methods of their cultivation for professional action and leadership in the environment 4.0. Environment 4.0, or Industry 4.0 or "Revolution 4.0," is an environment characteristic of which are trying to address various initiatives responding to what is called the Fourth Industrial Revolution. Environment 4.0, or else Industry 4.0 or "Revolution 4.0," is an environment whose characteristics are trying to address various initiatives responding to what is called the Fourth Industrial Revolution. An example of this may be the German initiative of 2013, called Industrie 4.0, or the Industrial Internet Consortium or the Smart Manufacturing Leadership Coalition in the USA or similar projects and programs of Japan and China. All of them emphasize an entirely new philosophy of system usage, integration and interconnection of various technologies with the dominant role of information and communication technologies, considering their sustainable and fast development. This "brand new" philosophy in a number of its supporting characteristics corresponds to the implementation of the NATO Network Enabled Capability (NEC) concept, i.e. the warfare with the use of modern information and communication technologies, which we have been focusing on since 2006, in the context of optimizing quality and human factor potential. It identifies and develops the qualities and competencies of professionals, leaders, and teams to pursuit functions and activities in such organized conditions and circumstances of missions, situations, and tasks in the security environment. In connection with the "National Industry 4.0 Initiative" prepared by the Ministry of Industry and Trade of the Czech Republic¹ in 2015, and taking into account the features of the so-called Revolution "5.0", emphasizing artificial intelligence, we consider useful to

contribute with our experience and knowledge to the evolving debate and express willingness and openness to cooperation.

2. Analysis of Characteristics of Environment and Requirements for Individuals

Human Systems and Their Management. The environment that we create as human beings with specific ways of life in different communities is changing and transforming more dynamically than the natural environment. In relation to these changes and transformations the requirements on the quality and capabilities potential of the professionals and leaders, i.e. people who pursuit specific functions and activities related to the organization and management of human systems, are changing either. The environment created by people in the process of human community development has approached the parameters of the unstable environment due to various specific changes and transformations (modern information technologies, globalization, etc.). We identify the characteristic aspects that are indicative of this approach in several areas:

- I. technologies, their development, and application
- II. relationships and their development
- III. thinking, cognition, and information

A partial summary: In terms of the natural potential of human resources in the 4.0 environment, the most significant is the problematics of digitalization of information, artificial intelligence, virtual reality, and mediated communication. All these aspects have, besides undisputed direct and obvious advantages and positive effects, also secondary and asymmetric, hidden or shadowed, complex and nonlinear influences and effects on the psychical condition, mind, and thinking of individuals or communities. The shadow effect of digitization and mediated communication is recorded in two modalities. The first suggests that their excessive use gradually transforms the quality of self-consciousness in the full sense of the term. The second effect associated with the growth of digitization, algorithmization and artificial intelligence is the reduction of intuition and analogy in cognitive processes and the creation of knowledge for decision-making and action in a particular situation, and a reduction in spontaneous adaptability to changes in the conditions and circumstances of task situations.

2.1. Systemic (ecological) and Situational Mobility

Systemic (ecological) mobility refers to the environment, and is characterized by the ability to stay in an environment with predominantly artificial characteristics and in environments with predominantly natural characteristics as well as in professional and collaborative environments. Situational mobility is shaped as

¹ Available at <http://www.businessinfo.cz/cs/clanky/narodni-iniciativa-prumysl-40-71386.html#!&chapter=3>

proactivity in the adaptability of changing conditions and circumstances.

2.2. Mobility in Relationships

This mobility includes social and organizational mobility. It is manifested on the social continuum (individual vs. team member), on the organizational continuum (hierarchical vs. network organizational structures) and on the management continuum (management/ leadership).

2.3. Mental Mobility

It represents the thinking in terms of the ability to generate knowledge for decision-making and action in the process of fulfilling the task and its most effective management (energy / least demanding way of performance).

Mobility on a cognitive, ecological, situational, social, and organizational continuum requires, in the end, a change of the attitude of each team member (the individual), in favor of personal self-development and self-fulfillment, individual development and cultivation of natural potential in the profession and position (Ambrozová, et al., 2016, Kolečák, 2015). The above-mentioned trends and requirements for the level of quality potentials of individuals and human systems require an upgrade in understanding the terms of management and leadership. They also need new approaches to identifying and developing the resources, potentials, and qualities of professionals and leaders operating in the current environment.

3. Critical Thinking

The definition of the content and meaning of the term of critical thinking is accompanied by considerable variations. Critical thinking, as the specific quality of thinking for decision-making and action of people in various situational conditions, is sometimes ranked among key competencies for the 21st century. It is a necessary skill to pay attention to in educational and training systems, especially in higher education settings. The International Panel of Experts in 1990 formulated critical thinking as follows: [Critical thinking is an efficient, self-regulatory reasoning the result of which is the interpretation, analysis, evaluation, and derivation, as well as the explanation of the obvious conceptual, methodological, contextual justification on which the reasoning is based on.²]

The etymology of the word critical shows that the root of the word *krinô* means to judge and relates to judgment, reasoning. Critical thinking is a skeptical thinking, i.e. exploring, perceiving thinking. Skepticism, skeptical, critical, because conjectural thinking has characteristics of subtle skills including openness; distance (neutrality and impartiality); mobility (in and out of the situation as well as stay in the gap); skepticism (skeptical, exploratory thinking, allowing to formulate reasonable doubts - questions, and putting forth reasoned arguments that distinguish simple idea from an opinion). The critical, because skeptical, inferring thinking has the characteristics of subtle skills (Ambrozová, et al., 2016), i.e. it contains openness; requires distance (neutrality and impartiality); the mobility on the cognitive continuum³ and under the circumstances and conditions (in and out of the situation, as well as a stay in the gap); it produces reasonable doubts and arguments, allowing to distinguish a view from an opinion. These are the qualities of thinking that each professional and leader should acquire for situational, tactical, operational (project) or strategic decisions.

It turns out that the essence of critical thinking in different task situations is always the distinction, the analysis and synthesis, and at the same time the assessment of similarities and observation, which allows insight into the situation of the task or overview of the whole situation and the environment. The insight and overview represent the aspects related to professional intuition, which is often considered as an opposite to the logic and analysis, or as its complementary, additional aspect in the whole process of thinking and cognition. Critical thinking is flexible, as shown by K. R. Hammond on the model of the cognitive continuum. The demand for mobility shows that it is necessary to free the critical thinking from the domain of formal logic and rationality and to place it in the area of reasoning, closer to the concepts of wisdom, knowledge, or quasi-rationality according to K.R. Hammond, as for instance P.M. Senge (2016) or Cognitive Management (Ambrozová, et al., 2016) do.

This allows thinking as a process to be better applied not only in linear tasks but also in all forms of heuristics (both by Hammond⁴, and Kahneman⁵ or other authors), or tasks requiring decision-making under uncertain conditions, permanent changes and transformations, or due to random processes, etc.

One of the possible versions of the positive operationalization of critical thinking, as the quality or ability that every individual, who has the right to lead other people and human systems should possess, is as follows: [Critical thinking is an individual's ability to create optimal conditions for correct judgment in a situation and a task that manifests itself in the mental mobility. The mental mobility saturates the following measurable parameters:

- A) Cognitive variability and mobility between analysis and intuition⁶
- B) Skeptical curiosity⁷ and courage⁸, openness and spontaneity of learning.
- C) Psychophysical condition in terms of stability of quality and quantity of performance of psychical functions in time (attention and memory).] (Ambrozová, et al., 2016)

Critical thinking plays a dominant role in terms of situational and systemic leadership and is manifested as the mobility on a cognitive continuum. The central concept of the cognitive continuum is a quasi-rationalist (Kostroň, 1997, Hammond, 2000), which represents an adequate presentation of analysis and intuition, as modalities of cognition, for a specific situation and task. The pre-concept⁹, often an individual's unconscious opinion, experience, cognitive model, methodical procedure or stereotype, from which

⁴ K. R. Hammond (2000) suggest the heuristics as tasks with multiple variations of solutions, i.e. offering more than one correct solution.

⁵ Kahneman suggests the heuristics as cognitive and decisive „shortcuts“. „...simple procedure, which facilitates the search for adequate, even if, frequently incorrect answers to complex questions. The term originates from the same basis as the famous *heureka*“ (Kahneman, 2010, p. 28-41; 2012)

⁶ Includes the ability to simultaneously visualize the whole and the insight in terms of fine and precise detail resolution; both concrete (positive) and abstract thinking; work with similarities, differences and relativity. Cognitive variability refers to the quality of a professional, not an expert insight, and refers, for example, to the ability to pragmatically, situationally create

a "meta-method" for cognition in a current task (whether from familiar elements and principles of methods (innovation) or to create, "discover" a new one. There is a continuous relationship (continuum, transition) between the intuition and analysis resulting in the usage of the term of cognitive continuum theory. In the sense of an adequate way of cognition in relation to the situation of a task, the transition can also be referred to as the "common sense" or by K.R. Hammond as quasi-rationality.

⁷ Skeptic in the sense of exploratory, conjectural thinking, including distance, neutrality, and impartiality allowing to formulate reasonable doubts and to put forward reasoned arguments that distinguish the simple view from the opinion.

⁸ In the sense of exceeding the task, context within time, space, and conditions; think the „un/thinkable“ (Taleb, 2011).

⁹ The basal pre-concepts can be divided into natural (reflective) and acquired (in a social and professional setting).

² See www.insightassessment.com/dex.html.

³ Involves both the systemic and concrete thinking reflected and manifested in the entire conditions of cognition, decision-making, and action (tactics and strategy) as well as the mental mobility on the continuum of analytical-intuitive.

the individual examines, recognizes and acts, is also reflected in the preference of ways of cognition and the effectiveness of decision-making and action. This "inner attitude" supports also a different self-concept under the conditions of the situation, the relation to the environment, the situation and the task as well as the different ways of perception and cognition, decision-making and action. The importance of truly critical thinking in leadership for decision-making in challenging conditions, complex and dynamically changing conditions is increasing for a number of reasons. As mentioned above, these reasons include both quantity and availability of information and knowledge, as well as their timeliness and reliability, validity. For example, the rate of obsolescence of information and knowledge is so high that the ability to create own and "fresh" information and knowledge significantly influences the potential success of decisions in different situational contexts. Similarly, the amount of information (related to cognitive optimum) is important in decision-making, and the ability of rapid, fine, and precise differentiation, falling more into the domain of insight and professional intuition, is a highly valued skill (Cejpek, 2005).

4. Results and discussion

The results of the environmental analysis suggest that the importance of mental condition and cognitive potential for critical thinking is growing, and it turns out that the quality of mind, thought, and knowledge of a particular individual is a common element or a central quality, potential and competence involved in all other competencies. This mental "vitality", as a central quality, has at least two modalities.

The first modality involves critical thinking; mobility on the cognitive continuum and optimal condition of mental functions involved in perception and cognition. The other modality can be considered as a mental mobility for decision-making and action in situations and tasks. Dominant characteristics of this modality are spontaneity (openness, curiosity, and courage) and flexibility (flexibility of thinking). The aspects of the first modality can be traced to a certain extent by various tests that measure the quantity and quality of performance of psychical and executive functions. The other modality level can be analyzed with the help of selected personality aspects that are identified by the different methods of personality questionnaires. Critical thinking as the mobility on a cognitive continuum, concerns both the functions and capacities involved in cognition for correct decision-making and effective action in the situations and the personality, in terms of the inner environment of individuals who evolve in this environment or are temporarily present within. In the concepts of analytical psychology of C.G. Jung and with reference to the concept of K.R. Hammond it is the finding of the state of balance of tension between the maxima of the cognitive continuum in relation to the requirements (conditions and circumstances). In situations, where the environment, by its characteristics, prefers forms of perception and models of cognition, linked to the digitization of information, mediated knowledge and communication, to algorithmization of "smart" technologies as well as artificial intelligence, there is a risk of loss of mobility, which is reflected in rigidity, standardization, and stereotyping, as well as non-cultivation, non-development, and thus the emptying of the natural qualities of abilities, or the shadowing of those natural ways of cognition, which relate, for example, to intuitive and analogical thinking functions that relate more to the logic of discovery than to the logic of reasoning (Alleau, 2008, p. 39).

A shift in this area may indicate not only the differences in the ability of professionals and leaders to move in solving various specific situations in the selection and preparation process as we have seen in recent years but also in partial changes in selected indicators that are related to this mobility. The selection and preparation practice shows some trends of change that need to be

adapted to the selection and preparation methods. The selection and preparation practice shows some trends in changes that need to be adapted to the selection and preparation methods. Therefore, it must reflect not only the changes in the requirements of the environment but also the changes in the qualities of abilities of those who want to apply with the professional environment as well as those who already work in it. A possible hint of these changes may be partial shifts in preferences as indicated by the following results.

These are groups of professionals and leaders operating in the security environment. The first group consists of 115 people monitored for their quality of skills in the course of 2014 and 2015. The other group consists of 127 people from the same environment where these qualities were surveyed in the course of 2017 and 2018. For the purpose of the article, indicators of selected global scales were applied using the GPOP method (Bents, Blank, 2009). In the table, we present aggregate values in the form of averages and standard deviations.

Table 1: GPOP aggregate values indicators of selected global scales in the form of averages (AVG) and standard deviations (SD).

2014-2015	S	N	T	F	J	P
AVG	6,1	6	6,6	6,1	6,6	5,4
SD	1,7	2	1,9	1,8	2,4	1,8
2017-2018	S	N	T	F	J	P
AVG	7,1	4,3	6,5	5,1	7,9	3,8
SD	2,9	2,4	2,4	2,1	2,9	1,7

The function of sensory perception (S) and intuition (N) are functions called irrational functions as they do not evaluate but are dependent on the act of perception. The preference of functions in terms of perception as information sources affects cognition and decision-making in various task situations.

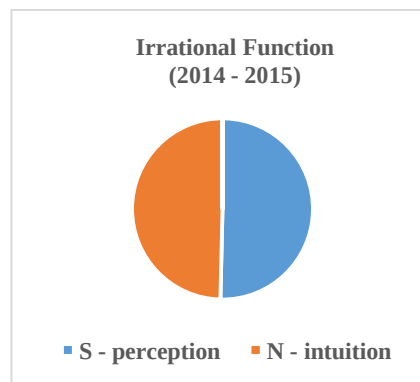


Fig. 1: The preference of irrational perception functions as information sources; years 2014-2015.

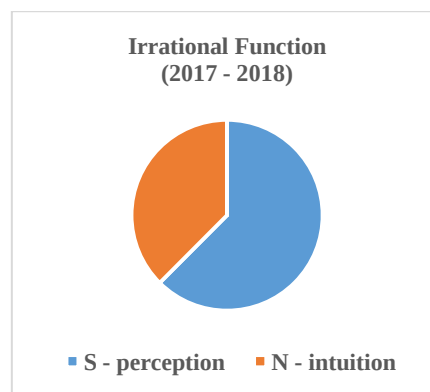


Fig. 2: The preference of irrational perception functions as information sources; years 2017-2018.

The functions of Thinking (T) and Feeling (F) are called rational as they allow rational evaluation of experience, information processing which reflects into a decision. Thinking "says" what a thing, an object, is, and usually works with facts, formal logic and the logic of reasoning, analysis, and synthesis. Feeling "says" what value a phenomenon, a thing has, it works by analogy, relationships and meaning.

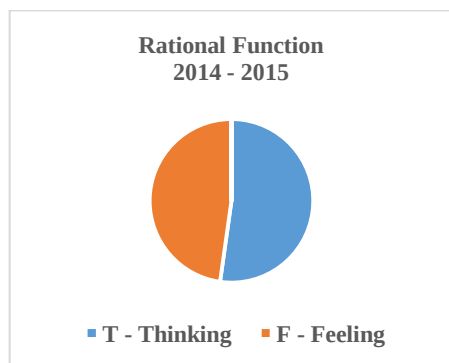


Fig. 3: The preference of rational perception functions as information sources; years 2014-2015.

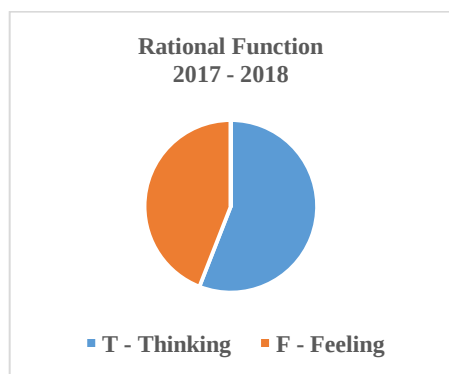


Fig. 4: The preference of rational perception functions as information sources; years 2017-2018.

For the correct situational and systemic decision-making, it is important to what extent the various cognitive models are involved in its constitution, creation, whether it is predominantly logical, factual or of a value. In general, the preference of a mode of cognition, decision-making, and action is growing and influenced by the coherence, positivist, direct, and rational thinking that prefers analysis and linear causality, developing and working with formal logic in language and mathematics. This is a modus from which the potential of digitization, algorithmization, artificial intelligence, mechanization, technology, and "dataisation" (Harari, 2017) originates. The ways of cognition and decision-making, based on correspondence and analogy, which are the natural "half" of the cognitive continuum of every living, recognizing person, are "receding into the shadows," as well as the potentials of the ability of analogous thinking, cognition, decision-making and action, based on the concept of correspondence, offer and enable.

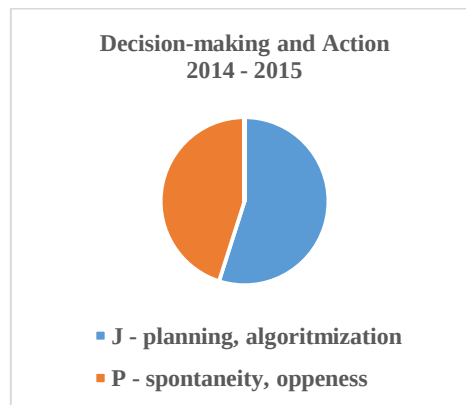


Fig. 5: The preference of decision-making and action; years 2014-2015.



Fig. 5: The preference of decision-making and action; years 2017-2018.

Further features affect what the individual, in terms of decision-making and implementation, prefers, whether the plan, a goal, a structure, and procedure of algorithm or process and spontaneity. It turns out that the preferences of decision-making orientation related to algorithmization and planning have increased significantly, and the preferences of spontaneity, creativity, and openness to opportunities that are the basis for successful solutions to complex and complexly evolving situations and processes as well as heuristics has decreased.

5. Conclusion

The above results serve only as illustrations and suggestions for reflection. They correspond to our "intuitions"

and "feelings and insights" of the professionals involved in the selection and preparation, as well as to the need to innovate and adapt the methods of preparation and verification of results to changes in population and environment. Experience shows both the need for a comprehensive, multidisciplinary approach to identifying the qualities of their potentials and the need to incorporate elements that enable support, training and development of various aspects of critical thinking in favor of mobility on the cognitive continuum. This issue is being focused by the complex project, the program, for the preparation of which we used the analysis and the pilot study, from which we have chosen and presented only partial aspects.

The requirements of an environment and a situation for the pursuit of activities and functions are constantly evolving and changing. From the nature of the changes and the characteristics on their background, the basic features of the quality requirements and competencies of individuals in professional systems and environments are formed. These requirements, in various aspects,

emphasize the mobility, consistency and "adaptability" of the thinking process of every person who is involved in some way in the organization, management and leadership within human systems, from the "lowest" levels, with the direct practical consequence (task situation) to the highest" levels representing systemic, strategic decision-making and action.

The professional security environment is currently more structured, in terms of preferred cognitive models, due to the digitization and use of modern and sophisticated communication and information technologies. However, the situation of specific tasks or missions is far more complex and requires professionals and leaders to have mental fitness and mobility on a cognitive continuum.

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RISK MANAGEMENT IN CONTEXT OF INDUSTRY 4.0

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Abstract: Prevention 4.0 as part of the enterprise's safety culture is developing HSE management system to address new challenges in prevention. Industry 4.0 anticipates new linkages between technology, man, and management systems to apply the most efficient IT systems to ensure the flexibility of the production process so that its output is a product that takes into consideration customer requirements. These changes include the existence of new types of risk due to the change of the position of man from the classical production centers to the area of superstructure activities, programmer, setter, maintainer, security technician for the digitization of production processes. Risk identification is based on defining the hazards and threats of a complex manufacturing system in the context of Safety and Security – Sa&Se, their formulation so that characteristic parameters can be efficiently digitized within the manufacturing process.

Keywords: SAFETY, SECURITY, INDUSTRY 4.0, AUTOMATION, DIGITIZATION, RISK MANAGEMENT, W- DEPENDENCE, PREVENTION, MAINTENANCE, SMART FACTORY

1. Introduction

The formation of cyber-physical systems incites the world economy to constantly adaptation to the complex requirements of new systems, creating new requirements for businesses that have to adapt their activities to change. The same process goes through the man and his role within the Smart factory⁶.

Industry 4.0 brings a great deal of change. Actually, functioning autonomous factories are no longer just the subject of debate and research focused on the implementation of Industry 4.0 elements to real industrial practice. Increasingly, the real world and virtual world are overlapping, even in this sector. Prevention 4.0 as part of the enterprise's safety culture is developing HSE management system to address new challenges in prevention⁸.

2. Industry 4.0

The term Industry 4.0 (see Fig. 1) means a way of managing activity within technologies where production and logistics processes and within them machines and products communicate with each other and organize individual steps in the production process autonomously in synergy with the human factor. The goal is that processes take into account the requirements for safe operation so that products at the end of the production process meet customer requirements. Enterprises are targeting to creation of Intelligent (Smart) Factory⁴.

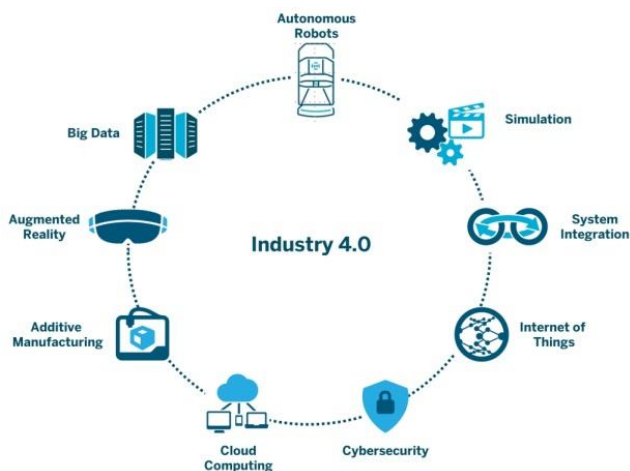


Fig. 1 Industry 4.0³

Industry 4.0 can be defined as a philosophy that defines the methods and methods of managing technologies that are already used in some areas of industrial production where machines,

machinery and products communicate with each other and organize themselves individually in the production process (Fig. 2).

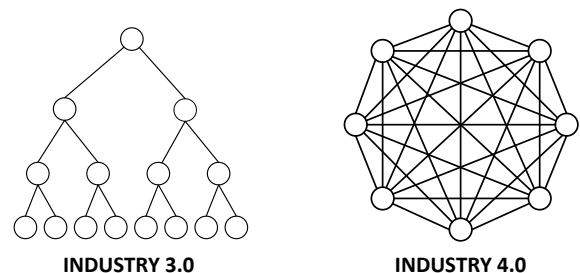


Fig. 2 Difference in information transfer - Industry 3.0 and 4.0

The term Industry 4.0 represents⁷:

- linking production to information and communication technologies,
- linking customer requirements directly with machine and device data,
- communication machines to machines - M2M,
- autonomous data acquisition and processing at both vertical and horizontal level,
- decentralized management,
- separate production created by communication between semi-finished products and machinery - a flexible, efficient and cost-saving resource².

It follows that meeting the requirements of Industry 4.0 will have the necessary impact on⁵:

- quality of work,
- requirements for qualification,
- new ways of organizing work and changing of many interactions and interactions in the human-machine-environment interface that we can imagine as new forms of collaborative work in the context of a digital factory.

Individual companies according to the degree of implementation of Industry 4.0 elements can be partitioned, for example, to five levels. Each level has a specific division of Integrated Safety & Security.

The individual levels of Industry 4.0 implementation:

1. Level - Basic level of digitization: The company does not address sector 4.0, requirements are not met or only partially met.
2. Level - Digitization between departments: the company is actively engaged in the topics of Industry 4.0. Digitization is implemented in various departments and the first

requirements of Industry 4.0 are implemented throughout the company.

3. Level - Horizontal and vertical digitization: The company is digitized horizontally and vertically. The industry 4.0 requirements were implemented within the company, and the information flows have been automated.
4. Level - Full digitization: The company is fully digitized beyond enterprise boundaries and integrated into value networks. Approaches in industry 4.0 are actively pursued and embedded within the corporate strategy.
5. Level - Optimize Full Digitization: The Company is a model for industry 4.0. Strongly cooperates with its business partners and therefore optimizes its value networks.

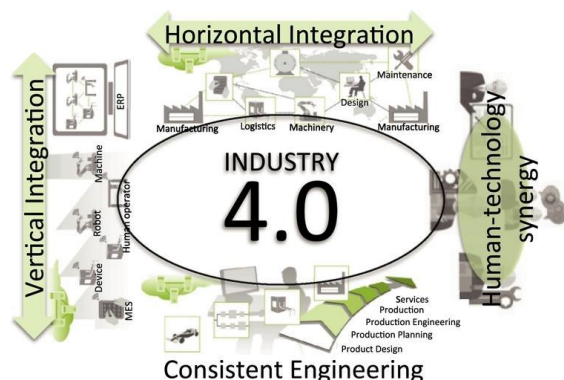
3. Safety & Security context

Industry 4.0 in its implementation in the company is emerging new safety requirements. On the one hand, such systems may not endanger people and the environment - "corporate (internal) safety" and, on the other hand, such devices must be protected for misuse and unauthorized interference - particularly in the area of data misuse, protection against unauthorized interference – Security¹.

Hence, the risk management methodologies in both production and logistics processes, and therefore also individual machines and machine systems, must meet the requirements of interconnection on the basis of Integrated Safety & Security at all levels of organization management⁴.

Integration of Safety & Security must take place (Fig. 3):

- a. in a horizontal plane (from the receipt and confirmation of the order to the end of life of the product);
- b. in the vertical plane (from the lowest level of automated physical process management to the planning of production resources)
- c. as well as in the level of integration of engineering processes (product lifecycle management).



Obr. 3 Horizontal a vertical integration in Industry 4.0²

Safety and Security ratios vary depending on the Industry 4.0 elements implementation level. This dependence can be called W - dependence. (Fig. 4). With the higher level of implementation of Industry 4.0 and the implementation of a higher number of robots, cobots in the factory, the number of workers exposed to work risks will decrease. Workers' safety will be more dependent on the security of digital technologies in the factory. In the area of security, cybersecurity will become more and more important, as a result of the threat of HSE over digital ways.

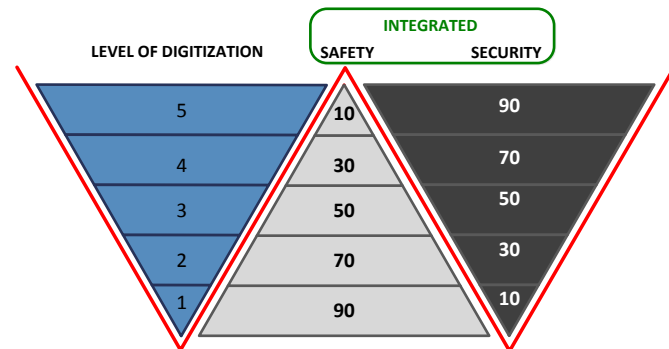


Fig. 4 W – dependency - Example of Safety and Security Ratio (%) depending on the Industry 4.0 elements implementation level

4. Results of discussion

The process of implementing Integrated Security Industry Sector 4.0 elements is divided into 6 steps (Fig. 5).

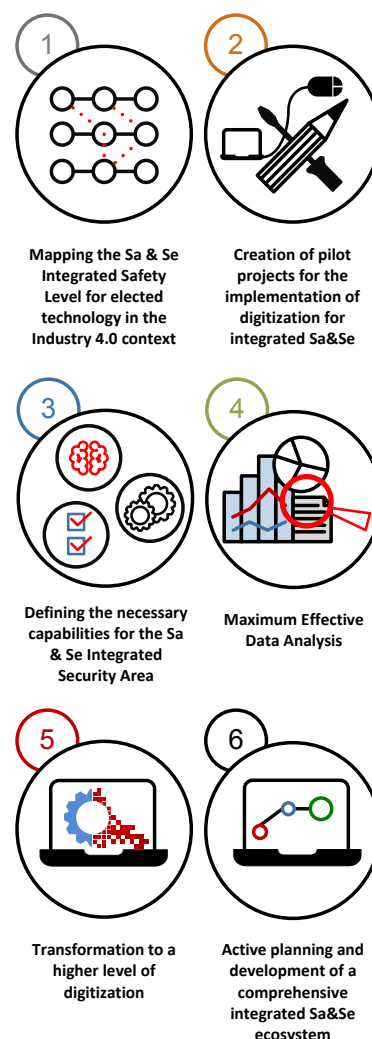


Fig. 5 The Implementation of elements of Industry 4.0

1. Mapping the level of integrated Sa&Se for selected technologies in the Industry 4.0 context - analyzing the processes that have the greatest impact on HSE from the point of view of Safety and Security, critical process analysis with the highest priority, and analyzing the devices with the highest added value ...etc.
2. Creation of pilot projects for the implementation of digitization for integrated Sa&Se - demonstration of a

- suitable concept for integrated Sa&Se and demonstration of business value.
3. Defining the necessary capabilities for the Integrated Sa&Se area - analyzing information from pilot projects, developing a strategy for the implementation of elements of Industry 4.0 and defining the needs and requirements for recruiting suitable staff.
 4. Maximum Effective Data Analysis - data collection between different levels of Industry Platform 4.0, a follow-up analysis for the need for effective implementation of Integrated Sa&Se elements at Industry 4.0 level and above, and the creation of "multifunctional" expert teams.
 5. Transformation to a higher level of digitization - digital culture support in the company, experimentation with new technologies, innovative ways of operation, implementation of Industry 4.0 elements to all areas of the enterprise.
 6. Active planning and development of a comprehensive integrated Sa&Se ecosystem - introduction of complex platforms.

5. Conclusion

Industry 4.0 strategy includes the integration of Safety and Security. Safety and Security supposed to be interconnected (influencing). Application of Safety and Security control systems changes the static principle to dynamic, assumes identification of all production and distribution processes, data mobility as part of BIG DATA technology and human factor activity to ensure the functionality of relevant applications. Industry Strategy 4.0 requires a proactive approach to risk analysis, the essence of which is to implement the Safety and Security principles into the development and construction of machines and complex technologies in the context of using the Cyber Physical Systems principles.

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