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Assessing the predictive maintenance readiness of enterprises in West Bohemian region

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Abstract

The approach to machinery maintenance has changed during the four industrial revolutions; from reactive control towards fault prediction. The aim of this article is to monitor the preparedness for predictive maintenance implementation into companies with upcoming 4th Industrial Revolution in several (manufacturing and non-manufacturing enterprise) companies cooperating with University of West Bohemia in the region.

Based on our previously published metamodels of machinery maintenance we can say that there is a growing trend between the development of maintenance and technologies used. The more sophisticated machinery maintenance, the more sophisticated technologies and skilled personnel is needed for its operation. The most evolved type of Machinery Maintenance is called Predictive maintenance or Maintenance using elements of Industry 4.0.

This article deals with pilot study of predictive maintenance implementation in west-bohemian region. During April 2019, a questionnaire about the utilization rate of Industry 4.0 elements was sent to representatives of companies in region of West Bohemia, Czech Republic. Responses were received from thirteen companies, mostly from technical, division and executive directors. For the purposes of this questionnaire, only the answers of medium and larger enterprises with 140 or more employees engaged in production or research were interpreted.

The final part deals with interpretation of results and their consequences for the future.

Keywords: Industry 4.0., predictive maintenance, pilot study

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1. Introduction

The term Industry 4.0. is associated with 4th industrial revolution. The word revolution itself, express something that suddenly changes society in a revolutionary manner with all its particulars, should mean that it is a phenomenon that will sooner or later each of us [1]. From the „machinery" point of view, the 4th industrial revolution ensures greater efficiency and flexibility for manufacturing companies in the future through the concept of Industry 4.0. [2].

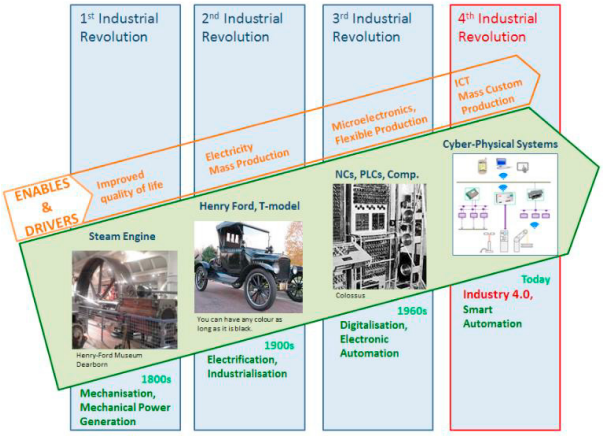

Fig. 1. Four Industrial Revolutions [3]

Engineering belongs to important industrial branches in the Region; it is related especially to Škoda facilities for both classical and nuclear power engineering and petrochemistry, products of ironworks and forges, heavy machine tools, facilities for rolling mills and sugar plants, hydraulic and curing presses, gear units, rail vehicles, trolleybuses, drive motors, steam turbines etc.

Other important industrial enterprises, which have an influence on the Region's economy are:

- DIOSS Nýřany a.s., producing products from sheet metals and tubing,
- Okula Nýrsko a.s., producer of traditional optical frames for glasses and processor of plastics,
- LASSELSBERGER s.r.o., which represents ceramics manufacturing.

The Plzeňský Region is very attractive for foreign investors thanks to its location. A dominant position among foreign investors belongs to Japanese plant Panasonic AVC Networks Czech s.r.o. producing flat panel display screen.

Other important foreign companies are:

- YAZAKI Wiring Technologies Czech s.r.o. producing components for automotive industry,
- VISHAY ELECTRONIC s.r.o., which deals with production of electronic parts,
- BORGERS CS spol. s r.o. producing textiles and textile floor coverings for the automotive industry,
- MD ELECTRONIC spol. s r.o. producing cable jumpers,
- Daikin Industries Czech Republic s.r.o. with production of heat pumps, air conditioning, and ventilation systems.[18]

The aim of this paper is to analyse, if the companies in this region are prepared for upcoming 4th Industrial revolution, especially from tie machinery maintenance point of view. .

2. State of the art analysis of maintenance in Industry 4.0.

The most „widely used "definition of machinery maintenance is by Swedish standard SS-EN 13306, which defines it as a "Combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function" [6]

Now, the highest form of maintenance using elements of Industry 4.0. is predictive maintenance (also called PdM 4.0). It allows the prediction of production equipment failures fails by analyzing production data to identify patterns and predict issues before they happen. To achieve this, technologies associated with Industry 4.0 (cyber systems, cloud storage or Internet of Things) are used. To detect anomalies, software tools like use big data analytics with combination of artificial intelligence are used. Control units, CMMS systems, maintenance reports, warehouse management and ERP provide necessary data for analytics.

When implementing PdM, staff training is also needed. Also, new expensive equipment (in average cost of more than € 30,000) is needed. So the question we are dealing with in the next part of the article is: Is the implementation of predictive maintenance despite of high entry costs and high personnel training cost effective [17]? Will it bring more benefits to the company?

The fundamental methodology used in this article is dealing with implementation of predictive machinery maintenance in companies. Based on results obtained from the analysis of models (Basl, 2017) were transformed into a creation of a maturity model (Poór, Basl, Ženíšek, 2019). This model presents a new (radical) change - predictive maintenance using elements of Industry 4.0, whose functionality is optimized on on-line data analysis (provided mostly by sensors). Maintenance processes are fully automated and digitalized operators are fully involved in CMMS and company network. Also, intelligent maintenance systems are used, remote monitoring and production control. For MRO, also augmented reality can be used, as other advanced technologies as cyber-physical systems, digital twins, automated guided vehicles, additive manufacturing and many others. The next part of the article is dealing with evaluating enterprises readiness for Industry 4.0.

3. Methods and materials

During April 2019, a questionnaire on the utilization rate of elements of Industry 4.0 was sent to representatives of companies in the Czech Republic.

The questionnaire was designed to cover 4 main areas:

- General information about the company (size, area of production, employees)
- Company and Industry 4.0 (implementation of I4.0, who is responsible for that…)
- Maintenance (what type, how it is done, maintenance software, indicators, OEE)
- Industry 4.0. in maintenance (implementation, monitoring, tools and sensors, data collection..)

In turn, responses were received from these companies: GRAMMER CZ s.r.o., Wikov Gear s.r.o., VZLÚ, a.s., STREICHEr spol.s r.o.Plzeň, Bosch, MOTOR JIKOV Group a.s., PILSEN TOOLS s.r.o, OMEXOM GA Energo, Aerotech Czech s.r.o, Grafia, MM publishing, KOH-I-NOOR Mladá Vožice a.s., ŠKODA JS a.s.

The questionarie was carried out in small (15,4%), medium (38,5%), big (15,4%) enterptises and in branches with head-office abroad. From each company we did get final answers and we decided not to take company size into account. Thatswhy the “final” result obtained results are an overall summary of maintenance in a particular enterprise. It may seem that only 13 results are weak, but for our initial study it was enough.

The direct persons answering the questionnaire were mostly company top-positions (CEO, Director, co-owner, Managing Director, Division Director) or people directly involved into maintenance: Facility managers, Technical Directors, Energy Managers, Service Department Manager, Director of Project Management and Technology. Some non-maintenance positions (clerk and business deputy, secretaries) were also involved, but most of these companies produce their products for engineering industry (Figure 2).

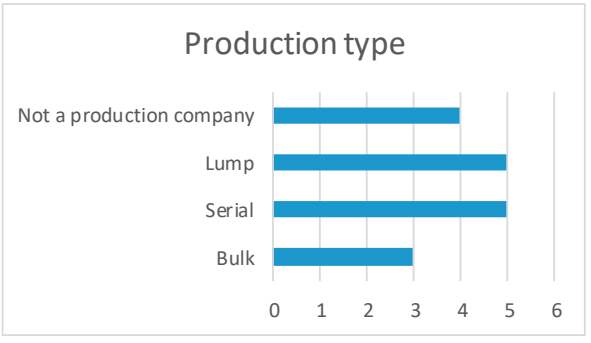

Fig. 2. Production type

That why, only the answers of eleven respondents who stated that they are medium and larger enterprises with 140 or more employees and engaged in production or research were interpreted.

The questionnaire asked 49 questions, divided into sections: Business Information, Enterprise and Industry 4.0, Enterprise Maintenance and Industry 4.0 Maintenance. In this article, we'll focus on the questions related to the "Maintenance Management in the Industry 4.0" context.

The aim of this questionnaire was to find answers to these questions:

1. What elements of Industry 4.0 do you use in maintenance?
2. How many percent of your devices are connected to the Internet and monitored?
3. How are your devices monitored?
4. What is the overall equipment efficiency (OEE) on your key devices?
5. What specialists do you employ in the maintenance team?

The questions were carefully chosen to answer the hypothesis whether the 4th Industrial Revolution has already caught up with maintenance in businesses of this region.

3.1. Industry 4.0 elements used in maintenance

The aim of this question was to find out how often elements of Industry 4.0 are used among companies and to what extent they are deployed there. The companies could choose from options proposed by us as the most “connected” with Industry 4.0 implementation: Internet of Things, Cloud, Cyber-Physical Systems, Big Data Analytics, Artificial Intelligence, 3D Printers and Virtual Twin.

For each of these elements, the respondent should check whether the element is:

- used for maintenance purposes,
- used in the enterprise and deployed in the maintenance,
- used in the enterprise, deployed in the enterprise,
- whether they are planning to deploy the element or
- not knowing about this at all.

The numbers in Table 1 show, in how many companies the elements of Industry 4.0. are used. If the respondent not checked either of these answers, we can conclude that they do not deal with this element or are not considering joining the company yet. If we look at the degree of involvement, we have to say that they clearly do not care about the elements most often or that they are only planning to deploy them in the company. The questionnaire showed that only one company uses two of these elements for maintenance, namely Big Data Analytics and 3D printing [15]. At the same time, the company replied that they already used a larger part of the elements in the company. [8]

Table 1 Which of the following elements of Industry 4.0 do you use?

How the elements are already involved	Internet of Things (IoT)	Cloud	Cyber-Physical Systems (CPS)	Big Data Analytics	Artificial intelligence (AI)	3D printing	Virtual twin
Used for maintenance purposes	0	0	0	1	0	1	0
We use and implement into maintenance	2	1	0	0	1	0	1
Used in the company	1	2	1	2	1	2	0
Deployed in the company	1	1	1	1	0	1	0
Plan to deploy in the company	4	2	0	3	3	2	2
We don't know what this is about	0	0	3	1	1	0	3
We don't consider to use	3	5	6	3	5	5	5

3.2. Internet connection and monitoring

One of the key factors of the ongoing 4th industrial revolution is the implementation of the internet, interconnectiong the company devices. The connection of machines and equipment varies greatly between companies. However, it can be stated that less than 50% of installations are involved and monitored in 63% of enterprises. In four companies they estimate the connection is 50-70%.

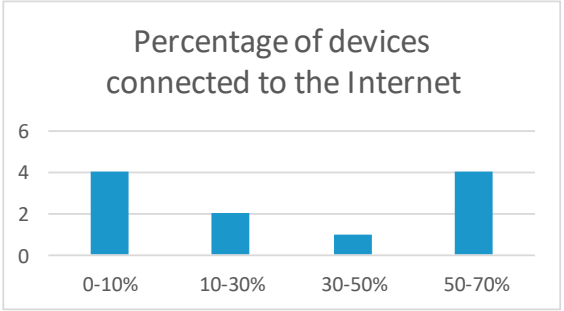

Fig. 3. Percentage of devices connected to the Internet

When asked how the devices are monitored, the most frequently answered (64%) companies were using tools and real-time monitoring. Only one company reported using predictive techniques.

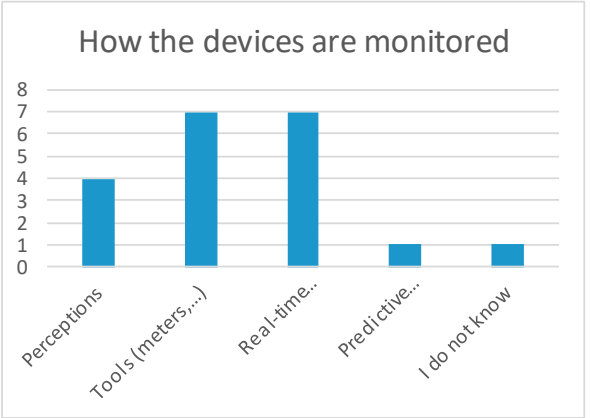

Fig. 4. How the devices are monitored

3.3. Maintenance team

When asked what company specialists are employed in the maintenance team, five out of eleven responded that they employed maintenance positions by other skills than only technicians. Most often, four times, they employed IT specialists. This only proves, that operators are fully involved in CMMS and network. With more improved machinery maintenance, less "repairman" skills are needed, but operators closely cooperate with dedicated maintenance. Data scientists and simulation analysts [9,10] are the personnel, you need.

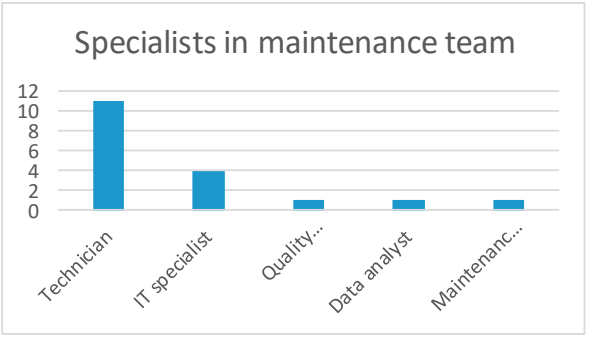

Fig. 5.Specialists in maintenance team

3.4. Overall Effectivity of Equipment

The Overall Effectivity of Equipment identifies the percentage of manufacturing time that is truly productive. An OEE score of 100% means you are manufacturing only Good Parts, as fast as possible, with no Stop Time. In the language of OEE that means 100% Quality (only Good Parts), 100% Performance (as fast as possible), and 100% Availability (no Stop Time). [11] According to research of [12], there is also an inverse correlation between the level of Maintenance and its "factor" OEE. The more developed maintenance, the higher the Overall Effectivity of Equipment is.

Table 2 Correlation of Industrial Revolutions and Maintenance [12]

Industry revolution	**Industry 1.0**	**Industry 2.0**	**Industry 3.0**	**Industry 4.0**
Characteristics	Mechanization, steam power, weaving loom	Mass production, assembly lines, electrical energy	Automation, computers, electronics	Cyber Physical Systems, IoT, networks, cloud, BDA
Maintenance type	**Reactive**	**Planned**	**Productive**	**Predictive**
Inspection	Visual inspection	Instrumental inspection	Sensor monitoring	Predictive analysis
OEE	<50%	50-75%	75-90%	>90%
Maintenance team reinforce	Trained craftsmen	Inspectors	Reliability engineers	Data scientists

When asked about the overall device efficiency (OEE) on key devices, 55% of respondents replied that they were monitoring OEE, 36% were not monitoring OEE and 9% did not. Most often respondents said that OEE on key devices is more than 90 percent.

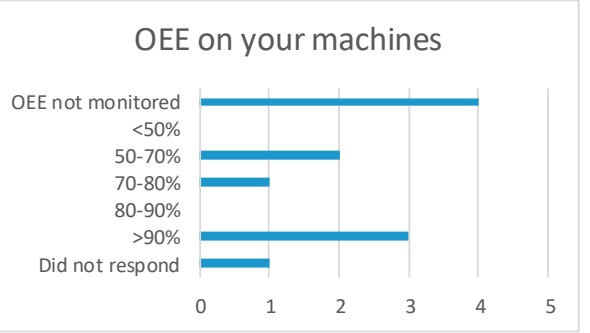

Fig. 6.Overall Effectivity of Equipment

The final part of the pilot study was dealing with the benefits of Industry 4.0. implementation into maintenance.

Main benefits are:

- Improving uptime
- Reduce maintenance costs
- Extending the life of an asset
- Higher customer satisfaction
- Risk reduction in the area of security [20], health….

Of course, in more than 53% of workers were aware of Industry 4.0. implementation into maintenance. Some of them were also motivated with trainings focused on this implementation.

According to [7] following savings result from the use of predictive maintenance:

- Return on investment: 10 times more
- Reduction of maintenance costs: 25% to 30%
- Troubleshooting: 70% to 75%
- Reduction of downtime: 35% to 45%
- Increased production: 20% to 25%

The results from our questionnaire were similar. People know, that implementation of "new" type of maintenance is a costly and long-term process. But later, this leads to maintenance costs. Also, downtimes are more likely to be reduced, which finally results in increased production of less faulty products.

4. Results

100% of the respondents think, that maintenance is part of Industry 4.0. This is in correlation with [13]. The companies are trying to implement Industry 4.0. into maintenance.

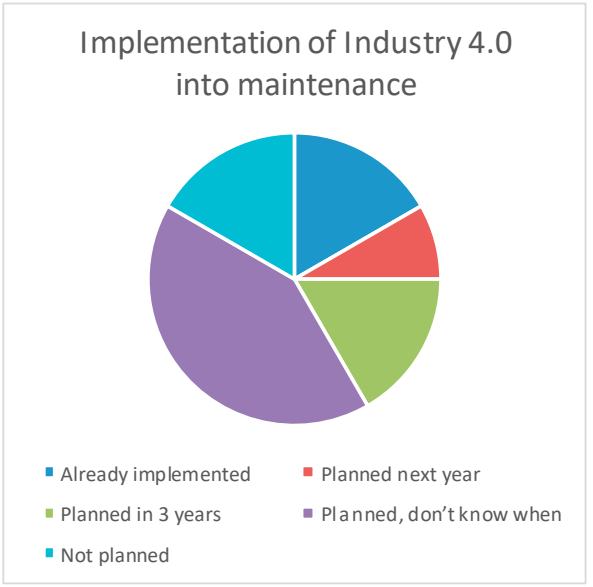

Fig. 7.Implementation of Industry 4.0 into maintenance.

The most reasons, why NOT to implement Industry 4.0 into maintenance were slow implementation (can take up to several years when implementing new type of maintenance into manufacturing processes) [14]. Another reason was that the company was dealing with piece production.

For predictive maintenance, it is very important to collect data. In companies various tools for maintenance management were used: Paper and pen, MS Excel, MS Access, WIFI/Bluetooth, Data storage, SPC software, Condition monitoring software, Cloud, Data software, Mobile networks, Internet of Things, 3D printing and Own software.

In some companies they do not use any software at all. That why we have some "pen and paper" replies from them. This is caused by several reasons. Or the company is too small, cannot afford software monitoring, has too few monitored devices, or the devices function in a long term without crash or any need to repair (we encountered a device that is fulfilling its action last 15 years without any malfunction, only routine maintenance is carried out here. This is the case mostly in smaller companies It is also very interesting, that the most widely tool used in most of the companies are still Microsoft Office tools (mostly MS Excel or MS Access due to its capacities to maintain databases.

Also, other companies use simple CMMS (Computerized maintenance management system) for basic monitoring.

Also, types of collected data were different:

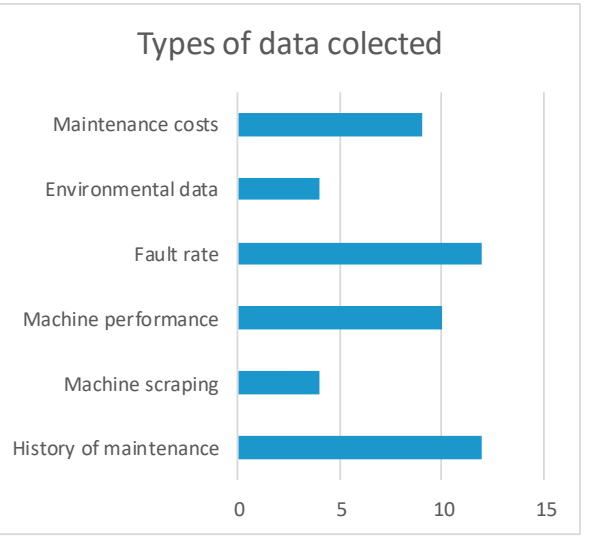

Fig. 8.Types of data collected.

The most "crucial" data here are connected with maintenance history, fault rate and machine performance. This is also with correlation of Industry 4.0. definition and advanced forms of maintenance. Collected data are stored into ERP systems mostly, but some companies still use paper and a pen.

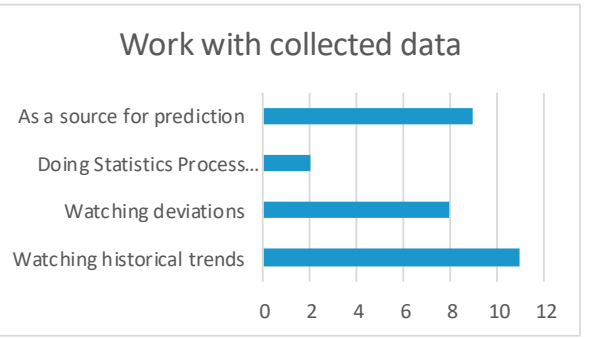

Fig. 9.How they use collected data.

As stated previously, this research was conducted as a "pilot" in west-bohemian region. The results were very interesting to us, and we think they could be applied elsewhere. A similar pilot study was carried out 2 years ago in Zlin region (another part of Czech Republic) (ODKAZ). It may be interesting at least to compare these two studies.

Also, our future works focus on creating a maturity model or assess the readiness of such enterprises with reference to the implementation of predictive maintenance.

5. Conclusion and discussion

The aim of this article was to monitor the preparedness for predictive maintenance implementation into companies with upcoming 4th Industrial Revolution.

During April 2019, a questionnaire about the utilization rate of Industry 4.0 elements was sent to representatives of companies in region of West Bohemia, Czech Republic. Responses were received from thirteen companies, mostly from technical, division and executive directors.

Comparing the results of the questionnaire to the maintenance management matrix in the context of industrial revolutions, we can conclude that maintenance in enterprises is only beginning to take advantage of elements of the 4th Industrial Revolution. Among the elements of the Fourth Industrial Revolution, businesses primarily use real-time monitoring with sensors and Internet access. The forecast is so far unique. The maintenance team most often includes technicians and IT specialists, but not data specialists. OEE is often not monitored and only 36% of respondents were above 90%. The most obvious reason, why NOT to implement new type of maintenance, are money and time. Big and rich companies also have their research departments, and here the process is smoother. A lot of data are collected, and already implemented into existing ERP systems. Also, companies are making their employers aware of the ongoing Industrial Revolution.

Although there were not many answers, it can be concluded that the level of maintenance is rather at the level of the elements characteristic of the third industrial revolution.

Acknowledgements

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References

[1] Yoder, Dale. Current definitions of revolution. American Journal of Sociology, 1926, 32.3: 433-441.
[2] Hofmann E., R. M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. Computers in Industry(89), 23-34.
[3] Rojko, A. (2017). Industry 4.0 concept: background and overview. International Journal of Interactive Mobile Technologies (iJIM), 11(5), 77-90.
[4] Poór,P., Basl, J.: Readiness of Companies in Relation to Industry 4.0 Implementation, Hradec Economic Days.
[5] WINIX Technologies: INDUSTRY 4.0 : The Digital Technology Transformation. May 25, 2018
[6] SS-EN 13306, 2001, p.7
[7] Bloch, H. P., & Geitner, F. K. (1997). Major process equipment maintenance and repair (Vol. 4). Elsevier
[8] Poor, P., Zenisek, D., Basl, J. (2019): Historical Overview of Maintenance Management Strategies: Development from Breakdown Maintenance to Predictive Maintenance in Accordance with Four Industrial Revolutions
[9] Kliment, M., Popovič, R., Janek, J. (2014) Analysis of the Production Process in the Selected Company and Proposal a Possible Model Optimization Through PLM Software Module Tecnomatix Plant Simulation, . In: Procedia Engineering : Modelling of Mechanical and Mechatronic Systems MMaMS 2014 : 25th-27th November 2014, High Tatras, Slovakia. Vol. 96 (2014), p. 221- 226. - ISSN 1877-7058
[10] Trebuňa, P,. Kliment, M., Edl, M., Petrik, M. (2014) Creation of Simulation Model of Expansion of Production in Manufacturing Companies, In: Procedia Engineering : Modelling of Mechanical and Mechatronic Systems MMaMS 2014 : 25th-27th November 2014, High Tatras, Slovakia. Vol. 96 (2014), p. 477-482. - ISSN 1877-7058
[11] htps://www.oee.com
[12] Coleman, D. C. (1956). Industrial growth and industrial revolutions. Economica, 23(89), 1-22.
[13] Poór, P., Basl, J. Ženíšek, D.: Historical Overview of Maintenance Management Strategies: Development from Breakdown Maintenance to Predictive Maintenance in Accordance with Four Industrial Revolutions. In: International Conference on Industrial Engineering and Operations Management Pilsen, Czech Republic, July 23-26, 2019, p 495-504
[14] Poór, P., Kamaryt, T., & Simon, M. (2015). Introducing autonomous maintenance by implementing OTH hybrid positions and TPM methods in metallurgical company. International Journal of Engineering and Technology, 7(3), 817-824.
[15] Martin Pollák, Jakub Kaščak, Monika Telišková, Jozef Tkáč: Design of the 3D printhead with extruder for the implementation of 3D printing from plastic and recycling by industrial robot / In: TEM Journal: Technology
education management informatics Vol. 8, no. 3(2019), p. 709-713 2019, ISSN 2217-8309.
[16] Martin Pollák et al. - The structural design of 3D print head and execution of printing via the robotic arm ABB IRB 140. In: ICIEA 2018. - Danvers : IEEE, 2018 P. 194-198. - ISBN 978-153865747-8
[17] Orosz, T. (2019) "Evolution and Modern Approaches of the Power Transformer Cost Optimization Methods", Periodica Polytechnica Electrical Engineering and Computer Science, 63(1), pp. 37-50. doi: https://doi.org/10.3311/PPee.13000.
[18] https://www.businessinfo.cz/en/articles/pilsen-region-7953.html
[19] ModSecurity IDMEF Module, By: Balaz, Anton; Adam, Norbert; Pietrikova, Emilia; et al. Conference: IEEE 16th World Symposium on Applied Machine Intelligence and Informatics (SAMI) Dedicated to the Memory of Pioneer of Robotics Antal (Tony) K. Bejczy Location: Kosice, SLOVAKIA Date: FEB 07-10, 2018 Sponsor(s): IEEE 2018 IEEE 16TH WORLD SYMPOSIUM ON APPLIED MACHINE INTELLIGENCE AND INFORMATICS (SAMI 2018): DEDICATED TO THE MEMORY OF PIONEER OF ROBOTICS ANTAL (TONY) K. BEJCZY Pages: 43-48 Published: 2018
[20] Potential of Low Cost Motion Sensors Compared to Programming Environments By: Mihal'ov, Juraj; Pietrikova, Emilia; Balaz, Anton; et al. ACTA POLYTECHNICA HUNGARICA Volume: 15 Issue: 6 Pages: 155-177 Published: 2018
[21]Broum, T., Simon, M.: Preparation of Collaborative Robot Implementation in the Czech Republic, Proceedings of the International Conference on Industrial Engineering and Operations Management Pilsen, Czech Republic, July 23-26, 2019
[22] Simon, M. and Broum, T. (2018). Layout Calculations Related to Product Insourcing. Proceedings of the 29th International DAAAM Symposium 2018, pp.0312-0318.