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Process planning in Industry 4.0 environment

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Abstract

Over the past few years world is facing the fourth industrial revolution. Working environment is demanded to be changed, rapidly, with hope that it will bring significant benefits in the future. Usual manufacturing processes are being automatized and connected to other activities within the company. One of the most important factors in Industry 4.0 environment is data management, big data management to be correct. It is done with use of cyber-physical systems (CPS), internet of things (IoT) and cloud computing. Human professions are obligated to adapt and change so the roles that are known are suggested to get a different structure in the future. Workers have to learn to deal with new situation and accept the term of life-learning process, constantly improving their performance. In the end, with use of both technological and human improvements, bigger productivity, product quality and income with lower product delivery (manufacturing) time and product price are expected. Apart from that, the term of mass customization has become very important and that demands very flexible manufacturing.
This paper will deal with change the role of process planner who will be presented as "product planner" in the environment of Industry 4.0. Product planner is not only new profession, but is the name of software that is being connected to other parts of supply chain and uses advanced optimization algorithms to generate process plan, order of operations and scheduling automatically. The idea and structure of "product planning software" will be presented, as a completely new approach to process planning, operation sequencing and scheduling.

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Keywords: industry 4.0; process planning; decision support; data management; lean manufacturing; scheduling; product planning

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1. Introduction

Industry 4.0 has brought many professions to change. People are obligated to learn new everyday tasks, but also to use hi-tech gadgets which are to become most important factor of their work [1]. Also, they have to rely on the data given by the machine, but also to be sure that the data is correct. With faster processes, they have to handle bigger amount of data and to make decisions from it, but also to make the predictive analysis [2].

This may seem as easy thing to young working force in developed countries, but when it comes to countries in transition, working force is slightly older and not familiar with new technologies available [3]. The education process is then longer and the resistance stronger [4]. One of those professions is a process planner that gets another dimension with coming of Industry 4.0. With implementation of Industry 4.0 concept, most of the working environment gets automatized with Cyber-physical systems and Internet of Things with data is being processed online using cloud computing [5]. Machine-machine communication is required, so the human is getting eliminated from some crucial parts of production process. Can process planning be completely automatized? What are demands for automatization and can knowledge of the human transport to future product? The decision making for primary process selection, operation sequencing and scheduling should be automatized and the knowledge of it should be imported in a system that could plan the process and do the scheduling based on the CAD and CAM model of future product and order from the customer as well. This is the new role and environment of a process planner in the Industry 4.0 that should be achieved. It is a continuous path from CAPP, implementation of artificial intelligence in process planning [6]. In the first phase of the research in this field the process planning in Industry 4.0 environment will be explored and presented and linked to previous similar achievements and approaches like CAPP that is the part of CIM. The future phases will be devoted to development of single parts of "Product planning" software.

2. Current process planning vs. Industry 4.0

Standard, traditional process planning, in some SMEs in Croatia is based just on the knowledge and experience of a single person or the team of co-workers. Those are technology experts not by the education but more of the experience. They are educated by traditional approach without the concept of life-long learning and without use of modern systems like CAPP. This only illustrates the basic situation and big obstacles one could face with implementing Industry 4.0 in such company, because those kinds of people are hard to be convinced in the obvious need for change [7]. The resistance gets bigger when it demands big initial investments in new equipment and digitalization process.

Since the demand for a change exists, existing solutions with characteristics of Industry 4.0 should be considered and reviewed. Industry 4.0 has been presented as an overall change by digitalization and automatization of every part of the company, as well as the manufacturing process. Very soon big international companies that use concepts of continuous improvement and have high standards for research and development will accept concept of Industry 4.0 and make themselves even more competitive on the market. SMEs with lower state of development will be left even more behind and couldn't keep up with the changes and demands of the market. That is why it is very important for them to develop their own strategy for Industry 4.0 implementation on time.

New integrative in factory is that all manufacturing resources are being connected to data and information exchange with constant quality and process control. Also, Industry 4.0 has an effect on company's business network and hi-tech communication with customers and suppliers [8]. Products are becoming so called "smart products" that carry the information and knowledge and are able to bring feedback from user/customer back to manufacturing system which is being analyzed and optimized with help of this data. Customers, as the center of the attention for every manufacturing company are able to be part of the process and to create customized products and give the suggestions easily and effectively [9]. Scheduling of the product manufacturing and in whole supply chain in environment of Industry 4.0 is being suggested to be resolved with dynamic scheduling with help of Structure Dynamics Control (SDC) approach. Still, it hasn't been concluded what is the optimal volume of information services needed to ensure operation of physical systems and how these services shall be scheduled at the planning stage and rescheduled in dynamics at the execution control stage [10]. Process planning has so far being digitalized only in a case of the single existing technology – spot welding. Data and knowledge has been transformed to software that makes a decision based on specific input of material combination and technical specification of the order given [11]. This is acceptable when there is only one technology process, but what would happen if the

company manufactures various products that require various production technologies? The basic principle could be used but when data gets bigger and processes more complicated, can this also be solved on the similar way? Manufacturing process is to become cloud manufacturing because of the constant virtualization. So far the hardware part was the only thing used, but now the importance of communication network and even the virtual reality is very significant [12]. This leads to the term of the "smart product" that has so far being presented as the useful tool to get proper customer feedback [13], but can the product carry the knowledge and decide about the process planning and scheduling stage? This is very interesting topic and state for the future research, continuing to CAPP foundation.

2.1. Product planning software – link between smart product and main system (ERP)

Since products have so far been used in term of "smart products" to include information about customer's customization demands and use feedback, the idea is to spread the use of data "smart product" collects for a use in automatized knowledge databases so the three main phases between product's design and development and manufacturing process. Those are process planning, operation sequencing and scheduling.

After the stage of product development the technology with parameters equipped must be defined. Process planning automatization has already been done with use of CAPP (although it has many limitations and problems that users are facing), as a link between CAD and CAM [14]. With growth of popularity of Mass Customization, variant CAPP could be used, but the trends from the technical point of view, generative approach to CAPP is the one to be used in this case. The goal of generative approach is to get a new process plan for a single product based on data received from knowledge database [15]. The same database can be used for operation sequencing and scheduling what brings to wider use of CAPP in the terms of Industry 4.0. The special code to define technology needed generates by the CAD model. The new, customized system is to define the code with STEP model so the use of specific 3D modeling software makes no boundaries in the process. Software that uses generative CAPP is already developed and being used, but Industry 4.0 demands upgrade of the software and linking to collaborate with other parts of the manufacturing process and supply chain. CAPP software is here just a part of "Product planning" software that includes actions required for process planning, operation sequencing and scheduling but is also linked to product design phase in earlier stage and manufacturing process with exploitation in further stage (Figure 1).

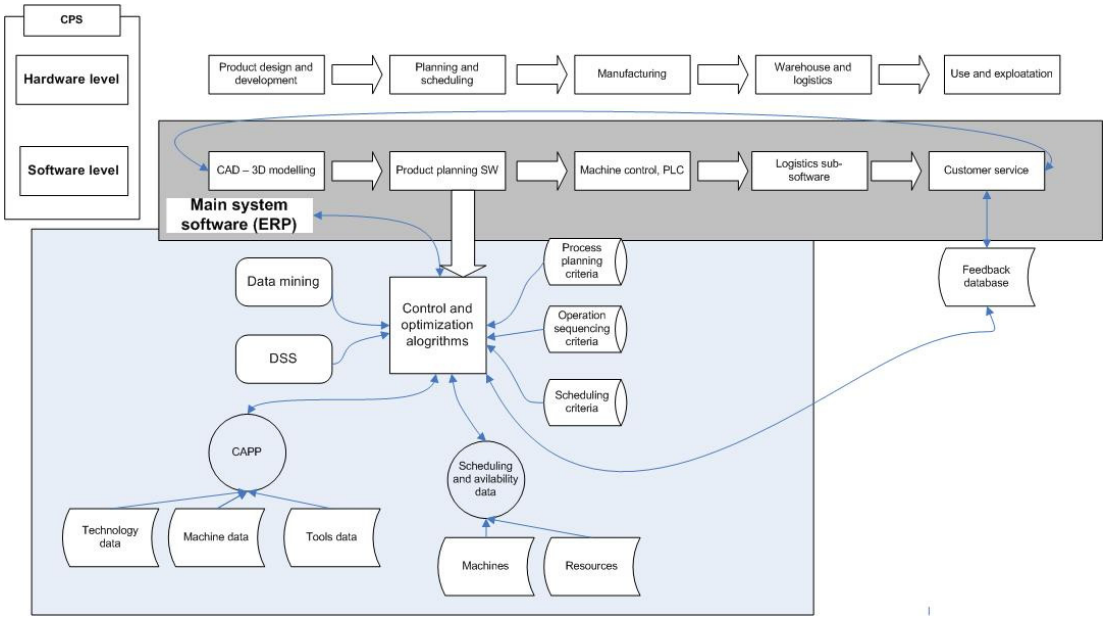

Fig. 1. Product planning software - schema with its connections

On the other hand, several control mechanisms should also be implemented in the process so that virtual system could be aware of the limits of the existing system. Advanced mathematical models and algorithms allow the recognition of the surfaces and special geometrical features of the product in order to plan the process. Calculation of preparatory, auxiliary and technological time can be defined by using this data and suggestion of the tools and machines needed. Control mechanism implemented in "Product planning" software consists of several criteria (Figure 2) that generates the feedback and sends information to general system to make the manufacturing schedule or to optimize the process if the given information is not able to be processed in the further stage.

In the Figure 1 the system hierarchy is shown. In the very core is the CAPP that generates the process plan, operation sequencing and scheduling by collecting data from existing databases and CAD model information. CAPP is being controlled by Product Planning software that generates the final manufacturing plan by getting the solution from CAPP and its validation through criteria shown in Figure 2 as control mechanism. Product planning software is linked to the general system software (ERP) based in the cloud. It connects "Product planning" phase to other phases of product lifecycle. Main system collects the data from various parts of the company, starting from the product design and development to customer feedback. Data once received and sent to Product planning software becomes the information that is then being transformed into knowledge needed to optimize the three phases in product lifecycle that are in Industry 4.0 environment closely connected and being considered as one.

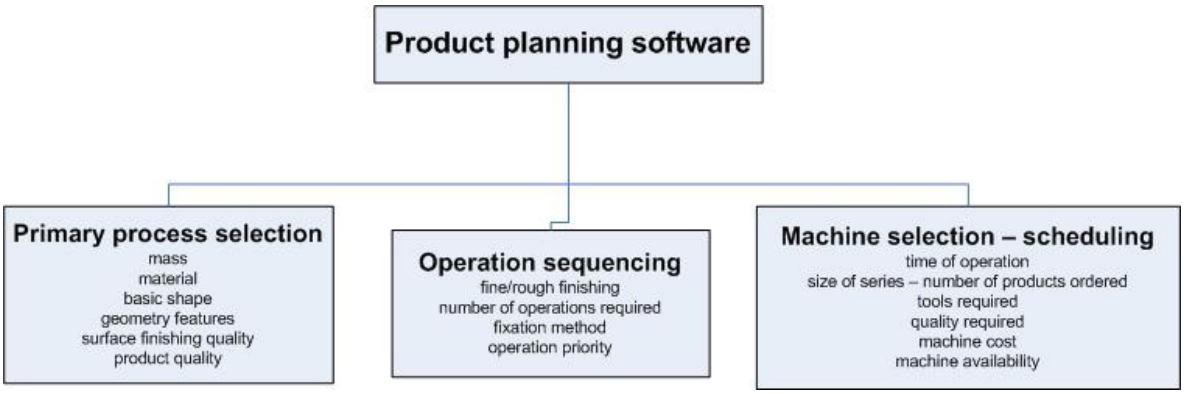

Fig. 2. Product planning software – control and optimization criteria

Figure 2 shows criteria tree included in Product planning software. First group of criteria are to control the process plan to be made. Software includes all limitations of the hardware system with data collected from the other parts of supply chain with organizational purpose.

Main process planning criteria are the product mass and material. The mass is not related only to the machining features but the logistics features and material manipulation in the manufacturing process. It includes the limits of the possible vehicles inside the hall or human transport and their limitations. Since this is Industry 4.0 environment, mass limitations can be related to limitations of the robots and manipulators that are included in transportation of the raw material from the supplier or warehouse but also the units for transportation of the final product to the warehouse with its own limits for product storing. Material as the criterion is related mostly to the machining process but also material specification is being controlled in the supplier's network and the availability and price with delivery time are being calculated and controlled, among others. Basic shape criterion simplifies the archiving process and comparison with previous orders so the continuous optimization can be made with every new order received. Geometry features criterion controls the possibility of the machines and tools available to make requested geometry features, while surface finishing quality does the same but with addition of cost and benefit calculation. Product quality criterion summarizes the effect and output received from the previous criterion and relates it to current archive with customer feedback in order to set the optimal quality of the product and do the cost analysis.

Second group of criteria are the operation sequencing criteria. Many different criteria influence the order of operations to be performed in manufacturing process, but the product planning software controls and deals with most important ones. First one is the control of fine/rough finishing operation. The eliminating factor is that rough

operation must be performed before finishing operations. This is also technical limitation that sounds trivial but when the whole process is being performed automatically, this must be controlled to eliminate possibility of waste that is not necessary. Number of operations required is criterion that compares the process and sequencing. Same technology can be used in different operations so the control should be made that one follows another with the link to following criterion and that is fixation method. Different fixation method requires piece manipulation between two operations. Optimization and control enables and improves the performance, increases the productivity, shortens the auxiliary times and decreases the costs. In the very end of the operation sequencing definition, final order gets set with operation priority criterion. One operation can demand to be performed before another because of the possible geometrical requirements or organizational requirements which are again recognized by information exchange between CAPP and general system software.

Third group of criteria are the scheduling criteria. Apart from time component, scheduling in product planning software includes machine selection that is closely related to available capacity of manufacturing system. The system itself leads product to decide on which machine previously defined operations will be performed. First criterion controlled is time of operation which includes preparatory time, auxiliary time and technological time. Calculation gives results of overall time for series of ordered product and final amount of products which is the next criterion. Those are linked together because of the optimization of the machines in use and the decision is made in progress, this can be called “just in time scheduling”. If the company has different machines that can perform the same operation product planning system has information about availability in the real time so it can lead certain amount of products to available machines. Alternative machines are selected by the tools available and performance required. By using advanced algorithms, software enables to calculate the optimal routes of inter transport and enables to perform the manufacturing process with the goal of lowest cost, or shortest time, depending on the situation needed.

The demands on product planning software are high, as a link between general system and CAPP, it planned to recognize and analyze different data process it in real time to do get the results needed for performance of physical manufacturing, but also to generate knowledge for the continuous improvement and optimization of the process. Roughly explained, it compares the data to limitations of the criteria, but their task is also to generate the importance of the criteria in various situations. Two methods can be used to build this software in practice. First one is predictive analysis using data mining. With many data available it can create the performance patterns and recognize the errors so it can predict the behavior (methods) used in the upcoming cases. Second one is the use of decision support system that gives different importance to criteria and by that it gives a solution as a final decision. The optimal in the practical use would be combination of both – use of data mining to process big amount of data and use of decision support system to generate different importance of the criteria with predictive analysis recognizing in which case certain criteria should be more important than another.

3. Implementation possibilities

The new environment that demands drastic changes has been explored and completely new term and process planning procedure has been defined and expected to be completely implemented to companies that will decide to follow the Industry 4.0 concept. Current state of the project of process planning transformation will be led by practical implementation and building of appropriate software to execute required actions. Before implementing the new approach, the readiness factor is about to be calculated. Companies that aren’t ready for Industry 4.0 demand radical changes with high investment cost. After readiness factor is being calculated, the depth of changes has to be defined along with project phases. Implementation can’t happen overnight so the new companies that are about to be planned and built have great advantage. CPS can then be planned from the very beginning so the product planning software can be planned for the specific situation as well. The general model of the software could be built, but it is advised it to be open source so the users could easily define it by their own needs. System security is also part of the further research because cloud platforms enable access to many different users. The knowledge inside the system must be kept as company’s intellectual property because it is the main factor for the process optimization that results in bigger income in the very end.

Product planning software would be the part of the new, main system software that can be related to current ERP system that company is using. It is closely connected to cloud computing/internet of thing concept that allows big data manipulation in real time and as well as machine to machine communication which is important for this software to function properly. Regarding its technical structure, it makes no problem for it to be implemented as part of the main system software because the demands are only to collect data from certain databases and analyze it to make further decisions. The problem is in the knowelege that stands behind product planning software. It has to be specialized for certain company by their own criteria within the working environment. This is why the creation and development phase will take much longer time than implementation phase. Software should be important part of company's intellectual property and can be easily used as advantage on the competitive market.

4. Conclusion

Industry 4.0 is the concept that every company to be built should accept from the very beginning. Complete system automatization and use of advanced technologies, internet of things and big data analysis minimizes the human factor in the process but also it changes professions inside the company as we know them today. One of the professions to be changed is the process planner. Since every aspect is being automatized, the process planning also has to be automatized and linked to other parts of the supply chain and manufacturing process. In the first phase of research the general idea of the change is given. It requires unification of process planning, operation sequencing and scheduling in one. That is the "product planning" phase with same-titled software as a link, control and optimization mechanism between CAPP with appropriate databases and ERP system, general software of the company. Automatically it creates process plan with exact order of operations after which it decides where the product will be produced among machines and tools available. The "smart product" carries the knowledge that is being used in the further manufacturing and exploitation process. To make optimal decisions product planning software uses predictive analysis like data mining combined with decision support system. The further research will be focused on the practical realization of the software. This opens many possibilities and makes big project to be realized in detail both in theory and practice. First path is the definition of the hardware needed and its connection to the product planning software. Second path is the programming of the software and possibility of modification by the requests of a various companies. Third path to be explored is in CAPP itself, the concept that has been known for several decades now, but now is time to test it in Industry 4.0 environment with algorithms available today and software that is able to do calculations faster than before. Fourth path is the research the link between data mining and decision support systems to make the product planning software more efficient with definition of data to be collected from other parts of supply chain and phases in product's lifecycle.

References

[1] Grecky D et al. Human-machine-interaction in the industry 4.0 era. 2014 12th IEEE International Conference on Industrial Informatics (INDIN) 2014.

[2] Waller M, Fawcett S. Data Science, Predictive Analytics, and Big Data: A Revolution That Will Transform Supply Chain Design and Management. Journal of Business Logistics 2013;34;2:77-84.

[3] Mason A, Lee R. Reform and support systems for the elderly in developing countries: capturing the second demographic dividend. Genus 2006;62;2:11-35

[4] Lines B et al. Overcoming resistance to change in engineering and construction: Change management factors for owner organizations. International Journal Of Project Management 2015;33;5: 1170-1179.

[5] Wang S et al. Towards smart factory for industry 4.0: a self-organized multi-agent system with big data based feedback and coordination. Computer Networks 2016; 101;4:158-168

[6] Integration of CAD/CAPP/CAM/CNC to Augment the Efficiency of CIM. Innovative Trends in Mechanical, Material, Manufacturing, Automotive, Automobile and Aeronautical Engineering, Delhi 2014;4;2:171-176.

[7] Cummings T, Worley C. Organization development and change. Cengage Learning 2014.

[8] Brettel M et al. How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective. International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering 2014;8;1.

[9] Qin J, Liu Y, Grosvenor R. A Categorical Framework of Manufacturing for Industry 4.0 and Beyond. The Sixth International Conference on Changeable, Agile, Reconfigurable and Virtual Production. Procedia CIRP 2016;52:179-179.

[10] Ivandov D, Sokolov B, Ivanova M. Schedule Coordination in cyber-physical supply networks industry 4.0. 8th IFAC Conference on Manufacturing Modelling, Management and Control MIM 2016 — Troyes, France. IFAC-PapersOnLine 2016;49;12:839-844.

[11] Andersson O et al. Digitalization of process planning of spot welding in body-in-white. 26th CIRP Design Conference, Procedia CIRP 2016;50:618-623.
[12] Thames, L.; Schaefer, D.: Software-Defined Cloud Manufacturing for Industry 4.0. The Sixth International Conference on Changeable, Agile, Reconfigurable and Virtual Production (CARV2016). Procedia CIRP, Vol 52, 2016, 12-17
[13] Gibbert M, Leibold M, Probst G. Five Styles of Customer Knowledge Management, and How Smart Companies Use Them To Create Value. European Management Journal 2002;20;5:459-469.
[14] Engelke W. How to Integrate CAD/CAM Systems: Management and Technology. CRC Press 1987.
[15] Architecture Technology Corpor: Computer Aided Process Planning (CAPP): 2nd Edition. Elevier 2016.