Management of tools in digital manufacturing - A case study

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Abstract. The rapid market changes and strong product individualization create the need for great flexibility of manufacturing management on new foundations, such as the Industry 4.0 model. Digital manufacturing is the basis for Industry 4.0, which has the following dimensions: (a) digital manufacturing based on advanced digital-oriented technologies, (b) smart products (advanced manufacturing model and new characteristics), and (c) smart supply - chain of raw materials and delivery of finished products). Bidirectional exchange of information in collaborative manufacturing, using it exchange also for digital platforms of design of the innovative products. In this paper we are show developed model of Serbian digital factory of home cookware and appliance manufacturing for tools lifecycle management (TLM) in workshop for metal forming as a part of MES model.

Keywords: Digital manufacturing, Tools Management, MES.

1 Introductory remarks

Rapid changes in the market and strong personalization of products create the need for great flexibility of production management in the plant on a new basis, where the Industry 4.0 model provides good solutions to these challenges.

Smart Manufacturing (SM) is a fully networked collaborative technology system (CPS / CM) that has real-time feedback. It enables the fulfillment of changing requirements and conditions in the factory and workshop, customer needs and requirements in the supply chain. MES is the basis for industry 4.0 model management in real manufacturing at the workshop, because it forms the hub of the engineering (CAD / CAPP / CAM / CAI) and business (CRM / SCM / ERP) planning functions from which the wokshop production management model (MES) grows [1]. In this sense, for the Industry 4.0 model, the application of MES management modeling agents has been shown to be inadequate for industrial applications. At this level of development and application of IT in production, the solution is currently given as software-defined control (SDC) [1] . This model coexists with the applied architecture model ISA-95, where MES and ERP are mutually integrated and logically centralized, which is shown on the example of tool management in this paper.

2 Literature review

All activities of an organization that include defining tool needs (CAD / CAPP / ERP), procurement (SCM) or tool production (CAM / MES), tool use and maintenance (ERP / MES) and decommissioning (PDM / PLM), represents an integrated process of management of all types of tools in their lifetime, tool life management (TLM). The performed detailed analyzes show that the TLM has key connections with ERP, PLM and MES models in the organization [4], which is also true for our model, which is presented in this paper.

Digitization is the basis of Industry 4.0, and the same goes for TLM, as part of this concept. In order to implement the TLM Module Digitization Project in one organization, a model with nine criteria and three target functions (tool availability, minimum inventory and product quality) was developed [5]. The first criterion is used to assess the initial / reached level of the Project: beginner, defined project, project is implemented, the project is implemented and the project is improved. Thus, a matrix of the current state of application of the TLM model is made for each organization, which provides guidelines for further work on this Project. In our example, TLM includes the third (criteria: 1,2,4,8) and fourth phase (criteria: 3,5,6,7,9) digitization, so it is between these two levels.

In [6], a model for the management of cutting tools at the CPS level is presented. This is a specific manufacturing where extremely high quality products are required, so it is necessary to manage the tool for a typical product. A knowledge base system for tool management has been developed, which contains knowledge of: cutting tools, cutting modes, technological forms, ERP and MES data for connection with these systems. Our approach has the same logic, except that it is a tool for plastic deformation processing.

The application of RFID technology in the Industry 4.0 model is extremely important, and in [7] a case study was given for home appliance manufacturing , which is also our case. This technology must also be applied in the TLM model.

The MES module is a key element of the production planning and control model in the Industry 4.0 concept [8]. TLM is an integral part of the work order management subsystem (WO), and it is directly connected to the ERP system in our example.

ERP model and its functions in scheduling manufacturing in the home cookware and appliance manufacturing industry are presented in [9]. TLM is an integral part of this model, as is the case with our research.

One of the key elements of Industry 4.0 is IoT, which is also a composite element of TLM. In [10], the IoT model for h ome cookware and appliance manufacturing is presented, and this concept (IIoT) is also used in our research.

In real large-scale production such as home cookware and appliance manufacturing, one of the most important functions of ERP is the cloud orchestration service system [11]. In our research, this aspect has been applied at the process orchestration level (MES) of work order management (WO).

3 Digital manufacturing model in Metalac Company

Digital chain model and data flow in the company Metalac which is home cookware and appliance manufacturing, is realized through the model shown in Figure 1, which has a unique database (knowledge) of all business factors, updated on a daily basis - with the latest (current) versions of products and history of their changes [15].

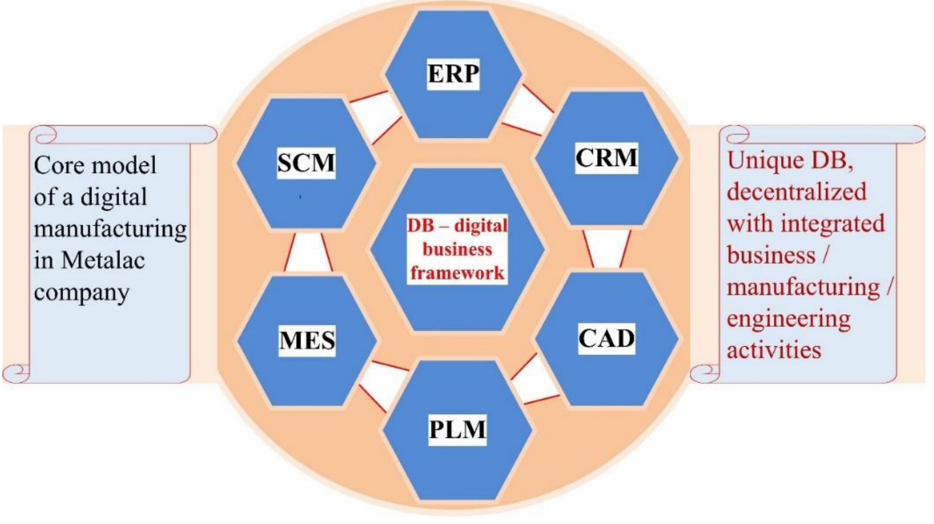


Fig.1. Digital model of Metalac company

How is a digital product chain established and functioning in this organization? Request for product offer - generated in the CRM module (customer relationship management), which after accepting the customer translates into a request for production and planning orders as part of the system - business information system (CRM module (purchase order / delivery note created directly in ERP) Thus, it becomes part of a single database system (DB), so the designer, based on standard dimensional parameters, automatically generates a standard CAD model (3D model of the product, components (structural, quantitative, modular)). CAD model, which includes: sequence of manufacturing operations + **extraction tools** + machines (3D machine model - digital twin) After CAM documentation, the system in the next phase generates CAQ (quality control plan for part, as part of ISO 9001 model). ERP forms a set of work order: degreasing sheet, enamel sheet, quality control sheet, calculates the cost of operation, forms a packing list, gives a plan of completion control. With the help of the SCM module, the procurement and quality control plan of input materials and raw materials are defined, thus forming a unique system of digital chain model for the product that will be produced in the planned quantity with a defined deadline, which is included in the unique business factor classification system. The PDM system is now in full application, and it is on the cloud, and now it is being expanded to a PLM system that would move from the product level at this time to the digital level of the production program, also to the cloud. Ensuring traceability and tracing errors is done backwards, through delivery requests and work orders, through ERP, because in it they are connected through levels (higher and lower). The MES system operates online, as a digital chain of production monitoring is provided. This means that the ERP system is monitored online, so the business plan is made on an annual basis, the production and delivery plan on a monthly basis and the term production plan on a weekly / daily basis.

4 Tool management model

Our focus in this paper is on tools for processing plastic deformation of sheet metal for the following operations: cutting, bending, extraction, deep extraction. This company has thousands of these tools in use, where more than 80% of them are related to cutting and deep extraction. This company manfacture these tools in the tool workshop, and within the digital model from Figure 1, and with the whole toll lifecycle management (TLM), Figure 2.

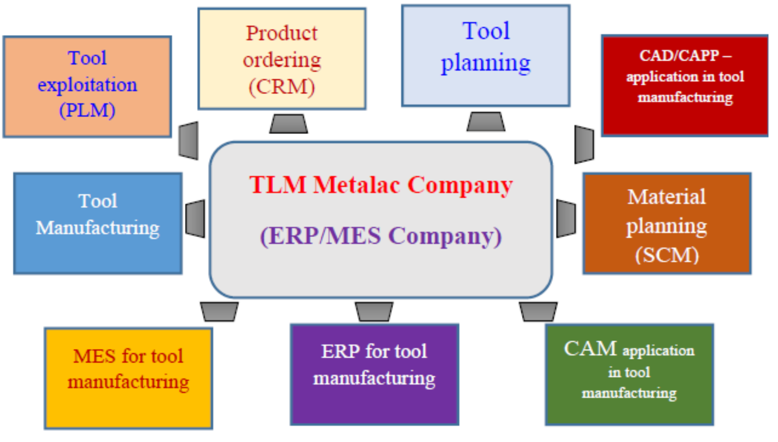


Fig. 2. TLM model in Metalac Company

The manufacturing of models and drawings of tools is done according to the product model, in machine technologies within the cookware factory, to which the tool workshop also belongs. Prototyping with 3D printing is checked through 3D simulations, using off-line digital twin. Solid works (CAD) and PDM are used for tool design, with 3D model generation, tracking and verification of changes. In the next step, these 3D models are taken over by the technology workshop tool designer (CAPP) and based on the approval, a work order (WO) is opened to create a specific tool in the ERP model. Necessary materials (SCM) are analyzed and procured, their quality control upon delivery and storage in the raw material warehouse, marked with a bar code. At the same time, the prices / costs per tool are updated based on the purchase price of the material. The term map (ERP scheduling) is now being completed, with deadlines. The CAM module defines the technology of tool making and completes the production work order in the tool workshop.

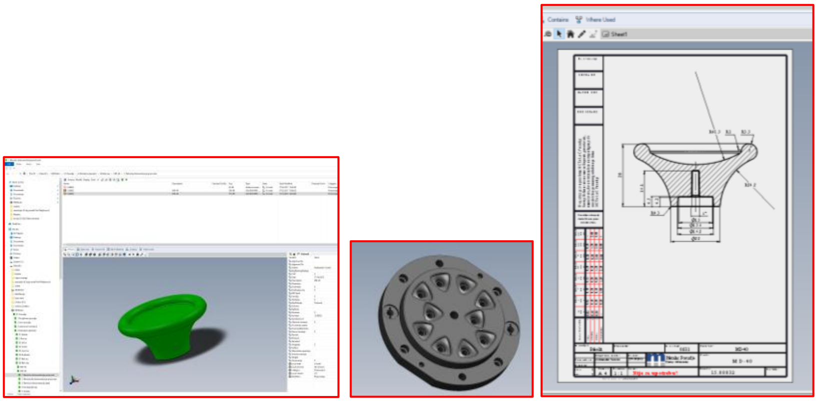
After the tool is made, tests and / or finishing are achieved until the final quality is achieved when the tool is handed over to the plastic deformation workshop (manufacturing of cookware). The service life of the tool is set, the period of inspection and maintenance of the tool based on the number of pieces made in it, which is added to the tool based on completed manufacturing orders (MES). Based on the need for tool service, a service order is opened in a tool workshop (initiated by manufacturing) for finishing, sharpening tools or repairs. In this way, the costs of tool maintenance are monitored individually (by tool), in groups (by tool type) or by workshop (manufacturing).

This structure of the TLM module in use at the beginning of the application (request for a new product) gives us the real state of the tool and its components and the traceability of all changes and refinements with the last valid state of the tool. Digital manufacturing has enabled us to make all tool parts from 3D models directly through the CAM modules of our machines in the tool workshop. In this way, we ensure the fastest delivery of products to our customers (CRM), manage the cost of tools in their lifetime and ensure the high quality of our products.

By connecting the TLM module with the ERP model, we monitor tools through: the number of pieces made, maintenance costs, reaching the tool life (planned / realized) and planning the development of new tools (expired expiration date of existing tools).

5 An example of TLM from company practice

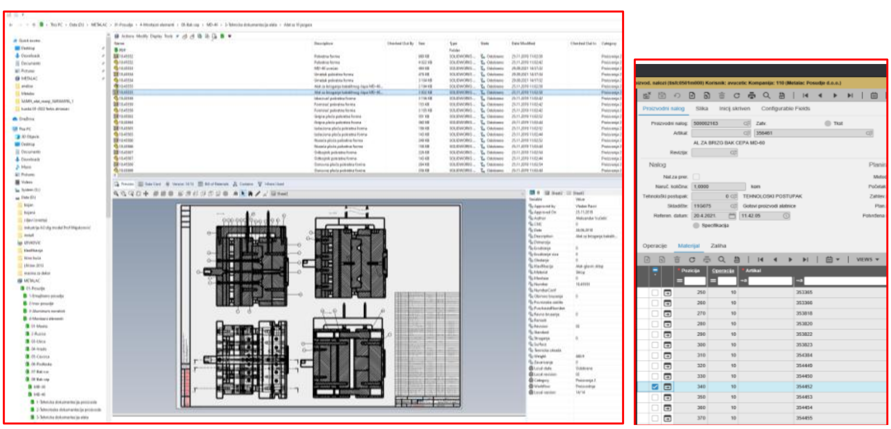
Engineering activities for the design of sheet metal processing tools begin with the design of the part to be made in it, Figure 3a, with drawing 3c. At the same time, the bottom plate (matrix) of the tool for this part 3b is designed. The obtained 3D model of the work defines the macro model of the tool, in accordance with the geometric shape of the work and the type of material from which the work is made.



3a) 3b) 3c)

Fig. 3. Part model (3a), bottom plate model (matrix) (3b) and part drawing (3c)

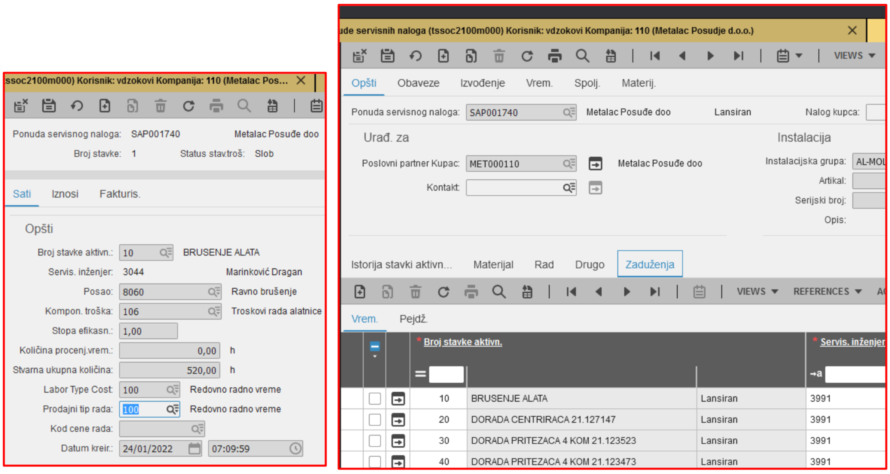
After this step, we move on to the TLM model and engineering design (CAD / PDM), using standard tool parts of steel plates, guides, pins, screws, breakers, sliders, insulation boards, heaters, Figure 4a. The output from the design are 3D tool models and the necessary technical drawings, as well as the structural component of the tool (EBOM).



4a) 4b)

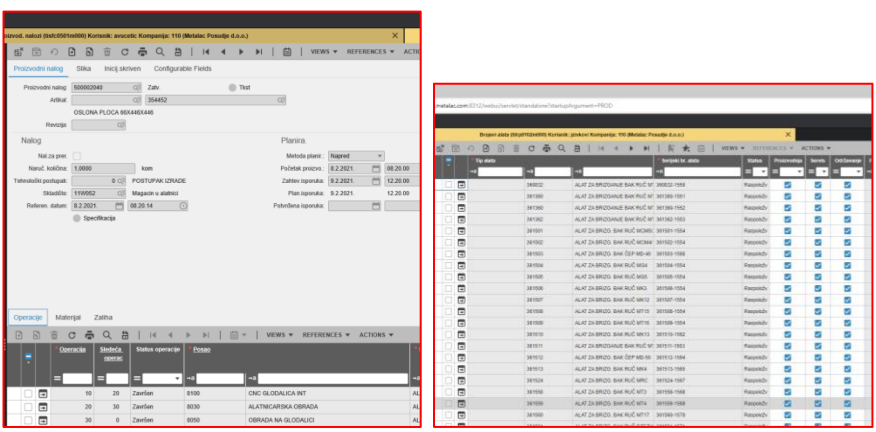
Fig. 4. Tool model (4a) and structure of sheet metal tool components (4b)

At this level we get all the geometric models, shapes and tolerances of the tool and its components, as an input to the design technology (CAPP / CAM) for him. This is done in the technology bureau tool workshop, Figure 5. This is how the technology component of the tool (MBOM) is created. The next step is to create a work order (WO) for the manufacturing of tools that provide us with the generated data on the prices of materials and time required for its production total costs and production time, thus defining the term plan of its production, Figure 6.



5a) 5b)

Fig. 5. Technological procedure of tool making - one operation (5a) and complete part (5b)



6a) 6b)

Fig. 6. Work order of tool production (6a) and term tool production map (6b)

After manufacturing, final control of production and assembly, the tool is assigned an identification-classification number, prescribes the service life and maintenance technology. All electronic documentation according to the ISO 9001 model (design and development) is generated on the cloud, then the tool carton is opened in electronic form and the operation phase begins, with online monitoring of tool operation via MES and ERP model of cookware.

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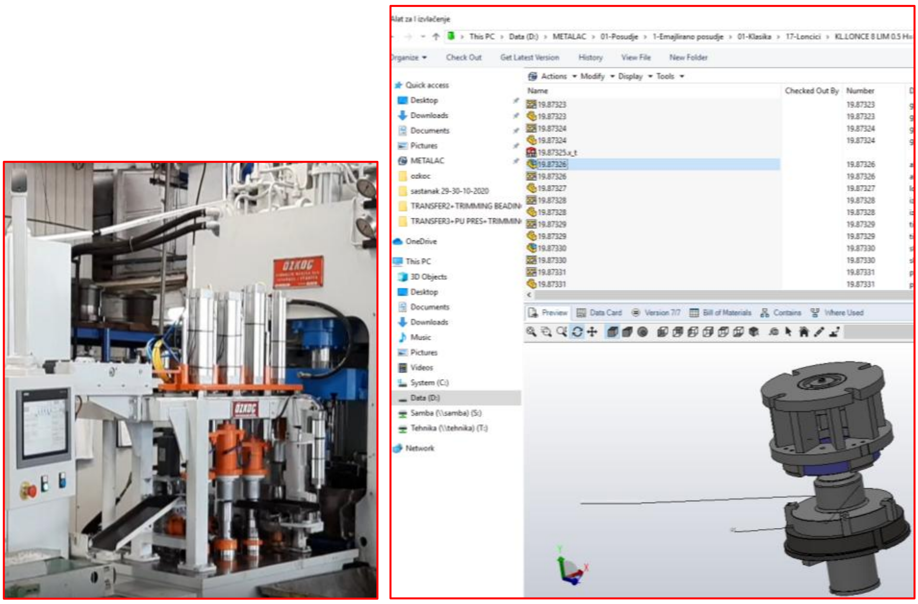
This factory has in its workshop several automatic machines for making products that work automatically and autonomously, such as CPS in CM environment. These machines (CPS) have multiplied productivity, and the quality of products on them has led to "zero defect". Figure 7 shows one CPS in operation and the tools used on it.



7a) 7b)

Fig. 7. CPS in the dishwashing plant and model of tools used on it (7b)

In this way, the tools in this organization (TLM) are managed, using the developed model from Figure 2, which enabled the implementation of the following: (a) reducing tool costs and increasing production quality, and (b) digitalization of this business segment of this company.

6 Conclusions and future research

Digitization has been applied in this company in all business segments (engineering and business). The elements of Industry 4.0 are now being implemented in the business-manufacturing and technological units, as follows: (a) CPS and digital model (twin off-line), Figure 8, (b) BDA analysis, for the area of maintenance and operation of tools, and (c) the same tool for optimizing tool making technology as utensils (especially the enamel thickness at the bottom of the cookware depending on the purpose of the cookware).

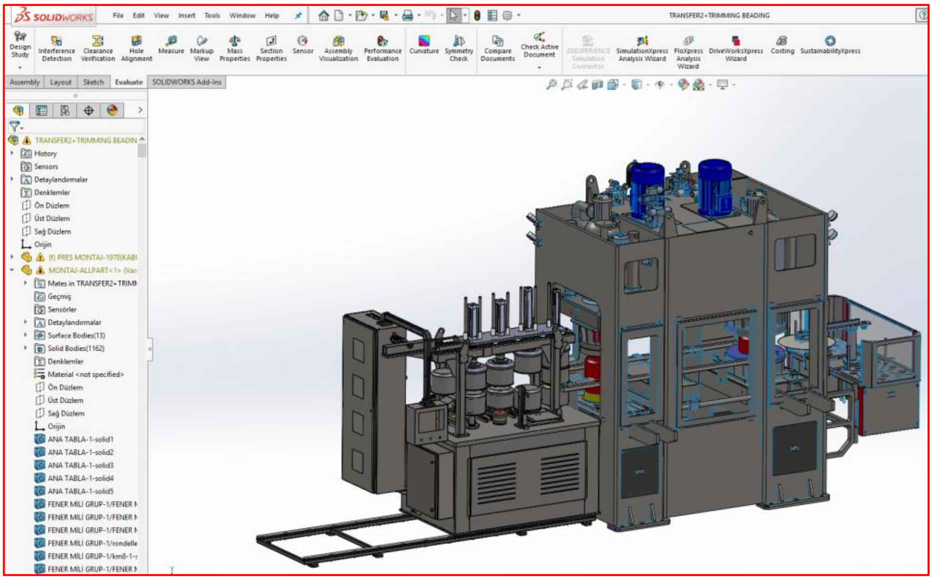


Fig. 8. Digital model (twin off-line) of CPS

Of particular importance is the project of online work order management (WO) using IoT [15], which is now being implemented and represents a further improvement of the digital ERP model in the manufacturing of cookware and tools.

References

[1]. Felipe Lopez, Yuru Shao, Mao Morley, James Moyne, Kira Barton, Dawn Tilbury, A software-defined framework for the integrated management of smart manufacturing systems, Manufacturing Letters, Volume 15, Part A, January 2018, Pages 18-21, https ://doi.org/10.1016/j.mfglet.2017.12.015 .
[2]. Alexandros Bousdekis, Dimitris Apostolou, Gregoris Mentzas, A human cyber physical system framework for operator 4.0 - artificial intelligence symbiosis, Manufacturing Letters, Volume 25, August 2020, Pages 10-15, https://doi.org/10.1016/j.mfglet .2020.06.001 .
[3]. Pai Zhenga, Abinav Sivabalanb, A generic tri-model-based approach for product-level digital twin development in a smart manufacturing environment, Robotics and Computer-Integrated Manufacturing, Volume 64, August 2020, https://doi.org/10.1016/ j.rcim.2020.101958 .
[4] Aneta Skowron **,** Tool Lifecycle Management in Industrial Practice **,** Management Systems in Production Engineering **,** 2015 **,** 2 (18) **,** 69 -75, www.doi: 10.12914 / MSPE-04-02-2015 .
[5]. Eva Schaupp, Eberhard Abele, Joachim Metternich, Potentials of digitalization in tool management, Procedia CIRP 63 (2017) 144 - 149, www.doi: 10.1016 / j.procir.2017.03.172 .

[6]. Ozbayrak M, De Souza RBR, Bell R. Design of a tool management system for a flexible machining facility. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture . 2001; 215 (3): 353-370. www.doi: 10.1243 / 0954405011515424 .

[7]. Zhiyuan Zhu, Jie Tan, He Ren, Wancheng Ni & Qiang Guan (2012) RFID application in manufacturing: A case study on a pilot RFID project in household appliance production, International Journal of Computer Integrated Manufacturing, 25: 1, 3-10, www.doi: 10.1080 / 0951192X.2010.512043 .

[8]. B. Saenz de Ugarte, A. Artiba & R. Pellerin (2009) Manufacturing execution system - a literature review, Production Planning & Control: The Management of Operations, 20: 6, 525-539, www.doi: 10.1080 / 09537280902938613 .

[9]. Nobuhiro Ishida, Toshiki Ishida, IoT-based Improvements in Home Appliance Manufacturing at Hitachi GLS, Hitachi Review Vol. 69, no. 1 90–98, 2020. https://www.hitachi.com/rev/archive/ 2020 / r2020_01 / 01a07 / index.html , last accessed 2022/04/25.

[10]. Shohin Aheleroff, Xun Xu, Yuqian Lu, Mauricio Aristizabal, Juan Pablo Velásquez, Benjamin Joa, Yesid Valencia, IoT-enabled smart appliances under industry 4.0: A case study, Advanced Engineering Informatics, Volume 43, 2020, https: // doi. org / 10.1016 / j.aei.2020.101043 .

[11]. Bufan Liu, Yingfeng Zhang, Geng Zhang, Pai Zheng, Edge-cloud orchestration driven industrial smart product-service systems solution design based on CPS and IIoT, Advanced Engineering Informatics, Volume 42, 2019, https://doi.org/10.1016/ j.aei.2019.100984 .

[12]. Serrenho, T., Bertoldi, P., Smart home and appliances: State of the art - Energy, Communications, Protocols, Standards , Publications Office of the European Union, Luxembourg, 2019, www.doi: 10.2760 / 453301 .

[13]. Bressanelli, G .; Saccani, N .; Perona, M.; Baccanelli, I. Towards Circular Economy in the Household Appliance Industry: An Overview of Cases . Resources 2020 , *9* , 128. https://doi.org/10.3390/resources 9110128 .

[14]. Pedro Daniel, Urbina Coronado, Roby Lynn, Wafa Louhichi, Mahmoud Parto, Ethan Wescoat, Thomas Kurfess, Part data integration in the Shop Floor Digital Twin: Mobile and cloud technologies to enable a manufacturing execution system, Journal of Manufacturing Systems, Volume 48, Part C, July 2018, Pages 25-33, https://doi.org/10.1016/j.jmsy.2018.02.002 .

[15]. Vojin Vukadinovic, Vidosav Majstorovic, Jovan Zivkovic, Slavenko Stojadinovic, Dragan Djurdjanovic, Digital Manufacturing as a basis for the development of the Industry 4.0 model, Procedia CIRP, Volume 104 , 2021, Pages 1867-1872. www.doi: 10.1016 / j.procir.2021.11.315.