



Available online at www.sciencedirect.com



Procedia MANUFACTURING

Procedia Manufacturing 54 (2021) 52-57

www.elsevier.com/locate/procedia

10th CIRP Sponsored Conference on Digital Enterprise Technologies (DET 2020) – Digital Technologies as Enablers of Industrial Competitiveness and Sustainability

Digital Manufacturing in SMEs based on the Context of the Industry 4.0 framework – one approach

Vidosav Majstorovic^a, Goran Jankovic^b, Srdjan Zivkov^c, Slavenko Stojadinovic^{a,*}

^aUniversity of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia ^bInmold, Pozega, Serbia, ^cSolfins, Belgrade, Serbia.

* Corresponding author. Tel.: + 381 11 33 02 407; fax: +381 11 33 70 364. E-mail address: sstojadinovic@mas.bg.ac.rs

Abstract

Serbia is rapidly working on the development and implementation of digital manufacturing models in SMEs, through the national Industry 4.0 Platform. The aim is to create a pilot intelligent workshop which would be used to develop and showcase examples of best practice for digital manufacturing. Currently, most SMEs use CAD, CAM, ERP models, which form the basis for the development of the concept of digital manufacturing through cloud computing, BDA, IIoT and smart supply-chains, as elements of Industry 4.0. This paper gives a practical example of an SME with all the above-mentioned elements of digital manufacturing.

© 2021 The Authors. Published by Elsevier B.V.

This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/) Peer-review under responsibility of the scientific committee of the 10th CIRP Sponsored Conference on Digital Enterprise Technologies (DET 2020) – Digital Technologies as Enablers of Industrial Competitiveness and Sustainability.

Keywords: Digital manufacturing, SME, case study.

1. Introduction and motivation

Industry 4.0 (I4.0) is a advanced model of automation of manufacturing systems, based on the connection and decentralized control of cyber-physical systems (CPS), using the Internet of Things (IoT) and support by cloud computing and artificial intelligence (AI) [1,2, 6]. I4.0 is a German manufacturing strategic initiative, aimed at the development of smart factories (SF), based on digital manufacturing (DM), which includes elements of I4.0. The aim of this paper is to show how a small and medium size enterprise (SME) in Serbia, develops and applies the concept of DM, as a basis for the application of the Industry 4.0 model in its business. The above example can be a good scenario for other SMEs in Serbia from the same industry, how to implement Project I4.0 in their environment. This paper has several sections: (i) how to start with digital production as a basis, apply the concept of

I4.0 for SMEs, (ii) set the DM model for a specific SME, (iii) example of application for SMEs, with discussion and (iv) conclusions and future research.

2. Related works - literature review

The CPSs are one of key factory components based on the I4.0 concept. They are characterized by local information processing, autonomy but also network connection, in order to transfer information from it and use information from the for environment monitoring and control (PLCs (programmable logic controllers), SCADA (supervisory control and data acquisition), MES (manufacturing execution system), ERP (enterprise resource planning)) of the cyber physical production (CPM) [1]. For our research, presented in this paper, the concept of CPM for SMEs is important, for which a case study was done.

^{2351-9789 © 2021} The Authors. Published by Elsevier B.V.

This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)

Peer-review under responsibility of the scientific committee of the 10th CIRP Sponsored Conference on Digital Enterprise Technologies (DET 2020) – Digital Technologies as Enablers of Industrial Competitiveness and Sustainability. 10.1016/j.promfg.2021.07.009

A particularly important segment of the I4.0 application is for SMEs, where we have a new model of automation of technological systems, such as cloud manufacturing (CM). It optimizes the use of hardware / software support for: design and production of the intelligent products based on information technology (IT), automated and flexible connection of the production chains and their generation and interaction through new services and business models [2]. In our research, a model of automatic updating of engineeringproduction documentation (EBOM / MBOM) and plantproduction documentation (ERP) is presented. These two units are interconnected through the manufacturing execution system (MES).

One of the important elements of the I4.0 in practice is the optimization and use of big data analytics (BDA), using artificial intelligence (AI) techniques and machine learning algorithms (ML) [3]. For the field of the production, which is the topic of this paper, ERP (especially intelligent scheduling) and predictive maintenance are the units where this concept is

most applied, and some examples for the field of the ERP are given in this paper.

A particularly important segment of the application of DM in SMEs is the real-time work order management (MES) [4,5,9]. The essence is to get feedback information from the plant on the status of work order elements (MES), which in this model is achieved using the Digital Shadows (DS) model. The DS is a DM with one additional automated flow of information between the state of an existing physical object and a digital model, which means that, if the state of a physical object changes, then the state of the digital object automatically changes, but not vice versa [13]. In our case study, a MES model for SMEs is given.

The DM in SMEs are characterized by limited resources (which can be compensated through the CM model), as well as the diversity of customer requirements, which leads to a disproportionate complexity of the management systems and rapid response to these requirements [8]. For these reasons, it is necessary to take into account the stated characteristics when developing the DM model for SMEs, Table 1.

Characteristics	Manufacturing system (conventional)	Digital manufacturing (DM)	DM in SMEs
Decision-making unit number	Multiple units	Multiple units	Limited
Units association relation	Normative and long-term	Dynamic association	Dynamic association
Responsivity	Low responsivity	High responsivity	Very high responsivity
Control precision	Low control precision	High control precision	Very high control precision
Decision method	All in one decision	Distributed decision	Distributed decision
Optimize target	Local control and optimization	Global control and optimization	Global control and optimization

Table 1. The specific differences between various manufacturing system models (adapted from [8])

One of the most important stages of the digital transformation of an SME is the transition to a new business model of information system (ISs), whose framework is the I4.0 model, which was done in our example in the case study. The reengineering process (BPR), from the existing information system, which is characterized by: (i) lack of complete information, (ii) meet limited business needs, and (iii) lack of integration and business intelligence, static of the data and unused of it; the transition to an intelligent business information system, characterized by: (i) autonomous operation and hierarchical networking, (ii) dynamic data structure and their simulation for online operation, digital twin and digital shadow, and (iii) self-optimization (BDA).

A model of the DM information system for SMEs is shown in Figure 1 [10].

In [10] it is stated that modern platforms for the development of enterprise information systems (EIS), such as Industry 4.0, can be a good approach for enterprise development? How? Using social networks, for example, customers define their requirements online, and the company should be ready to satisfy them, preferably immediately or as soon as possible. For that, he needs a new platform for EIS, and our research and example in this paper are on the way to such approaches.

The key elements of ISs in DM model for SMEs are [11,12]: (i) value creation. It is the driving force for the different stakeholders, that make on the core value added business process (innovation in design, planning, or/and manufacturing); (ii) information flows and business process

connecting. The SMEs have to monitor the logical structure and flow of business information (request - acceptance design - planning - production and delivery), through their integration, unambiguity and knowledge creation. But here the importance of interoperability must be emphasized, which is the most important element of this model, which in the DM model, i.e. 14.0, have to be realized; (iii) functional structure. The functional structure is the main form of ISs, based on an advanced management method, the functional structure resolves the enterprise operation management (integrates subinformation systems, and on the functional needs of the department and the cross sectors), and (iv) knowledge management and data stream.

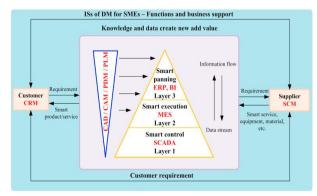


Figure 1. Framework of ISs in DM model for SMSs (adopted from [10])

A production in SMEs is faced daily with the creation of new knowledge, which arises from individual customer requirements for the product. The knowledge are: factual knowledge, conceptual knowledge, procedural knowledge, and metacognitive knowledge, so its processing and use is an imperative of this concept, because it is the basis for the development of SMEs. It is generated from a unique database, from data from the past and present.

This example also provided a framework for the development of our DM for SMEs, which was presented as case study.

In [9] the general framework of the NIST-defined smart manufacturing model is presented, which makes up the DM infrastructure that can be applied to SMEs, Figure 2 [9].

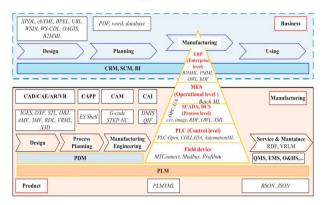


Figure 2. DM framework supports various data formats (adopted from [9]).

The general structure starts from three units, which can be recognized in conventional technological systems: (i) business (sales (CRM), procurement (SCM), general business functions (BI)), (ii) manufacturing, which includes engineering functions design (CAD / CAE / PDM), planning (CAPP / CAM / QMS / CAI), and production (with four levels of management (PLC, SCADA, MES and ERP), including maintenance and (iii) product, which integrates all digital lifetime information (PLM), including EOL (end of life). All three elements of this digital infrastructure are supported by different languages (XPDL, B2MML, LISP, PROLOG, ES Shell, ...) for modeling business and technological processes, and standardized formats (IGES, DXF, STL, ...) for data exchange in the digital platform that makes up the overall DM model.

The subsection 3.2 presents some examples of our research, which relate to previous considerations.

3. Problem description and model formulation

3.1. Basic framework

When we consider the detailed structure of the Industry 4.0 model, we can conclude that there are forty-five elements, which are applicable in large organizations. Our research shows that this model for SMEs in the field of manufacturing should have between fourteen and twenty-two elements depending on the type of manufacturing that SMEs are

engaged in. For the organization from the example in this paper, that number of elements is 22.

Our research shows that MES is a key element for the development of the DM model, as a basis for I4.0 in SMEs. In the context of I4.0, the framework, today's trends for development and implementation, as well as the functions of MES are [11,12,13]: (i) completion of the technicaltechnological information on the product (EBOM, MBOM), (ii) macro and micro production planning and scheduling (ERP), with their online monitoring and re-scheduling of work orders (records of lots, orders and resources), by applying the advanced optimization algorithms, (iii) collection and exchange of the production data, coordination and monitoring of the production quality compliance, at the CPS level, including QMS, EMS, ..., (iv) managing the resources required for all types of data, which are necessary to calculate the optimal production plan online. (v) monitoring and managing the content of the intranet at the plant level, (vi) coordinating vertical and horizontal integration in the CPM model, (vii) monitoring the efficiency of production, with visual and graphic exchange of information, (vii) predictive and corrective maintenance, monitoring and emergency management (viii) statistical analysis and synthesis of big data sets, with the provision of additional services based on them, and (ix) exchange of information with supply chains (SCM) and product life cycles (PLM).

3.2. Case study

As it following real examples of DM from SMEs are given, in the text that follows. How to establish and operate a digital chain in SMEs, which includes elements (Table 2) are most important.

Table 2. The elements a digital chain in SMEs

Design, construction - CAD, CAM, CAE, CAI CAD bill of parts, 3D model - BOM	
Manufacturing technology, 3D model, Simulation -	
CAM, CAI	DD1
CAD bill of parts, CAPP bill of parts - EBOM	PDM
Monitoring of the change process,	
Quality, Quality Control Plans, FMEA, Procedures	
Certification, regulation, traceability - QMS, EMS,	
Maintenance planning and management - AR / VR	
CAM bill of parts - MBOM	
Procurement and Supplier Management - SCM	
Customer Relationship Management - CRM	
Employee resource planning - HR	
Work order, Production planning and monitoring	
(scheduling) - ERP	mMES/
Inventory management, warehouse operations (materials, tools,)	
Packaging bill of parts	mERP
Delivered bill of parts	
Service management	
Monitoring of products in exploitation	
Accounting, finance	
necounting, interior	

The request for product offer is generated in the CRM (customer relationship management) module, after accepted by the customer translates into a request for production and planning orders as part of the system - business information system - Iss (CRM module (purchase order / delivery note created directly in ERP). Thus, it becomes part of a unique

database system (DB), so the designer, based on standard dimensional parameters of previous projects, automatically generates a typical or special CAD model (3D model of the part, component (structural, quantitative, modular)) - EBOM. In the next phase, the designer generates a typical CAM technology for the CAD model, which includes: the sequence of manufacturing operations + cutting tools, as well as cutting parameters + machine tools (3D machine model - digital twin) - MBOM. After the CAM documentation, the system in the next phase generates a CAQ (quality control plan for the part, as part of the ISO 9001 model). In the next step, mERP (mini ERP - for SMES) forms a set of work order: sheet of tools and fixture, sheet of heat treatment, sheet of quality control, calculates the costs in plant, gives the plan of final control. The SCM module defines the procurement and quality control plan of input materials and raw materials and thus forms a unique system of the digital chain model for the product that

will be made in the planned quantity with a defined deadline, which is included in an unique system of classification of the business factors. The PDM system is now in full application, which means that a system for product variants and projects has been established. It is possible to place it on the cloud. and it is possible to expand it to a PLM system that would at this moment move from the product level to the digital level of the production program, also to the cloud. The ensuring traceability and tracing errors is done backwards, through delivery requests and work orders, through mERP, because in it they are connected through levels (higher and lower). The MES system works online, because a digital chain of production monitoring is provided. This means that the mERP 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 basis, Figure 3.

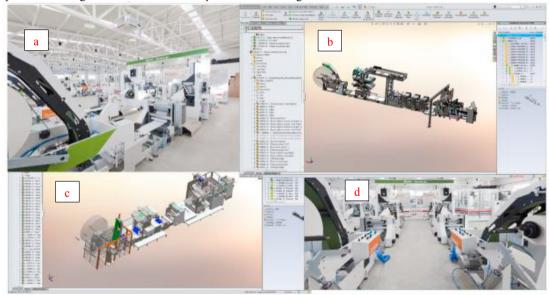


Figure 3. An example of PDM output for SMEs in the DM model - a) real machine in assembly and trial operation, b) 3D model - EBOM, c) digital twin machines, d) machine in exploitation - MES.

The following example is part of the mMES (mini MES for SMEs) module - MBOM technology component for parts of product from Figure 3, Figure 4.

Figure 4 shows a dialog box within which technological operations are defined with their order and execution times. All information is actually entered on a 3D model of the projected part or assembly. A characteristic of this approach is that this information is transmitted by copying 3D models, which significantly reduces the time of technology development in new constructions. This approach makes sense for companies that produce products to customer order or that configure products to market demand, where the product itself has a large number of components that are variable from project to project.

Although this approach can be used with simpler products with fewer parts being produced, in these situations it is not crucial for user productivity. An extremely important aspect of mMES is the online monitoring of all elements of the work order, Figure 5.

MES software automatically reads the information of approved items from the PDM / PLM system for the management of the construction and technological documentation (EBOM / MBOM) and it always contains the current version of the information needed in production.

MES software has two modes of operation, one is based on printed work orders where scanning the bar code of the technological operation initiates the process of monitoring production through a web application and second, if necessary, the process of recording control characteristics of parts based on prescribed AQL. The application also records information about the operators, machines, measuring and control accessories used for a specific item and a specific work order.

															Dec. or
 Check Out 	Get Latest Version	History View File New Folde	r												III •
	Name	ify • Display • Tools •	Materijal		Masa [kg]	StatusTPa		State		File Type		Checked Out By	0.1.10.11	Modified	ର୍ •
		Naziv		Tip pripremka		Status IPa					5 F 2 - 5	Checked Out By	Checked Out in		Category
	22 P009700	Pogonskii valjak zavarena kon	C0361	120000000000000000000000000000000000000	5.831			Odobreno			Drawing Document			12.10.2020 15:08:12	Tehnička dokumenta
	Sec. 1009700	Pogonskii valjak zavarena kon	C0361	Cev (okrugla)	5.831	Tehnologija ko		Odobreno		SOLIDWORKS				12.10.2020 15:08:12	Tehnička dokumenta
	2 P009701	gonjena remenica Z=42	C1531	1	3.926			Odobreno			Drawing Document			12.10.2020 15:08:14	Tehnička dokumenta
	Sp009701	gonjena remenica Z=42	Č1531	Sipka (okrugla)	3.926	Tehnologija ko		Odobreno	525.63 KB					12.10.2020 15:08:14	Tehnička dokument
	22 P009702	Nova osovina	C4732.4		5.088	200000000000000		Odobreno			Drawing Document			12.10.2020 15:08:14	Tehnička dokument
	P009702	Nova osovina	Č4732.4	Šipka (okrugla)	5.088	Tehnologija ko		Odobreno		SOLIDWORKS				12.10.2020 15:08:14	Tehnička dokument
	2009703	Zupčasta letva m=2mm	Č4732		0.315			Odobreno	496.84 KB		Drawing Document			12.10.2020 15:08:00	Tehnička dokument
	P009703	Zupčasta letva m=2mm	Č4732		0.315	Tehnologija ko		Odobreno	149.48 KB					12.10.2020 15:07:58	Tehnička dokumenta
	P009704	Pokrivka ruke	C0146		10.061			Odobreno			Drawing Document			12.10.2020 15:07:58	Tehnička dokument
	P009704	Pokrivka ruke	Č0146	Lim (flah)	10.061	Tehnologija ko		Odobreno	534.1 KB					12.10.2020 15:07:58	Tehnička dokument
	28 P009705	Stranica ruke	Č0361		16.318			Odobreno	589.93 KB		Drawing Document			12.10.2020 15:08:06	Tehnička dokument
	6 P009705	Stranica ruke	Č0361	Ploča	16.318	Tehnologija ko		Odobreno		SOLIDWORKS				12.10.2020 15:08:06	Tehnička dokument
	P009706	Stranica ruke	C0361		16.318			Odobreno	630.96 KB	SOLIDWORKS	Drawing Document			12.10.2020 15:08:06	Tehnička dokument
	9009706	Stranica ruke	C0361	Ploča	16.318	Tehnologija ko	01	Odobreno	285.74 KB	SOLIDWORKS	Part Document			12.10.2020 15:08:06	Tehnička dokument
	22 P009707	Odstojnik R-05	Č1531		0.535		01	Odobreno	453.92 KB	SOLIDWORKS	Drawing Document			12.10.2020 15:08:06	Tehnička dokument
	SP009707	Odstojnik R-05	Č1531	Cev (okrugla)	0.535	Tehnologija ko	01	Odobreno	93.61 KB	SOLIDWORKS	Part Document			12.10.2020 15:08:06	Tehnička dokument
	22 P009708	Gomji decodstojne ploce R 03	Č1531		2.726		01	Odobreno	600.09 KB	SOLIDWORKS	Drawing Document			12.10.2020 15:08:04	Tehnička dokument
	P009708	Gornji deoodstojne ploce R 03	Č1531	Ploča	2.726	Tehnologija ko	01	Odobreno	163.54 KB	SOLIDWORKS	Part Document			12.10.2020 15:08:04	Tehnička dokument
	222 P009709	Bočne strane odstojne ploče	Č1531		0.634		01	Odobreno	462.07 KB	SOLIDWORKS	Drawing Document			12.10.2020 15:08:04	Tehnička dokument
	 ponomo 	Rožna strana odstolna oloža	C1531	Dinia	1.53.0	Tehnolooiis ko	01	Odobrano	75 75 KR	SUI IDMURKS	Dart Document			12 10 2020 16-08-04	Tahnijka dokumant
	La Preview III D	ata Card 🛛 🔏 Version -/8 🔲 Bill of Mo	aterials 💑 Contains	Where Used	SOLIDWORKS	Manage									
	C. Preview E D	🌖 💿 ሾ Default	stenals 🔏 Contains	Where Used	SOUDWORKS	Manage									8
	C. Preview E D	🌖 💿 ሾ Default	apuna tehnoloških dimer		SOUDWORKS	Manage									8
	Preview 🔛 D	🌖 💿 ሾ Default	opuna tehnoloških dimer		 SOUDWORKS Izradio: Stefat 		Dana: 14.2	2.2020	A/Ø [42	[mn]	Spisak operacija	a	na O_C		
	La Preview D	Se Postault Konstrukcja Opis p ID. P0097	opuna tehnoloških dimer	zja		n lic	Dana: 14.2 Dana: 14.0		A/Ø: 42 D. lima / zida:		10 Sečenie testerom				8
	La Preview E D	S e Postault Konstrukcija Opisi p ID: P0097	opuna tehnološikih dimer 02 osovina	zja	Izradio: Stefar Odobro: Stefar	n lic	Dana: 14.0		D. lima	[mm]	10 Sečenje testerom 0 0 Testera 0 20 Struganje Raditi k na tolerisane kote, osta	Seci Č.4732.4 fi42 tote prema crtežu. V sviti na predmeru za l	na L=586mm. oditi računa brušenje.		
	La Preview E D	See Default Konstukcja Opis p ID: P0057 Naziv: Nova	opuna tehnoloških dimer 102 2000/ina 14	zja	Izradio: Stefar Odobro: Stefar	n lic n lic	Dana: 14.0		D. lima / zida:	[mm]	10 Sečenje testerom 10 0 Testera 0 20 Struganje Raditi na tolerisane kote, ost Uraditi gnezda za bruše Univerzalno struganje 30 Glodanie Raditi #	Seči Č.4732.4 fi42 tote prema crtežu. Vi sviti na predmeru za l mje sa obe strane ko 1 0 jeb za kašu prema ci	na L=586mm. oditi računa brušenje. mada. 0 0		
	La Preview E D	Image: Control Image:	opuna tehnoloških dimer 102 14 14 14	nzia Revizia: 01	Izradio: Refa Odobro: Stefa Nupovna kom Proizvođač : Stra	n lic n lic ponenta (Kaii, Lana	Dana: 14.0		D. lima / zida: B šima: H -Veina / dužina: 586	[mm]	10 Sečenje testerom 10 0 Testera 0 20 Srugarje Raditi) na tolerisane kote, osta Uraditi gnezda za bruši (Univerzalno struganje 30 Glodanje Raditi 2) Univerzalno glodanje 40 Brušenje obieno	Seći Č.4732.4 fi42 tote prema crtožu. V sviti na predmeru za l snje sa obe strane ko 10 jeb za kajtu prema ci 0	na L=586mm. oditi računa brušenje. mada. 1010 težu. 10101		8
	La Preview 🔤 D	Contraction of the second seco	opuna tehnoloških dimer 102 14 14 14	nzia Revizia: 01	Izradio: Stefa Odobro: Stefa Kupovna kom Proizvođača : Štra proizvođača :	n lic n lic ponenta (Kaii, Lana	Dana: 14.0		D. Ima 0 / zida: 0 B šima: 0 H -Visina / dužina: 506 Stanje m	imm] imm] imm] aterjala:	101 Sečenje testerom 1 101 01 Testera 10 201 Struganje 1 Raditi i na tolerisane kote, odz Uraditi gnezda za bruše Univerzalno struganje 301 Glodanje 1 Raditi 2 Univerzalno glodanje 1 dv1 Brušenje 0 501 Povninska zastita	Seći Č.4732.4 fi42 tote prema crtožu. Vr prije sa obe strane ko 10 jeb za kajtu prema cr Raditi kote prema crt	na L=586mm. adti računa brušenje. mada. 1010 težu. 10101 ežu. 10101		
	La Preview 🕅 D	C POUR Krontulogo Que po D. POUR Naarvi Maarvii Corrz Maarvii Formicha zahita Temicha zahita	opuna tehnoloških dimer 102 14 14 14	nzia Revizia: 01	Izradio: Refa Odobro: Stefa Nupovna kom Proizvođač : Stra	n lic n lic ponenta (Kaii, Lana	Dana: 14.0		D. Ima D. Ima B Sittna: H -Vaina / dužna: Stanje m Stanje m	irm] irm] irm] aterjala:	10 Sečenje testerom 10 0 Testera 0 20 Struganje Raditi traditi enekata za bruda U kraditi gnezda za bruda U kriverzalno struganje 30 Glodanje Raditi 21 Univerzalno glodanje Holi Rušenje-obinno Brušenje 0	Seći Č.4732.4 fi42 tote prema crtožu. Vr prije sa obe strane ko 10 jeb za kajtu prema cr Raditi kote prema crt	na L=586mm. adti računa brušenje. mada. 1010 težu. 10101 ežu. 10101		
	La Preview Mil D	Contraction of the second seco	opuna tehnoloških dimer 102 14 14 14	nzia Revizia: 01	Izrado: Stefa Odobro: Stefa Hupovna kom Proizvođač : Šdra proizvođača : Web	n lic n lic ponerta (Kaš, Lana 9. Septembar	Dana: 14.0		D. lima / zida: B isrna: / dužina: Stanje m Status ter	jmm] jmm] imm] aterjala: v	101 Sečenje testerom 1 101 01 Testera 10 201 Struganje 1 Raditi i na tolerisane kote, odz Uraditi gnezda za bruše Univerzalno struganje 301 Glodanje 1 Raditi 2 Univerzalno glodanje 1 dv1 Brušenje 0 501 Povninska zastita	Seći Č.4732.4 fi42 tote prema crtožu. Vr prije sa obe strane ko 10 jeb za kajtu prema cr Raditi kote prema crt	na L=586mm. soditiračuna prušenje, mađa.1010 težu.10101 sžu.10101 unija za		9
	La Preview 🕅 D	C POUR Krontulogo Que po D. POUR Naarv Maarst 500 Povelinida zalita Temolka zalita	opuna tehnoloških dimer 102 14 14 14	nzia Revizia: 01	Izradio: Stefa Odobro: Stefa Kupovna kom Proizvođača : Štra proizvođača :	n lic n lic ponerta (Kaš, Lana 9. Septembar	Dana: 14.0		D. Ima D. Ima B Sittna: H -Vaina / dužna: Stanje m Stanje m	jmm] jmm] imm] aterjala: v	101 Sečenje testerom 1 101 01 Testera 10 201 Struganje 1 Raditi i na tolerisane kote, odz Uraditi gnezda za bruše Univerzalno struganje 301 Glodanje 1 Raditi 2 Univerzalno glodanje 1 dv1 Brušenje 0 501 Povninska zastita	Seći Č.4732.4 fi42 tote prema crtožu. Vr prije sa obe strane ko 10 jeb za kajtu prema cr Raditi kote prema crt	na L=586mm. adti računa brušenje. mada. 1010 težu. 10101 ežu. 10101		9

Figure 4. MBOM for the product

	a proizvodnj	je								Lista			ih nal	oga	po operacijama		ł	2		
for kolt	IN ANTIMUC NAMES	CALLS STREET	mercourne area	A DESCRIPTION OF T			lier.chost	Connel (1-64)/14		month			Arrest	incari -			the later of	-		
Radetla					Romansla	0			-											
Paeleja Bec	P090-01	-					-			Bi rettri	-	Postar-	Straps maller	Part.	fait speeds	trains .	Total .	Tates .		
Kainada	1			-		a				-	-10	111200	12.0004	4	160 C107 RU to 1-800-0.700-0			TARAPANE.	(annual t	
Rodni ealog:	181 A000038	_		1		u				-					deride .			1110-61	Detail) Detail	
Enij spanelja: Grupa malina	11	-		10		-			- C										diam'r.	
	4C fieldere			1.5	Radic spotter	1.00	0494			10	-16	WHERE .		1	Commit performing spectrum.		Antoniol		(100000)	
Opis operadje	\$41,03101,825 se 1-3	Date Chooli II	Carl Science									10	Research 1					1124	(0x0))	
Viene lande																			Industry	
Nammana									10.00	and the second	. **	PERMIT	NO DAL	1	Autorizati genera cristo na meta folimitate intel conarti dulletturo		-stronen	PUBLIC	Distant I	
franks	Deidencia protocol	the monthly	with samp from	hele area	ir, habi tolo	·	20000	in the set				heiter	is second	the last	site and only. Publishing arrest	·	-	i.	Contract of	
Rite (ispec) Pochije Pro - ARCESCO (21)	Lista evid	11		h i zav				_		2			diran tiyat k	feet	mena faling sing *) Kenganingan		1994	-		-
894- (1994), (1996), (1997) 4954952000 (101) 101(1900-0) 4954952000 (101)	Lista evid	11					Prival same	_	racijama C				dran nyari		need failing alige *		1994			
RAN (agent) Procision Anno Addition (J.D.) Min (Procession	Lista evid	100	in the second			Dark.	Prival same	peine Ope Rene addendje					and the second second	1	need failing alige *		ither:			
894- (1994), (1996), (1997) 4954952000 (101) 101(1900-0) 4954952000 (101)	Lista evid	Anna Anna Anna Anna	anti interiore	Normal State	-	Dolarh Isseada	Prival same	geline (ge Datas addardy Million (b	с				Concernant of the local diversion of the loca		need failing alige *		ither:			
Rde (1994), 1 Pockija 400–4002000 (20) 101(2000) 401–4002000 (20)	Lista evid Internet internet Present Ministry Annual Present Ministry Annual P	nation Ro-Region Party Ro-Region	Autoreter N. Poster	Normal Social State	anj manan Natar	Dolarh Isseada	Prival same		C				dense nyari t		need failing alige *		ither:			
894- (1994), (1996), (1997) 4954952000 (101) 101(1900-0) 4954952000 (101)	Lista evid Instanti instanti Instanti Instanti Instanti I Instanti I Instanti I Instanti I Instanti I Instanti I Instanti I I Instanti I I Instanti I I Instanti I I Instanti I I Instanti I I Instanti I I Instanti I I Instanti I I Instanti I Instanti I I	Radial Ro-Roptor Roll Ro-Roptor Roll Ro-Densi	anti anti gin anti anti a successi a successi	Normal Sectors Sectors Sectors Sectors Sectors Sectors Sectors	end minister filter filter filter filter	Dolarh Isseada	Prival same						Aviena a sport versa				ither:			
894- (1994), (1996), (1997) 4954952000 (101) 101(1900-0) 4954952000 (101)	Lista evid Inter sectors Inter sectors Inter and Internet Inter Coll Inter Co	Radial Market Market Peter Peter Peter Const Ro-Const Const	1. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2.	Martina Martin	ng ng nang nang nang nang nang nang nan	kanta ka kanta ka ka ka ka ka ka ka ka ka ka ka ka ka	Prival same	delara (pel Dense Bibliotopi anteres in Alteres in Alteres in					Aviena a sport versa		need failing alige *		ither:		d	
Rde (1994), 1 Pockija 400–4002000 (20) 101(2000) 401–4002000 (20)	Lista evid International Personality Personality Mathematical Mathe	Radia Al-Angles Fell Ro-Angles Ro-Angles Ro-Angle Ro-Angle Ro-Angle Ro-Angle Ro-Angle		10000 10000 10000 10000 10000 10000 10000 10000	ng Norder	kanta ka kanta ka ka ka ka ka ka ka ka ka ka ka ka ka	And any	delara (pel Dense Bibliotopi anteres in Alteres in Alteres in					Aviena a sport versa							

Figure 5. The work order monitoring - a) production records, b) list of the launched work orders by operations, c) list of records of started and completed work orders by operations, and d) histogram of completeness of the work orders

One of the most important features of this concept (DM) in practice is online reporting, Figure 6.

All information related to product design projects, technological procedures and information on the status of work orders in production can be summarized on control panels in accordance with the wishes of users.

Control panels are updated in real time.

All the above examples represent good manufacturing practice according to the DM model, with elements of Industry 4.0, which raises the competence and competitiveness of domestic industry in the international market.



Figure 6. Real-time reporting - a) team list and their tasks, b) histogram of the state of execution of tasks per person, c) graphical presentation b, d) histogram of the state of execution of tasks per team, e) overview of projects and % of their execution.

4. Conclusions and future researches

In Serbia, the National Platform for Industry 4.0 has been created and adopted, which means that in the triangle: decision makers (government, ministries, economic associations) scientific community (faculties, institutes) - economy (primarily SMEs) organized systematic efforts to implement Industry 4.0 [7]. On the other hand, the Faculty of Mechanical Engineering in Belgrade has organized five international Conferences on the Industry 4.0 Model for Advanced Engineering / Manufacturing - Industry 4.0 and Smart Manufacturing since 2015 and held 28 Panels about Industry 4.0. This has led to the fact that digitalization is an imperative of the moment in the development of the Serbian economy, and Industry 4.0 is the goal to be pursued. The considered examples in this paper are the best practice of DM, which is spreading more and more in Serbia. Currently, more than 20 SMEs are working on DM projects in their environment. The future MEF research in this area will relate to the application of the intelligent CAI model in DM, which was developed in the previous period.

References

- Sander Lass, Norbert Gronau, A factory operating system for extending existing factories to Industry4.0, Computers in Industry Vol. 115, February 2020, 103128, https://doi.org/10.1016/j.compind.2019.103128.
- [2] Tariq Masood, Paul Sonntag, Industry 4.0: Adoption challenges and benefits for SMEs, Computers in Industry, 121, October 2020, 103261. https://doi.org/10.1016/j.compind.2020.103261.
- [3] Cristina Morariu, Octavian Morariu, Silviu Raileanu, Theodor Borangiu, Machine learning for predictive scheduling and resource allocation in large scale manufacturing systems, Computers in Industry 120, September 2020, 103244, https://doi.org/10.1016/j.compind.2020.103244.
- [4] Szilárd Jaskó, Adrienn Skrop, Tibor Holczinger, Tibor Chován, János Abonyi, Development of manufacturing execution systems in accordance with Industry 4.0 requirements: A review of standard- and ontology-based

methodologies and tools, Computers in Industry 123, December 2020, 103300, https://doi.org/10.1016/j.compind.2020.103300.

- [5] Francois Vernadat, Enterprise modelling: Research review and outlook, Computers in Industry 122, November 2020, 103265, https://doi.org/10.1016/j.compind.2020.103265.
- [6] Reiner Anderl, Industrie 4.0 Advanced Engineering of Smart Products and Smart Production, Technological Innovations in the Product Development 19th International Seminar on High Technology (Piracicaba, Brasil October 9th, 2014), https://www.researchgate.net/publication/270390939.
- [7] Majstorovic, V., et al., Program Advanced Industrialization of Serbia and Industry Policy, horizon 2020/2030, Mechanical Engineering Faculty, 2016.
- [8] Kai Zhanga, Ting Qub, Dajian Zhoud, Hongfei Jianga, Yuanxin Lina, Peize Lie, Hongfei Guoc, Yang Liuc, Congdong Lia, George Q Huang, Digital twin-based opti-state control method for a synchronized production operation system, Robotics and Computer Integrated Manufacturing 63, June 2020, 101892, https://doi.org/10.1016/j.rcim.2019.101892.
- [9] Yesheng Cuia, Sami Karaa, Ka C. Chan, Manufacturing big data ecosystem: A systematic literature review, Robotics and Computer Integrated Manufacturing 62, April 2020, 101861, https://doi.org/10.1016/j.rcim.2019.101861.
- [10] Yuanju Qu, Xinguo Ming, Yanrong Ni, Xiuzhen Li, Zhiwen Liu, Xianyu Zhang and Liuyue Xie, An integrated framework of enterprise information systems in smart manufacturing system via business process reengineering, Proc IMechE Part B: J Engineering Manufacture 1–15, IMechE 2018, https://doi: 10.1177/0954405418816846.
- [11] Sameer Mittala, Muztoba Khana, David Romerob, Thorsten Wuest, A critical review of smart manufacturing & Industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs), Journal of Manufacturing Systems, Volume 49, October 2018, Pages 194-214. https://doi.org/10.1016/j.jmsy.2018.10.005.
- [12] Dan Li1, Åsa Fast-Berglund, Dan Paulin, Current and future Industry 4.0 capabilities for information and knowledge sharing - Case of two Swedish SMEs, The International Journal of Advanced Manufacturing Technology (2019) 105:3951–3963, https://doi.org/10.1007/s00170-019-03942-5.
- [13] Negri, E., Berardi, S., Fumagalli, L., & Macchi, M. (2020). MESintegrated digital twin frameworks. Journal of Manufacturing Systems, 56, 58–71, https://doi:10.1016/j.jmsy.2020.05.007.