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SYNERGIA SYMULACJI I DRUKU 3D W ZAKRESIE MODELOWANIA I POPRAWY WYDAJNOŚCI PRODUKCJI

Streszczenie: Obecne technologie dają inżynierom przemysłowym i procesowym szerokie możliwości w zakresie modelowania produkcji oraz jej doskonalenia w zakresie wydajności. Praca koncentruje się na dziedzinie modelowania zarówno urządzeń produkcyjnych realizujących proces transformacji, jak i produktów i części, z których się składają i stopniowo przechodzą przez ten proces. W artykule opisano tworzenie modeli i ich późniejsze wykorzystanie w symulacji 3D oraz tworzenie wirtualnego obrazu rzeczywistej operacji. Modele te są następnie wykorzystywane do stworzenia fizycznego modelu tej operacji za pomocą druku 3D.

Słowa kluczowe: modelowanie, Tecnomatrix, symulacja

SYNERGY OF SIMULATION AND 3D PRINTING IN THE FIELD OF MODELLING AND IMPROVING PRODUCTION EFFICIENCY

Summary: Current technologies offer industrial and process engineers a wide range of possibilities in the field of production modelling as well as its improvement in the field of efficiency. The paper focuses on the field of modelling of both production equipment performing the transformation process, as well as products and parts of which they are composed and gradually go through this process. The paper describes the creation of models and their subsequent use in 3D simulation and the creation of a virtual image of the actual operation. These models are used to create a physical model of this operation using 3D printing.

Keywords: modelling, Tecnomatrix, simulation

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1. Introduction

The paper is focused on the processing of a simulation model of the production process in an industrial enterprise. One of its goals is to document the production process of a water meter shaft product in a manufacturing company. The manufacturing process was modelled in the Autodesk Inventor software environment. These were all entities that intervened in the creation of the final product. Subsequently, the paper focuses on the creation of a simulation in the interface of the simulation program Tecnomatix Plant Simulation from Siemens. Where all these input data were collected and computer-modelled 3D objects were used to create a simulation of the manufacturing process. The last part is the creation of this production process in the form of a scale model using 3D printing technology. When all the simulations involved in the equipment, such as the machines, were extruded by this technology, and with them, a scale model of this production hall was created [6].

2. Manufacturing process

In the production of a plastic water meter shaft, extruder welding using additional materials in the form of polypropylene wires is used in the welding of plastic profiles. At the beginning of the entire production process, in addition to the information flow, there is also a flow of input material, which is transformed into individual components and semi-finished products during production, which subsequently becomes our product at the end of production - a water meter shaft [2, 4].

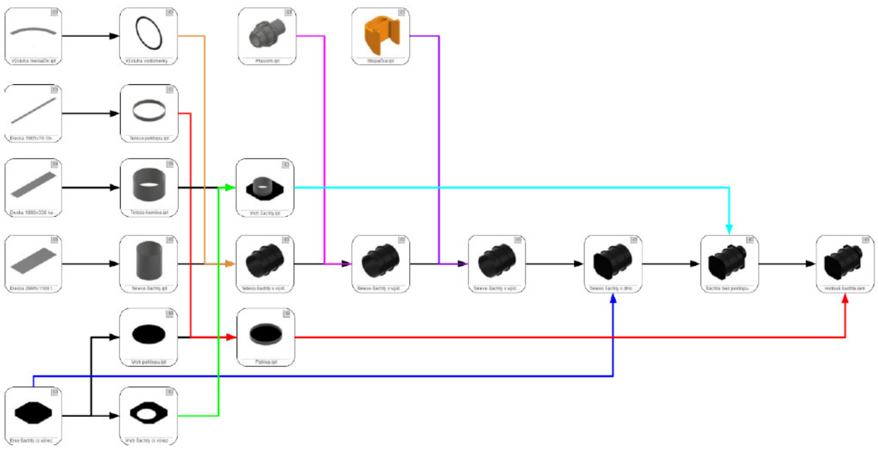

Figure 1. Diagram of production process steps

As we can see in the diagram of our production process. At the beginning of each input, there is a semi-finished product from the input material, which in the next step is transformed into individual components, which are already produced at individual workplaces. After this step, our individual components are combined into subgroups of the production process. These subgroups consist of two or more components. From the fourth step, we can notice that the division of the diagram has narrowed to one line, which forms the assembly unit. During the steps, additional components (components) are added to this assembly unit only according to the technological process. The final product of our diagram is the product. These are the output goods leaving the production process in order to be provided to the consumer on the market. In the next step, our production process was the aim of research not only in terms of the composition of individual components step by step, but also in terms of time - time of individual steps of the production process, and also in terms of quantity of components to achieve the final product. This research was done in order to understand the processes, and also to create the upcoming simulation. When we could compile the simulation more reliably with the help of the data collected in this way. All these steps, working hours and quantities are contained in the following Table 1 of data of individual operations [3].

Table 1. Data of production process operations [1]

No.	Operation	Working time [min./s]	Quantity [ks/1 final product]
1.	Cutting of input material 1	10:00	1
2.	Welding reinforcement	30:00	4
3.	Welding the collar of the hatch	20:00	1
4.	Chimney body welding	20:00	1
5.	Welding of the shaft body	20:00	1
6.	Installation of shaft reinforcement	20:00	2
7.	Plassim installation	20:00	2
8.	Installation of risers	45:00	3
9.	Cutting input material 2	2:00	2
10.	Carving the top of the hatch	3:00	1
11.	Welding the hatch	10:00	1
12.	Shaft chimney welding	10:00	1
13.	Adding the bottom of the shaft	30:00	1
14.	Add a shaft top	40:00	1
15.	Fitting the cover	1:00	1

As a small note on the content of the table is a reminder of the fact that the first 8 steps of our production process takes place using and processing input material no. 1 - polypropylene plastic board dimensions 4000x1500mm thickness 5 mm. The steps of operations No. 9 to 12 are performed by using and processing the input material No. 2 - polypropylene plastic board dimensions 1000x1000 mm, thickness 15 mm. In the final part of the production process from step 13 to step 15, the contents of the production operations are together both input materials.

3. Simulation

In this part, we set about creating a production process in the environment of the Tecnomatix Plant Simulation 15 software from Siemens. Before that, however, we created all the necessary 3D models of parts, semi-finished products and assemblies of a given production process of a water meter shaft in the Autodesk Inventor software (Figure 2).

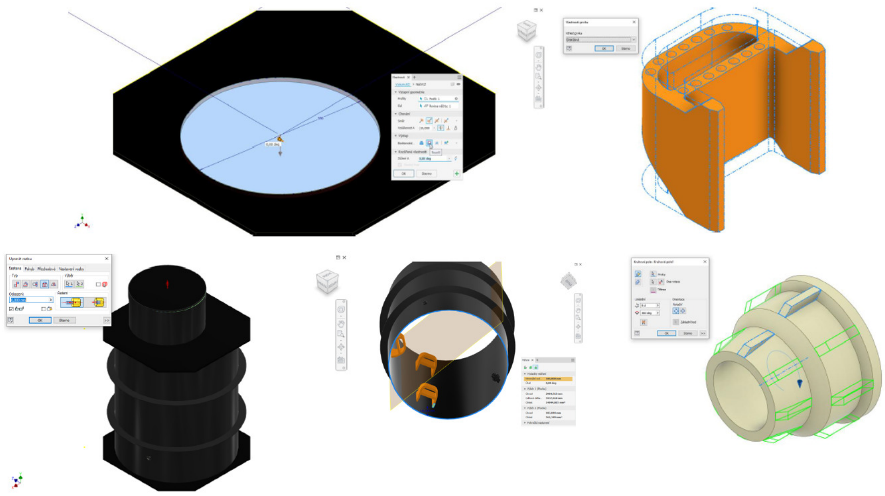

Figure 2. Gradual product creation in Autodesk Inventor software [5]

The components of the production process created by us, all machines, resources and tools then had to be converted into the .jt format, with which the Plant Simulation program works. After uploading all the necessary files for creating the production process, we created our simulation in a 2D environment. The process simulation took place within one production hall. The input parameters of our simulation can be seen in Table 2.

Table 2. Input parameters of the simulation

Source	Quantity
Shift length	8
Number of employees	10
Number of inputs	2
Number of outputs	1
Number of workstations	13
Number of bins	10
Number of products produced	5

There are two material inputs at the beginning of this simulation. One of these inputs will be referred to as Input 1 - represents the material of a 5 mm thick plastic polypropylene board in the number of 5 pieces for the entire production process. Next to input 1, we create Input 2. This will serve as the input flow of material of a 15 mm

thick plastic polypropylene board in 12 pieces. In our case, the flow of input material then goes to the first station. We will use the DismantleStation for this purpose. At a given station, which represents a circular, a 5 mm thick polypropylene input plate is cut into a total of 4 other semi-finished products - parties. We have already created these parties in Autodesk Inventor, and each of them goes to a separate tray, which we created using the Buffer function. In order for the program to recognize which bin each new individual blank should go into and in what quantity we have created a table with the help of the DismantleTable function, in which we describe the journey of our newly created semi-finished products by means of individual paths to individual bins and in what number. As in reality, we simulated this station with the help of 2 workers (Worker), who work on the station together. We set the time of each cycle on this station to the value of 10 minutes.
As the first next station in our case, using new parties - semi-finished products from our containers, the next step is the reinforcement welding station. The station is operated by one worker and its activity is to create a reinforcement of a water meter shaft. In this case, we set the processing time to a constant of 30 minutes per cycle. The next working position is the workplace for bending semi-finished plastic plates into a rotating body shape. The bending duty cycle of one material was chosen to a constant value of 20 minutes. 1 worker was used to operate the workplace, who thus processes all boards from the input 3 bins during the entire shift of operation. In the next step, it was necessary to return to the beginning of the input material. In this case, the focus was on the material of Input 2. This input directs our material to its first station for processing. This station was named Cutting, and with the help of one operator, the existing input material was machined into a blank, which was directed to a newly-created 1-piece blank stack per input plate. The second by-product in the table is waste in the form of cut-off parts of the corners of the board in the number of 4 pieces, which were directed to the waste collection bin of the Drain station. An interesting simulation of our production process is the fact that this station produces as its only waste in its operation. All 12 pieces of machined plate from the inlet 2, which ended up in the tank, are subsequently used as a cover plate of the bottom and top of the water meter shaft. Therefore, half - 6 pieces of this processed board went to their further processing at another station – Cutting 2. At the given station, an inlet opening with a diameter of 590 mm for the top cover plate will appear. After this working cycle, lasting 3 minutes, these 2 new emerging semi-finished products each find themselves separately in their own container for further processing. It is these 2 newly formed parts that come into contact with the products from the welding station in the next step. The first work activity is at the next workplace - Welding_ of covers. This workplace represents the connection of the looking circle - the top of the lid, together with the collar of the lid. Both of these components represent inputs at a given workplace. A very similar station is the secondary workplace Welding chimney, which in this case completed the second outlet part from the previous station Rezanie_2 - the top of the shaft, together with the chimney body coming again from the welding station. In this case, the finished output blank was completed again in a 10-minute duty cycle. The finished output semi-finished product was waiting at the given station for its use in the next step. At this stage, it took over the role of the main element in the next "belt line" of production consisting of several workplaces. The first step was a series of welds of two complete reinforcements around the shaft body. This 20-minute duty cycle provided the assembly for the first time as its output.

This assembly unit in the form of a shaft body with reinforcements continued on the given line to another workplace. At this workplace, two pieces of plassim were mounted to the unit in a work cycle of 20 minutes. After the successful completion of the operation, our assembly unit in the form of a shaft with reinforcements and plassims followed to its next workplace – Adding risers. At this given workplace, risers were mounted inside the shaft to the assembly. The second source served us this, which again recorded the arrival of the assembly unit to the workplace, sent 3 pieces of risers to this workplace for assembly.
The final completion of our assembly unit took place at the last two workplaces. At these two workplaces, the work of adding the bottom and top, which represent components made of the material of the board of Input 2, took place. The created complete assembly unit was finally moved to the last workstation - Deployment of the cover. In this case, the already existing formed component in the form of a cover of the shaft inlet opening waited for its mounting in the container of the formed covers. After the finished manhole was moved to the station, a hatch was placed on top of it during the last 1-minute work cycle. This act concluded the entire production process of converting input materials into a finished product. The last step of our simulation was to move the manufactured plastic water meter shaft to the outlet, which represented the export from the production hall to the warehouse of finished products out of the production hall. The final version of the simulation and the whole hall with individual workplaces created in Tecnomatix Plant Simulation 15 software can be seen in Figure 3.

Figure 3. Simulated production workplace

As an output from the entire simulation, the Tecnomatix Plant Simulation program provides a summary table (Table 3), which is generated by the program at the moment of the end of the simulation, when all workstations have finished their work by converting the entered inputs into outputs.

Table 3. Overview of statistics of the simulated production workplace

.Models.Model

Simulation time: 11:50:00.0000

Cumulated Statistics of the Parts which the Drain Deleted									
Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Drain	Odpad	0.0000	12	1					
Výstup	Hotová_šachta	1:00.0000	5	0	100.00%	0.00%	0.00%	100.00%	

Conclusion

Work in the field of 3D modeling, simulation creation and ultimately 3D printing only more interconnects the digital form of processed data collected during simulation creation with real output in the form of a created model, which can clearly present not only the real production process but also a process or idea does not exist yet. The creation of a model of a water meter shaft with the use of knowledge from 3D printing created for the first time a model usable for attendance and training purposes. In this case, a simulation is a tool for debugging production steps in the event of changes in the production process. A possible proposal may be the possible use of 3D printing from the premises of a manufacturing plant to create hands-on difficult-to-create plastic models, or for training purposes.

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REFERENCES

1. TREBUŇA, P. et al. MODELOVANIE V PRIEMYSELNOM INŽINIERSTVE. Kosice: Technical University of Kosice, Faculty of Mechanical Engineering, 2015. 978-80-553-1953-7.
2. SKIDMORE, P. Why is 3D Modeling Important for Product Manufacturing Companies? [Online] 22. 10. 2021. *https://www.cadcrowd.com/blog/why-is-3d-modeling-important-for-product-manufacturing-companies/*.
3. MALINDŽAK, D., ŠINDLER, V. Modelovanie výrobných procesov. Kosice: Technical University of Kosice, Faculty of Mechanical Engineering, 2003. 80-8073-061-X.
4. RUDY, V., MALEGA, P., KOVÁČ J. Výrobný manažment. Košice: s.n., 2012. 978-80-553-1265-1.
5. KOVÁČ, J. Systémový prístup k projektovaniu a manažmentu výroby. Košice: s.n., 2010. 1337-7094.
6. EngUSA, Admin. Tecnomatix Plant Simulation for Manufacturing. [Online] *https://www.engusa.com/en/posts/tecnomatix-plant-simulation*.