Applications of Digital Manufacturing in Manufacturing Process Support

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Abstract

Three new approaches and models are developed for improvements related to manufacturing processes. The main focus is on planning in a digital environment before the actual manufacturing process is carried out. The first approach, which will be presented in this paper, is digital manufacturing, which gives us an opportunity for performing an entire manufacturing process in a virtual environment. In this way, engineers virtually define, plan, create, monitor, and control all production processes. The planning phase can be done simultaneously, while other manufacturing processes are already in place. In this way, processes can continue with no interruption. Various product lifecycle management tools have databases of various programs that are used for interfacing and communication with machinery, such as CNC machines and industrial robots. Ideally, after the manufacturing process has been verified in the digital environment, control data can be uploaded to numerically controlled machinery so that the production process can start. Two special models, presented in this study, have been developed for more detailed insight into special types of manufacturing processes. The second approach represents a model for the unique type of production that takes into account all resources as the most important factor in the manufacturing processes. The main variables that were included in this model are the availability and the presence of all required manufacturing resources needed for every single manufacturing operation. The third approach represents a model for large-scale production

that includes all significant parameters of a manufacturing process, as well as all required intermediate storages. The last two models, which will be shown in this paper, were developed as parametric, and the users in the training process can easily make tests for different types of input data.

Introduction

Manufacturing process analysis is necessary for manufacturing companies to improve market competion [1]. The digital environment is used for student and workforce training. Various studies in the field of engineering education have proven that training is very effective with the use of the dynamic control of manufacturing process, where participants observe a simulation of the manufacturing process in the digital environment to the given set of parameters and the output [2]. In our research, the digital manufacturing models have proven to be a very useful tool for the training of the planners of production processes and for training and educating the mechanical engineering students. The use of the digital manufacturing models is suitable for designing new production systems or improving the existing ones [3]. A major advantage of the concepts is that the digital manufacturing models do not consume any material, resources or energy; we operate only with data. As well, during the training process, the production process is not interrupted and, consequently, the equipment is not occupied and cannot be damaged [4]. Based on the findings of this research, two special concepts and models were developed that were shown as useful for the training during different levels of production.

Manufacturing is a complex system that contains sets of tasks, materials, resources (including human resources, facilities and software), products, and data [1]. Frequently, because of the intricacy of practical problems in manufacturing process management, their mutual interdependencies can lead to the mathematical model that is too high to be solved by typical analytical methods [5]. For the purposes of detailed insight into special types of manufacturing processes, two models were developed: a model for unique type of production (UTP) and a model for large-scale production (LSP).

Model for Unique Type of Production

The concept for the model of a unique type of production treats operation as the elementary unit of the production process. The concept includes a logical rule that states that every single operation can be performed only when all the required resources, the data sets and the materials, are available and present at the place of the operation performing [6]. The sequence of operations representing the production process is shown in Figure 1.

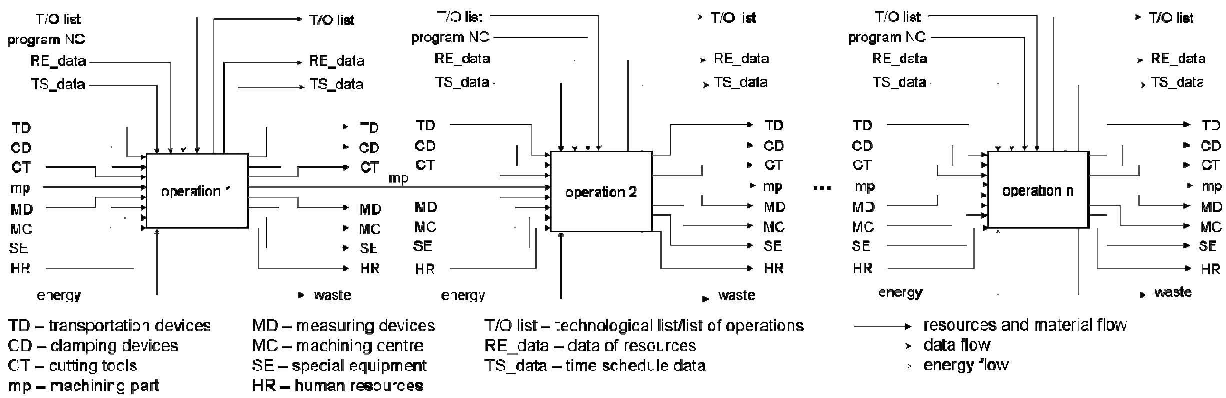

Figure 1. The logical scheme of the simulation model for a unique type of production [7, 8]

The production process model for UTP, besides data, has the presence of resources taken into account due to the unavailability of resources where deadlocks frequently occur. Between the most important resources are counted transportation equipment, clamping equipment, cutting tools, and measuring devices, machining centers, special tools and equipment, and human resources. Based on the logic model (Figure 1), a simulation model of the production process for UTP was constructed in a computer environment, Tecnomatix Plant Simulation [9] (Figure 2).

The model is designed as a parametric, so that the user in the model inserts input data intended for the real production process for the observed period. Among the input data are considered schedule plans, a list of available resources, a work calendar, and the number of available workers. After the initial setup, the user performs a simulation for the desired observation period or for production of the desired number of finished pieces. During the execution of the simulation, the speed can be set for simulation execution, the simulation can be carried out step by step or stopped at any time. It is also possible to configure the production parameters for each production process. In the presented model are pre-designed indicators for real-time tracking of the number of finished parts, consumed production time, and occupancy analysis of individual resources.

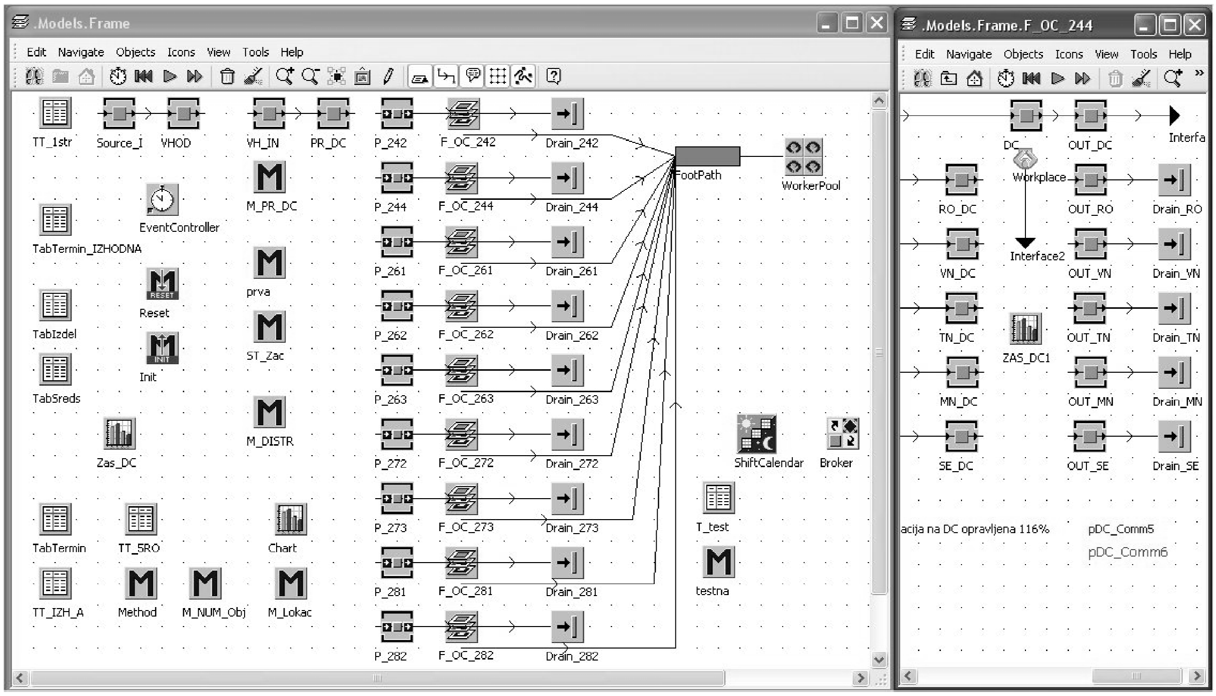

Figure 2. An example of virtual factory for UTP in Plant Simulation [3]

The indicators can be displayed in text format on the screen or structured in table format. With simple additions, any indicator can be installed, or any calculations and analysis can be performed ongoing. A set of input data in the model contains information about the sequence of operations in the production process, as well as a list of required resources that are necessary to perform every individual operation. An output, or acquired data, from the simulation for every individual operation covers the start time of operation execution, the end time of operation execution, and the anticipated duration of operation execution. In the execution of simulation, the user can optionally choose the starting date or observe the output of the production process, after a specified number of calendar days.

Model for Large-Scale Production

In the concept for the model of a large-scale production, the assembly or production cell is treated as the elementary unit of the production process, and in the model, the unit is treated as a sub-model (Figure 3). The model is developed as parametric in a way that it allows the setting of the production process parameters, which depends on the product type.

In the production process model for LSP, the efficiency of production units plays an important role. This means that the amount of produced units depending on production time is significant. Inefficiency of production units occurs as a consequence of scheduled maintenance, parameters setting, calibrating, insufficient quantities of materials, and unscheduled stoppages or failures. The next purpose of the model development is the real-

ISBN 978-1-60643-379-9

time monitoring of stocks in intermediate storage. Stocks should not exceed the maximum capacity that the production process does not stop. Based on the logic model (Figure 3), a simulation model of the production process for LSP was constructed in a computer environment, Tecnomatix Plant Simulation (Figure 4).

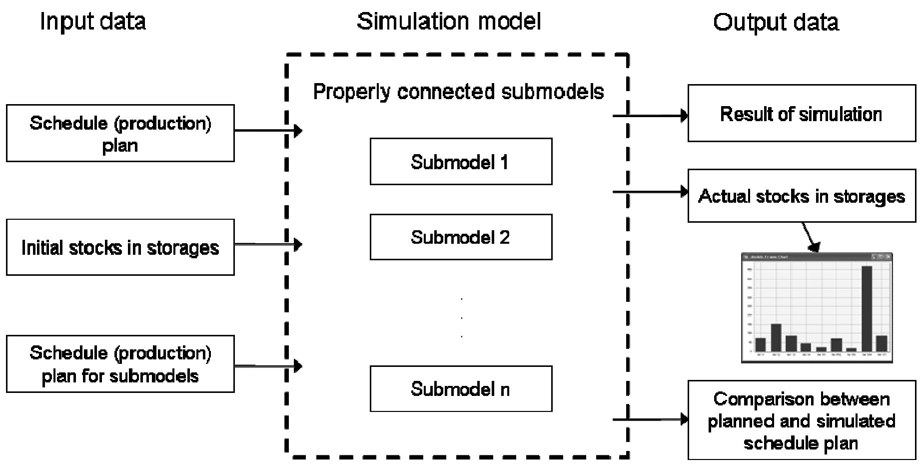

Figure 3. The logical scheme of the simulation model for a large-scale production

The model is designed as a parametric, so that the user inserts the input data into the model, which is aimed for the real production process for the observed period. The main schedule plan, the schedule plan for sub models, the value of the initial stocks in storage, and the work calendar are considered between the input data. A simulation for the desired observation period, or for production of the desired number of pieces, can be performed after the initial setup of the model. The user has an option to set the speed of simulation execution, execute the simulation step by step, or stop at any time. The user also has an option to configure the production parameters for each production process in the model.

In this model, the indicators are pre-designed, which enables real-time tracking of the number of finished parts in intermediate storages, consumed production time, and occupancy analysis of individual production place. The indicators can be displayed directly on the screen in text format, in charts, or can be structured in table format. With simple additions, any indicator can be installed in model, or any calculations and analysis can be performed on-line. Input data comprise data about the sequence of batches production on the production line. In this case every batch represents a number of identical pieces in the series. An output or acquired data from the simulation for each batch covers the start time of production execution, the completion time of production execution, the expected duration of the production execution, and the spent time to produce one piece in a batch [9]. As with the UTP model, the user can optionally choose the starting date for performing the simulations, or observe the production process, for a specified number of calendar days.

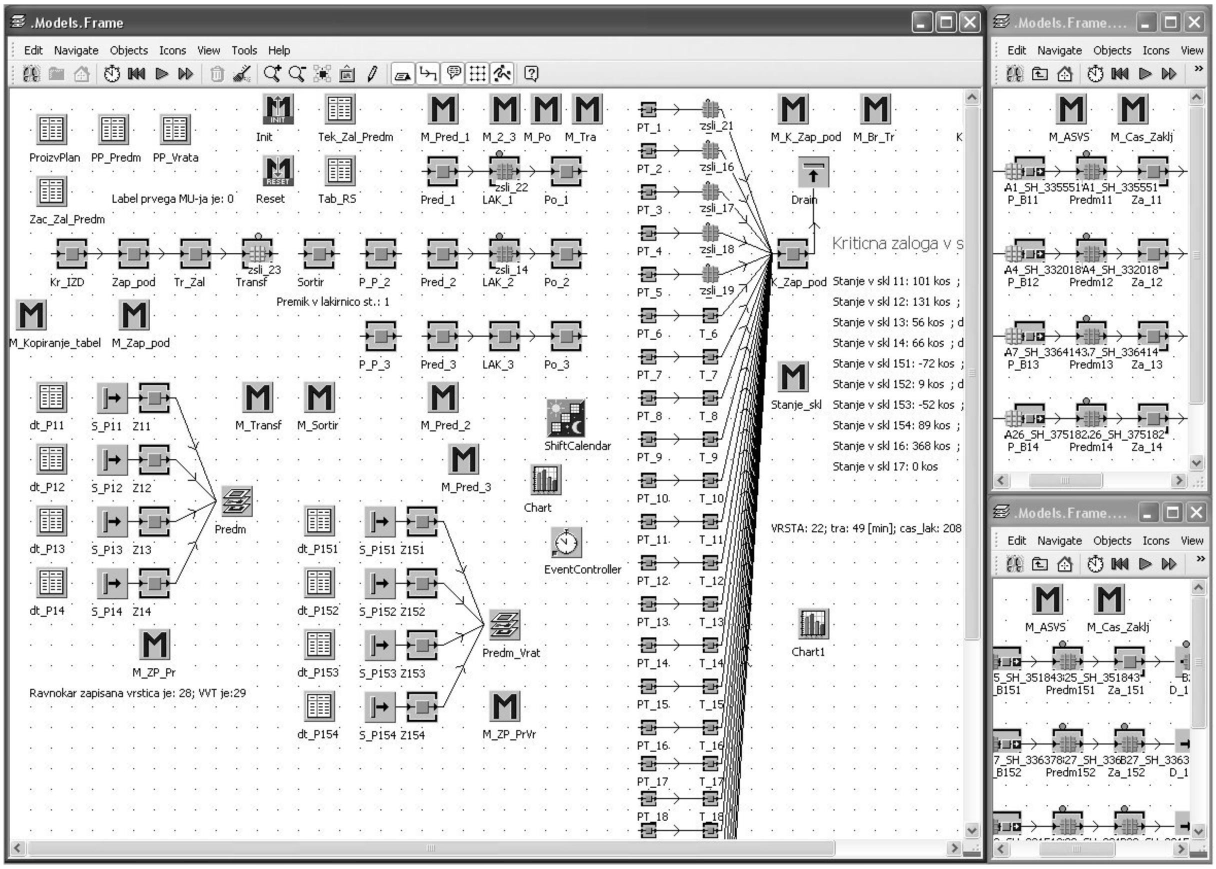

Figure 4. An example of virtual factory for LSP in plant simulation

In the simulation model, a special chart is designed (Figure 5), through which an actual state of stock values in intermediate storage are plotted. This allows the user to continuously monitor the stock movements and comparison of the values with the maximum capacity of intermediate storage.

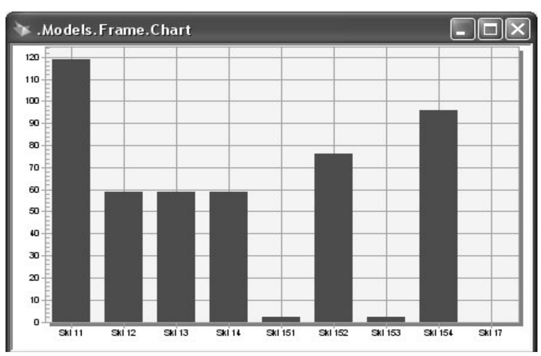

Figure 5. An example of the chart for monitoring the values of stocks in intermediate storages

Conclusion

Future research would focus on validation of exiting approach through data collection, analysis, and testing. Two models which were developed as a part of this research will be evaluated, analyzed, and tested in the e-environment.

The use of both special digital manufacturing models for the purposes of training and education brings a number of advantages. The first advantage is quickly obtaining the simulation results about the estimated execution of the schedule plan. The testing has proven that the execution of a production process in the digital manufacturing models, for an entire work shift, takes only a few minutes. Furthermore, with the testing of production plans in the digital manufacturing models, we do not intervene in the real production system and, thereby, not cause any disturbances. Because of this, we have practically unlimited possibilities of testing different schedule plans where we observe the behavior of the production system as a function of time for an individual plan or only observe the outputs of the production system. The models of production processes are designed parametrically, so we can easily test different production plans' input data for the purposes of learning. Developed models are user-friendly, so that the user inserts the input data into the model, sets the process parameters, performs the simulation, and evaluates the results of the simulation.

Engineers and students can perform a simulation for an existing, or known, production system. They can observe the outputs of the model according to different rearrangements in the digital manufacturing models. By using the simulation, they can also study a planned production system where they test various configurations of the production system, or test the response of the planned system to different settings, among which we include the number of shifts, a working calendar, the number of employees, different break times, different process times, the number of machines, variants of parallel processes, transport times, different transport routes and different manner and a transport strategy for components. Based on the different settings and acquired responses the engineers and students can determine the optimum production parameters.

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Biography

VUKICA JOVANOVIC is currently an assistant professor in the Engineering Technology Department at Old Dominion University. Her research is focusing on mechatronics, product identification, product lifecycle management, assembly systems, collaborative engineering, automation, and energy efficiency. She had internships in engineering services, aerospace, and power generation industries. Dr. Jovanovic received M.Eng.(dipl.ing.) degree from University of Novi Sad, Serbia, in Robotics, Mechatronics and Automation and M.Sc. (Magistar) degree in Production Systems Design, both at Department of Industrial Engineering. She received a PhD in Mechanical Engineering Technology from Purdue University.

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MILETA TOMOVIC is currently a professor and the chair at the Engineering Technology department at Old Dominion University. Dr. Tomovic received BS in Mechanical Engineering from University of Belgrade, MS in Mechanical Engineering from MIT, and PhD in Mechanical Engineering from University of Michigan. Prior to joining ODU, Dr. Tomovic had seventeen years of teaching and research experience at Purdue University, with emphasis on development and delivery of manufacturing curriculum, conducting applied research, and engagement with Indiana industry. While at Purdue University, Dr. Tomovic served as W. C. Furnas Professor of Enterprise Excellence, University Faculty Scholar, director of Digital Enterprise Center, and special assistant to the dean for Advanced Manufacturing.