IMPLEMENTATION OF SIMULATION MODELS IN THE FIELD OF MORE EFFICIENT PRODUCTION

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Abstract

Today, the digitization, improvement and acceleration of all processes means the efforts of manufacturing companies and companies to move their production to a higher level. They try to find such possibilities that will allow them to optimize production as best as possible under the most favorable economic conditions. With the help of digitization and various simulation programs, it is possible to optimize production more accessible to a wide range of manufacturing companies. The paper aims to describe the production line in the virtual environment of the computer simulation module Tecnomatix Plant Simulation. Subsequently, to reveal the potential for possible improvement of the properties of this line. After identifying bottlenecks, eliminate them in the simulation model and suggest possible options for improvement. The simulation will also include specific models of products produced on the line in question and will also include models of equipment that ensure the transformation of semi-finished products into finished products.

Keywords: Digitalization, simulation, effeciency of production

1. INTRODUCTION

We define the production process as a purposeful activity in which a material or semi-finished product is transformed into a finished product or service. We characterize it as a creative process, whose function is to create utility value and is the main activity of the company [1,7]. Production processes can also be characterized as a major global profit generator [2]. One of the main characteristics of the production process is production capacity and flexibility. Production capacity is the ability to produce a production unit over a period of time. It is given by the maximum range of power that a given production unit can deliver in a given period of time. Production flexibility means the ability to adapt, move or adjust the production system when changing jobs [3].

The company's production processes and activities, which appear to be inefficient in terms of efficiency, need to be thoroughly analyzed, deficiencies and errors identified and subsequently optimized [4,8]. Optimization is the process of finding the best practices. One of the main benefits of flexibility is the automation of the workplace - production line (**Figure 1**) [5,6].

Using a variety of simulation software, users can optimize material flow, resource utilization and logistics for all levels of plant planning, from global production facilities, through local plants to specific lines. The computer software Tecnomatix Plant Simulation was developed for this solution, which was developed by Siemens PLM Software for modeling, simulation, analysis, visualization and optimization of production systems and processes, material flow and logistics operations. The software focuses on the workplace as a whole and its task is to find and create optimization solutions that take place within the production. It allows you to create strategies, statistics and experimentation with the layout of the production. Plant Simulation is used by individual production planners as well as multinational companies, especially for strategic layout planning, management logic and the dimensions of large and complex production investments. It is one of the major products that dominate this market.

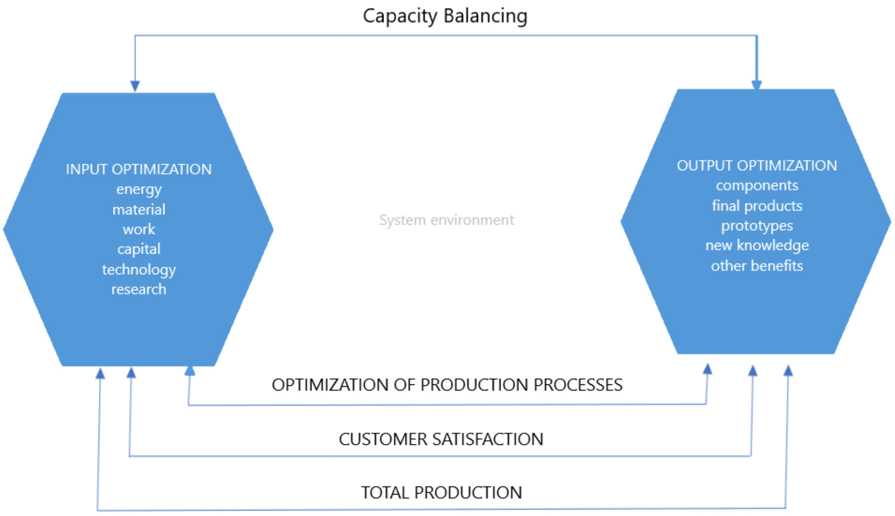

Figure 1 Production workplace optimization scheme [5,9]

2. CONDITION ANALYSIS

As part of the analysis of the state and description of the problem that we will address in this section, we will focus on the production line of the local engineering company, which we had the opportunity to analyze and the task was to optimize production for a specific production line. The company is the newest manufacturing and research and development center in Europe and covers the development and production of electronically commutated BLDC motors and innovative drive technologies.

2.1. Production line

The solved line can be defined as a semi-automatic production line, which consists of four stations or workplaces, the first of which is manual, where the operator works, and the remaining workplaces are automatic, where the production takes place with the help of robotic hands and sensors. The production takes place on a belt conveyor, on which a certain number of pallets with three nests move, in which the components are stored, which are subsequently adjusted at different stations according to the type of operations that take place at the given stations. The production line serves as a pre-production part of the main line for the production of the main product, ie the type of product that is produced on this researched line can be classified as a pre-production piece, which we call the stator. The stator consists of six components that are inserted during its production. Two-shift production operation takes place on the production line and the total cycle time on the given output line is 11 seconds. **Figure 2** shows the production line simulation in the current state in the Tecnomatix program. We can also see the layout of the stations and the route of the conveyor belt.

We divided the production process of the investigated line into areas: Station 1, Station 2a and 2b, Station 3, Station 4 and Test station. The operator performs two operations on the first station. The first is sampling and visual inspection. After removing and then placing the finished piece in the box with finished pieces, it gradually places three types of components L, S, and U (lower, stack, upper) in the prepared free space on the pallet. There are 3 free nests on the pallet, between which the given piece is moved during production. Properly installed components travel to the next station using a conveyor belt. Operation at station one takes 10.5 seconds after measuring the cycle time. Upon arrival at station 2a, the operation of loading the two TP components, which are inserted into the assembly, takes place. The measured cycle time at this station is 10.4 seconds. The assembly with components L, U, S, and TP (terminal pin) continues to station 2B, where the last component GP will be inserted. Insertion of GP (ground pin) takes 8.8 seconds according to the measurement cycle time. The assembled components travel to a third station, where an exchange takes place between the wound stators and the unwound stators. The prepared piece arrives on the pallet, which is then removed by the robotic arm and placed on the winding station behind station three. the piece starts to be wound up and the already wound up is placed in a free position on the pallet. The winding takes place in parallel and the winding station has four winding positions, which means that it can prepare four wound stators in advance. At this parallel station, the stators are wound with copper wire. The cycle time at this station is 8.7 seconds. The wound stators continue to the fourth station, where the TP pushing operation takes place. The operation takes 8.7 seconds. Another operation continues at the given station, namely TP soldering, whose cycle time is 9.8 seconds. After passing through all stations, the completed finished piece reaches the last station and that is the test station - tester (**Figure 3**). The electrical and mechanical properties of the stator and its functional use are checked on it. The test line operation takes approximately 10.5 seconds. From the test station, the finished piece on a pallet travels back to station one to the operator, who visually inspects the piece and stores it in the box for finished production. The finished production is waiting to be transferred to the final line, where the processing and completion of the final product continues.

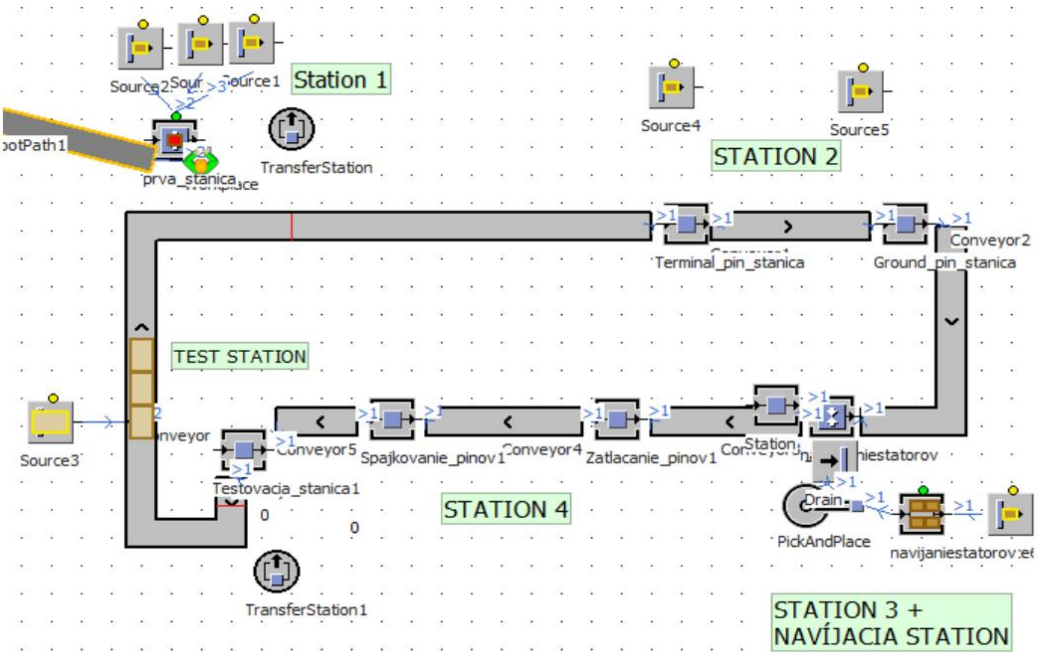

Figure 2 2D Representation of the production line

3. PRODUCTION LINE OPTIMIZATION DESIGN

Subsequently, a simulation was performed based on the data provided to us by the surveyed company. These were cycle times, the approximate number of OK and NOK pieces, the number of production hours, and planned and unplanned stopwatches. We entered this data into the created simulation and monitored how the production on the given line flows and what the outputs are for individual time periods, per hour, per change, and per day. Because the line v is semi-automatic, ie the operator works at one of the workplaces, the networking time on the given line is 11 hours with a 12-hour work shift. Therefore, we set 60 minutes as the scheduled downtime in each change. We drew unplanned downtime from the provided data and in the simulation, we set these downtimes in the given changes randomly during the given shifts. The results of the number of finished products on the production line came to us approximately the same as from the provided data. Based on this result, we can evaluate that we managed to set the simulation correctly. The production line produces small pre-production stator components, which continue to the next final line, where the final piece is completed. According to the provided data and the analysis we performed, we calculated that the production line produces about 3,500 pieces per change. According to the company's plan, the order and demand for the given pieces are to increase to 4,000 or more pieces per change from the summer, which is a problem for the given company. After tracking how the current production takes place and where bottlenecks arise, we stated that it is necessary to make changes at the first and last (test) station on the given line. In **Figure 3** we can see the current state of the first and last station before optimization.

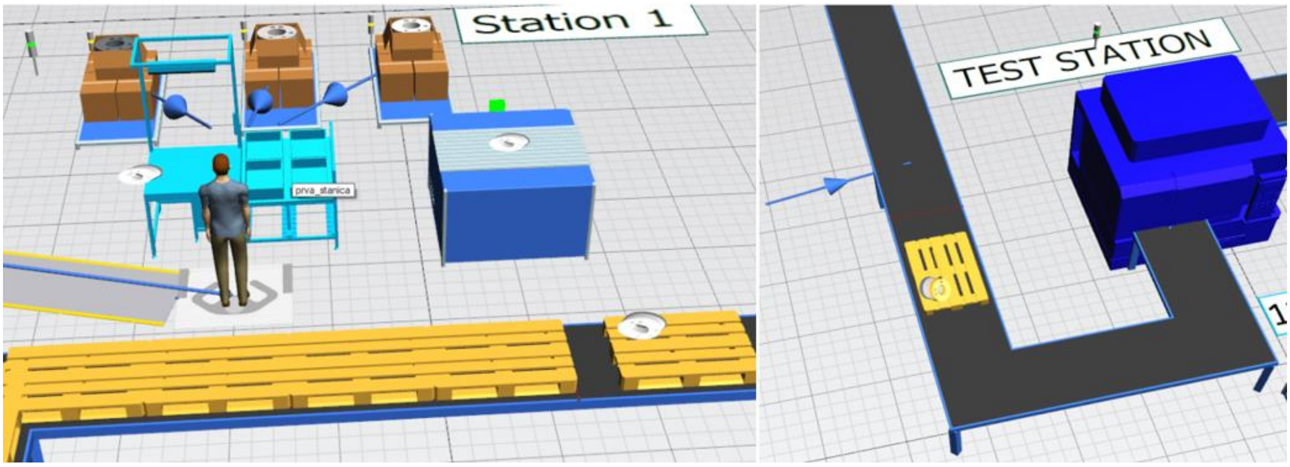

Figure 3 State of the first and last (test) station before optimization - 3D model

First, we added a small camera for visual inspection to the test station (**Figure 4**). I would choose a Keyence X-ray camera that could be mounted on top of the tester, and in parallel with testing the electrical and mechanical properties, we would be able to use the camera to find out if the finished product also has any visual defects or damage. Although the cycle time does not accelerate at the last station, it saves us the time needed for collection by the operator, who also had to visually check the finished piece during collection. Each visual inspection by the operator lasted about 2-3 seconds. This also saved the operator from taking the finished pieces. If, after testing the given piece, it turns out that the piece is in order, it immediately proceeds to the box of the finished production. If it turned out that the piece had an error after either a mechanical or visual inspection, it would proceed to the scrap box.

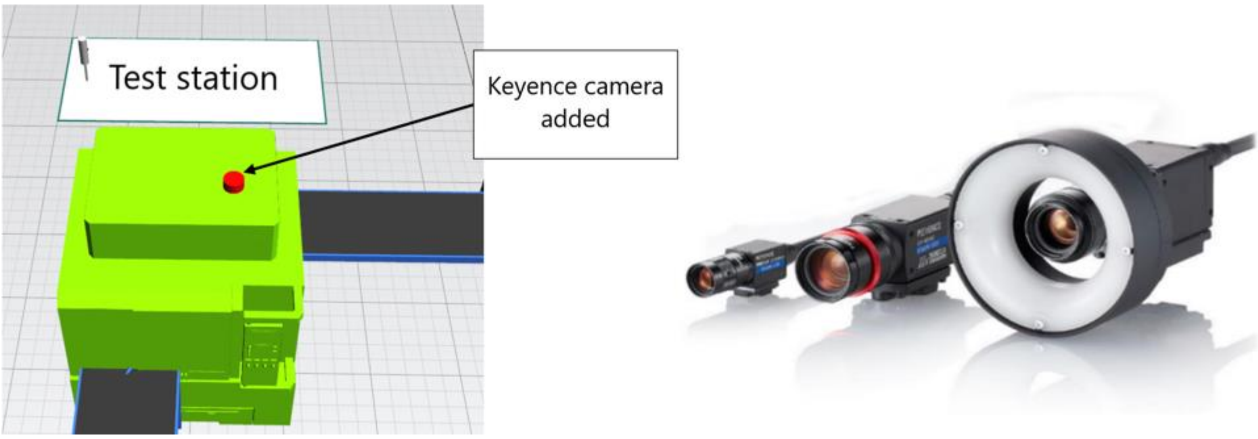

Figure 4 Modified test station after adding Keyence camera

The second improvement proposal is the implementation of the KUKA robotic arm, which will place the individual components on a pallet and directly in the nest, as the operator did. We would fasten this robot flush with the conveyor belt along which the nest pallets move so that there is no unnecessary downtime between the individual movements between the components and the nest so that the robot makes minimal movement in the shortest possible time. The advantage of this step will be that the line would change from a semi-automatic to a fully automatic line. Another advantage is that the production time is increased since, in a semi-automatic line where an operator works at the first station, the operator has a 1-hour break with a 12-hour change. With a fully automatic line, production would run continuously for 12 hours. Another advantage of this exchange is that the cycle time at this first station is reduced by about 3 to 3.5 seconds, which we can expect a higher output with a 12-hour change. In **Figure 5** we can see the proposed Robot Kuka-KR QUANTEC ultra, which is suitable for application and operation on the optimized Station 1.

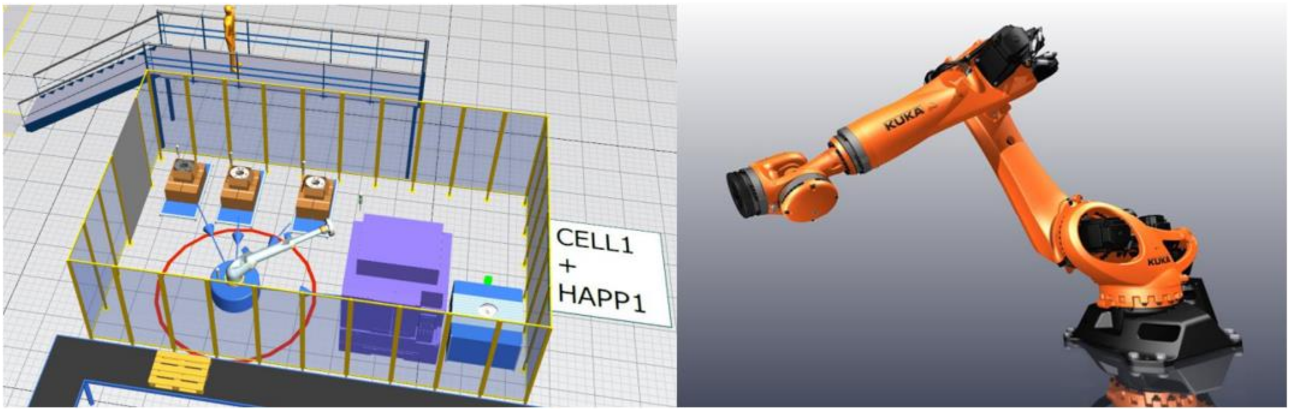

Figure 5 Optimization on station 1 using Robot Kuka-KR QUANTEC ultra - 3D model

After applying these two implementation proposals, the line works as in the current layout, all stations are preserved, as well as production times on them. The line is simulated in 2D and 3D in the Tecnomatix Plant Simulation program (**Figure 6**). The simulation is created mainly in 2D view, where we set the main functions and settings of the lines, their cycle times and also the individual methods. We subsequently converted the line simulated in this way into a 3D version, for better perception and presentation of the given line.

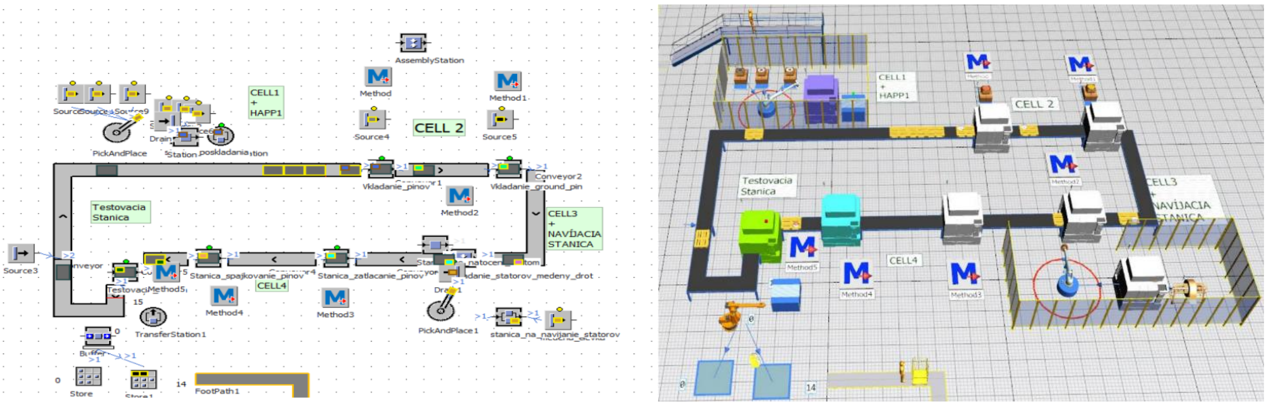

Figure 6 2D and 3D version of the production line after design implementation

After adding improvement designs to the simulation, we were able to track certain changes that took place in the production process on the production line. After adding a robotic arm to the first station, our production time at the first station was slightly adjusted and a change also occurred in that we turned the semi-automatic line into an automatic line. As a result, we have removed the necessary break for the operator who worked at the first station, and thus we have a 12-hour working time in this variant from the net 11-hour time. With this step, we gained 1 hour of net working time per change, which will then be reflected in the output of the number of finished products. Other production times at other stations did not change significantly.

4. CONCLUSION

The aim of the paper was to point out the importance of implementing the simulation in the evaluation, streamlining and optimization of production processes. This area facilitates the implementation and saves resources both in the planning and implementation of new production processes and in the restructuring of existing processes. It is an excellent tool not only for project evaluation and selection of the most suitable variants of process changes, but also a good marketing tool for presenting the results of these proposals, as long as it is processed at a good graphic and digital level. Current versions of simulation modules offer the opportunity to present the processing and results of the simulation by projection with the help of virtual reality. Thus, it is possible to see real outputs physically and in detail, processed not only on a computer monitor, but also transformed into a more realistic image.

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