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Analysis of the Utilization of Machinery in the Production Process Using Computer Simulation

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Abstract. For the efficient operation of each production process, individual machines and equipment must be used in the maximal possible measure. For this reason, it is necessary to know their utilization and to take measures to ensure their effective use. For performing such an analysis and to design subsequent measures, the use of the computer simulation method is very effective, e.g. simulation in Tecnomatix Plant Simulation program.

1 Introduction

The production process has a major impact on the efficiency of each industrial enterprise. It affects its market position, its ability to compete, satisfying the requirements of individual customers, and, last but not least, influences the overall economic situation and logistics [1, 2]. For the proper functioning of the transformation process, it is necessary to make effective use of available production capacities, machinery, and equipment [3, 4]. This is a problem that many people still underestimate and do not pay adequate attention to it. A frequent argument why they neglect this fact is the difficulty of collecting and evaluating information. However, current production logistics recognizes several methods that can be efficiently used to solve the problem, such as the use of Petri Nets [5] and the method of computer simulation [6].

Precisely the method of computer simulation is a very effective means. More specifically described by Chramcov et al. [7]. In their contribution, the specific use of heuristic algorithms is discussed. Heuristic algorithms can be used, for example, for reducing economic costs [8]. This issue is more closely dealt with by Bucki et al. [9], which focuses on automated manufacturing systems in his research.

However, heuristic optimization can also be used in the creation of production plans as described [10]. This is specifically about the use of discreetly oriented simulation for the need to efficiently optimize the planning of the production process [11]. A similar issue was dealt with also Bensmaine et al. [12].

As follows from mentioned, the computer simulation method has a wide spectrum of applications in logistics. For this reason, it was also used in the analysis and subsequent

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adjustment of the production process of the selected part from the assembly of welding pliers.

2 Characteristics of the production process

The production process of the selected part from the welding pliers set, which is shown in Fig. 1, begins by aligning the clamping surfaces on a conventional milling machine, which takes about 2 minutes. At the same time, the program is created by the 3D model and drawing documentation that lasts 30 minutes. Meanwhile, the trained operator clamps the part into Machine 1. The generated program is inserted into the machine and the NC production is started.

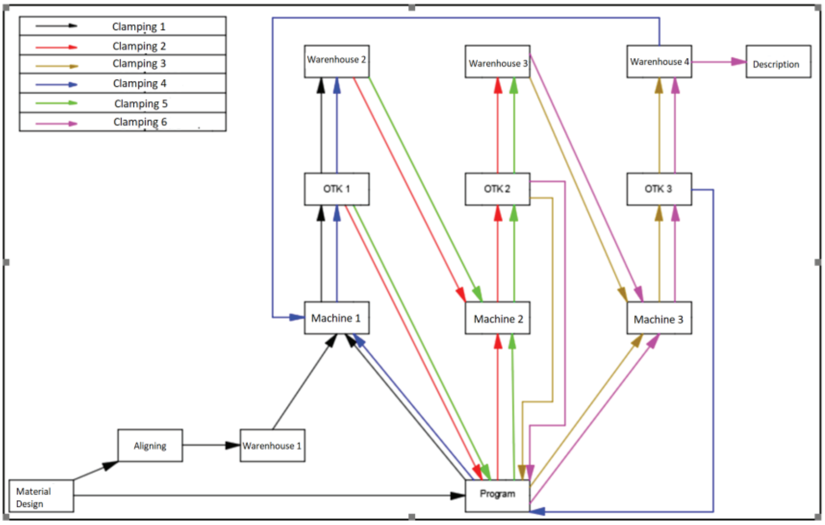

Fig. 1. Diagram of the production process. Source: authors

After the first clamping (Fig. 2), which lasts for 30 minutes, a part goes through the control (OTK). If the checked part is in good order, production continues and every fifth piece is checked. The parts are stored while the programmer generates the program for the second clamping to be run on Machine 2. In parallel with the creation of the program, the operator clamps the part and arranges the tools according to the instructions of the programmer. This operation ends after 25 minutes (Fig. 2).

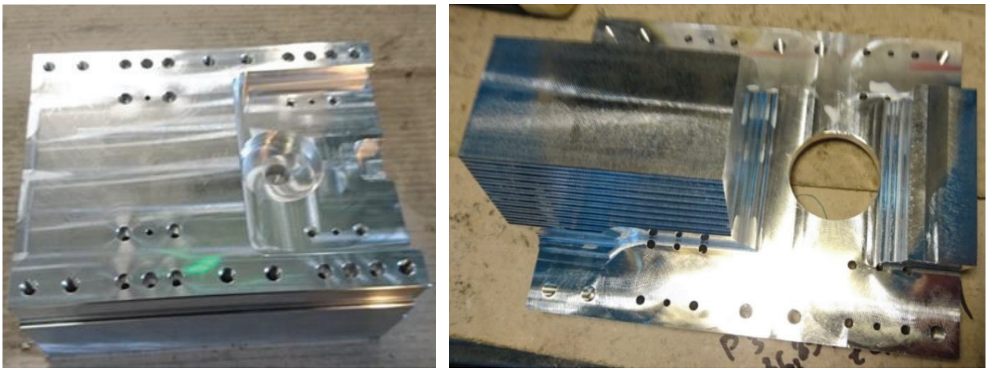

Fig. 2. A machined part after the first clamping and the second clamping. Source: authors

If a worker at control approves the quality of the part manufactured, production continues and checked is every tenth piece because the correctness of the manufactured part can be easily visually checked by the servicing worker in the machining center.

The parts are moved to the warehouse and the programmer generates the third clamping program (Fig. 3), which takes 45 minutes. The production in the third machine is running for 30 minutes. The difficulty of this process requires a check of every third part. After the third clamping is waiting for Machine 1, in which the fourth clamping will take place (Fig. 3). Production proceeds the same procedure till the sixth clamping (Fig. 4), working times are variable and are listed in Tab. 1.

Table 1. Working times for individual operations and clamping. Source: authors

Program	Programming [min]	Machining [min]	Control [min]
1. clamping	30	30	2
2. clamping	20	25	1
3. clamping	45	30	4
4. clamping	10	6	0,5
5. clamping	15	5	1
6. clamping	20	10	10

The first clamping (Fig. 2) serves as a priority for creating the surfaces on which the next clamping is performed. At the same time, tolerated holes are drilled in the component, which could be created even with the third clamping, but it would be technologically more demanding. Milling resulted in surface areas that serve to clamp the blank in the following operations. When the first piece passes through the check, a stop is installed in the machine, making it easier for the operator to replace the blanks and eliminating the need to focus each workpiece separately.

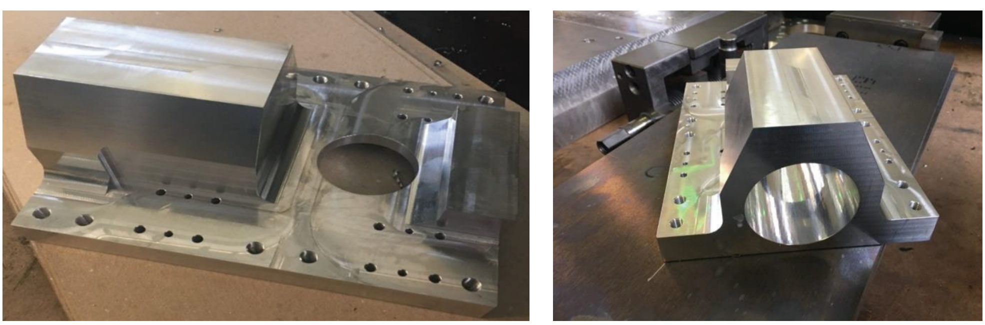

Fig. 3. A machined part after the third clamping and the fourth clamping. Source: authors

There is a part after the finishing operations in Fig. 3. Its dimensions are identical to the drawing documentation, which is achieved by the smaller forces needed to hold the material in the machine. After this machining, increased attention is paid to the control as the resulting elements are geometrically tolerated. The check is carried out on every third piece, since the elements that are created fit exactly into the welding pliers' assembly.

After the third clamping, the blanks are stored on the pallets until the Machine 1 is released from working in the first position. After it has finished, it is necessary to clean the machine, arrange the tools and set the clamping device that is specific for this kind of machining. The operation performed here consists of milling an exact hole (Fig. 3). Zero point focusing as well as the measurement to control adherence to tolerated dimensions is automatic and performed by the machining center with a workpiece probe. The check is simplified and therefore only every fifth piece is checked outside the machine.

After the machine 2 is released, the machining center is ready for fifth clamping. This clamping consists of a T-shaped groove milling (Fig. 4) into which the metal segment of the assembly fits. The focus is also performed automatically. Check measurements are performed by the operator outside the machine.

In the final phase of the production process (Fig. 4), the welding joint is formed on the part together with screw holes ensuring its functionality. The parts in this form head to the output control, where the trained worker checks them using the 3D measuring device. Products that have passed the final control are marked with a labeling device. The description consists of the assembly number, position number, and date of manufacture. The expedition worker is responsible for correctly packing products in boxes, which includes preventing damage during shipment to the customer and marking the shipment for easier identification of packaged products.

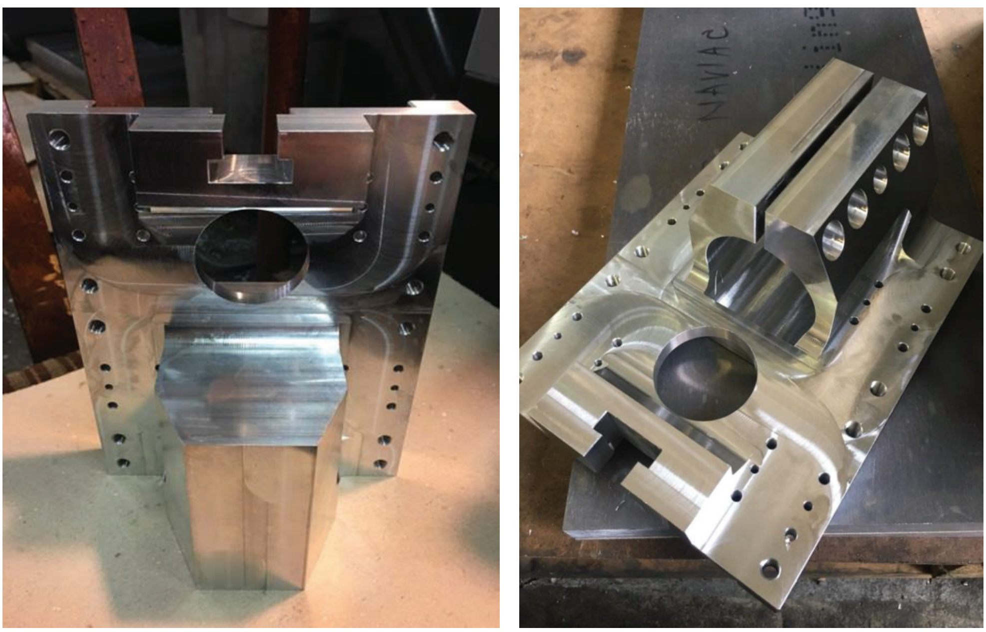

Fig. 4. A machined part after the fifth clamping and the sixth clamping. Source: authors

3 Simulation model

The entire production process as described has already been realized inefficiently from the point of view of utilizing the capacities of individual machinery. However, there was no information available that would accurately quantify the percentage utilization of available machinery capacities. For this reason, it was necessary to analyze the whole process in detail, using the method of computer simulation.

The outputs of the individual simulation experiments are the time values of the whole process, the percentage expression of the machine utilization, their downtimes and the storage space utilization (Fig. 5). After finishing the simulation of the existing production process, the total production time (Fig. 6) of 500 pieces with 3 machines was determined.

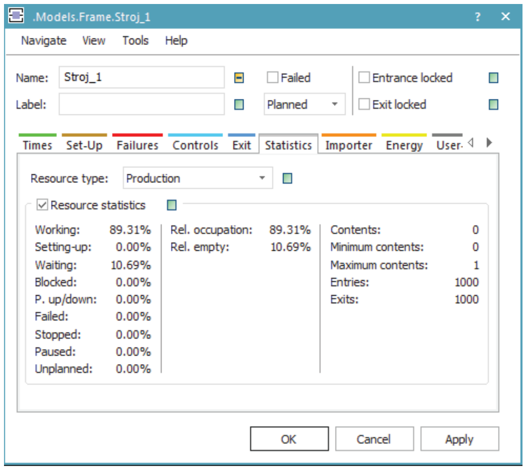

Fig. 5. Output values of the Machine 1 after the production process simulation. Source: authors

Simulation time: 13:23:54:00.0000

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Popisovanie	Vstup	12:01:39:34.5600	500	1	0.64%	0.00%	99.36%	0.64%	

Fig. 6. Output values in Tecnomatix program after the production process simulation.

Percentage utilization of machines and their downtimes are shown in Tab. 2. As obvious from results, the production process used in the company for the work order processing is not ideal. Machine 2, for example, shows downtime of 25.57 % of the total working time. The task was, therefore, to try to optimize the process to achieve higher efficiency of work equipment.

Table 2. Results of original production process simulation. Source: authors

Machine	Working time [%]	Downtimes [%]
Machine 1	89.31	10.69
Machine 2	74.43	25.57
Machine 3	99.24	0.76.

4 Proposal for efficient machines utilization

On the basis of the information obtained from the simulation experiments and the material flow analysis, several variants were proposed to redistribute the activities of the machines so that the most time-consuming clamping in the production process were processed by several machines at once (Tab. 3). This has been supposed to shorten the total time needed to produce the chosen component, increase machine utilization and eliminate downtime that is undesirable in existing production.

Based on suggestions for possible solutions, the first clamping was divided into the devices - Machine_1 and Machine_2. This operation ended at both machining centers at the same time. Meanwhile, Machine_3 would work on the second clamping, and also Machine_1 after the work there was finished.

Machine_2 then processes the blank with a third clamping. By analogy, after the processes that run on the remaining two machines are completed, they are connected to the second machining center, so all available devices work on the third clamping together until they complete it.

The fourth clamping was again assigned to machines - Machine_1 and Machine_2. Machine_3 then performs the fifth component manufacturing process in sequence.
The final operation is run on Machines 1 and 2 again.

Table 3. Proposal for reallocation of processes between individual machines. Source: authors

Clamping	1.	2.	3.	4.	5.	6.
Machines	**1**	**3**	**2**	**1**	**3**	**1**
	2	**1**	**3**	**2**		**2**
			1			

At the end of this experiment, the overall simulation time was found to be shorter compared to the production process currently used by the company. By using an optimized production process, 500 units on 3 machines are manufactured in 12 days 15 hours and 41 minutes (Fig. 7). The difference between these two processes is 1 day 8 hours and 13 minutes.

Simulation time: 12:15:41:00.0000

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Drain	Vstup	11:14:18:17.1600	500	2	0.66%	0.00%	99.34%	0.66%	

Fig. 7. Output values in Tecnomatix program after work process optimization. Source: authors

Percentage of machines downtime has decreased significantly in this production process and the production on the machines has increased. The production on all machines and their downtime before and after optimization is listed in Tab. 4.

Table 4. Results of a modified production process experiment. Source: authors

Machine	Productivity [%] after/before the change	Downtimes [%] after/before optimization
Machine 1	99.69 / 89.31	0.31 / 10.69
Machine 2	99.83 / 74.43	0.17 / 25.57
Machine 3	91.35 / 99.24	8.65 / 0.76

5 Conclusion

The problem of determining the use of machinery in the production process with a focus on optimizing and subsequently increasing machine productivity is relatively simple but very effective when using computer simulation [13]. Several available simulation software can be used to verify proposals. In the case described in the paper, the simulation program Tecnomatix Plant Simulation was used, in which the basic model of the production process was created.

The model corresponds to the actual process used by the company to produce the specified component. This process at first glance showed signs of inefficiency, which was confirmed by the results of the simulation experiments.

The adjustments that could be made in the production were limited by the company's conditions. Only three machining centers could be used for the production, and only improvements were made that were attainable with the equipment that the company has. Therefore, the adjustments concerned mainly logistics or more efficient division of production among machines.

Prior to optimization, the 90 % productivity limit exceeded only one machine. Machining center number 2 showed a high value of downtime. Of the total processing time, it was more than 25%. The total production time of the 500 products was 13 days, 23 hours and 54 minutes.

The next step was to create an optimization proposal that was applied to the previous model. The result has increased the productivity of all machines beyond 90% and reduced downtime below 10%. The total production time was significantly shortened, which can be considered a great result.

However, this procedure should also be applied to the production of the remaining parts of the assembly ordered by the customer. This application of computer simulation and subsequent optimization is evidence of the importance of paying attention to factors influencing the transformation of inputs to outputs of the production process. In a relatively simple way, by using software simulation, it is possible to reduce costs, increase production and improve the ability of an enterprise to compete in a particular market.

Regarding Tecnomatix program, program basic functionality is quite simple at first glance, but possibilities of this program are almost unlimited thanks to the SimTalk language [14]. This is also related to the area for which this software is intended [15]. Using this program, it was possible to model the production process and immediately perform the simulation. But fine-tuning the correct behavior of the entire process was achieved by logic programming that was relatively complicated and time-consuming.

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