

Simulation and Optimization of Saw Blade Production in Plant Simulation

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ABSTRACT

The aim of this paper is to propose improvements of the selected production process, which would contribute to its optimization and it is oriented on very important topics, which nowadays simulation and optimization surely are. Secondary goals of this paper are oriented on the introduction of simulation software Plant Simulation, because this software is one of the best software on the market and is widely used in practice. Practical application of the software is oriented on the production process of saw blades. Results of this work is the optimization of the production system in concrete conditions, which bring specific improvements in concrete case - increased pieces of final product, better utilization of production time and reduction of storage times to minimum.

Keywords: saw blade, Plant Simulation, optimization, production process, simulation model.

INTRODUCTION

The development of technology allows the managers of companies to decide about the usage of simulation programs, which are a trend of today's competitive environment. Simulation programs are tools that test the effects of different decisions on the model and then evaluate production capacities, duration of operations and other production parameters [1]. They also eliminate the possibility of introducing a change into the process that would not be advantageous for the process. In the paper, we will create a simulation of the concrete production process.

Simulation is a support tool that allows you to test the effects of different decisions on a simulation model. It is the modern tool for the analysis of individual business processes [2]. To reduce risk, we can verify in advance by „replaying“ the process and its behavior after making the changes that we require, verify the future behavior of the system, which can be removed in advance, avoid it, as well as solve any problems [3]. This allows

us to better clarify and understand the production processes during real production process [4]. Computer simulation has the ability to evaluate the capacities of the production layout, the operation of the transport and storage system, information flow and management system [5, 6].

Simulation and simulation programs are now increasingly used in industrial enterprises. Competition pressure and customer requirements are still increasing, so businesses need to simulate production processes [7, 8]. The simulation program Plant Simulation is now one of the top simulation programs and therefore we selected it [9].

Plant Simulation (previously eM-Plant, Simple ++) is standard software for simulation of very complex production systems and managerial strategies. Object orientation, graphical and integrated modeling, simulation and animation of systems and business processes characterize the tool named Plant Simulation [10].

The aim of this paper is the creation of a simulation model of the saw blade production process

and consequently to propose the possibility of improvements of this production process.

Characteristics of Plant Simulation

Businesses are increasingly trying to improve on-going production processes to become optimal. Plant Simulation is the ideal solution to improve the current state of production processes [11]. The biggest advantage of this software is that we introduce the changes to the process after data analysis from the simulation, i.e. if the optimization has been achieved [12, 13]. The working environment in Plant Simulation is in Figure 1.

Siemens Plant Simulation is a tool for creating digital models and on the basis of these models we can create simulations. The power of simulation experimentation is that it can create scenarios of the future state at the time of planning [14]. The possibility to use extensive analytical tools such as statistics, charts and diagrams is the reason why output is always measurable and well-founded results. Thus obtained results provide us information that are important for quick and correct decisions even in the early planning phases and also shorten the production start. Plant Simulation can create simulations of planned but also of real processes [15, 16]. The generated simulations acquire real values, with which the user can

experiment without any intervention into production [17]. Plant Simulation also delivers cost reduction in the enterprise.

Plant Simulation currently utilizes every successful enterprise in various industrial areas, without exception of their size. Every day they rely on the power of simulation that gives them competitive advantages on the market [18]. Using Plant Simulation, we can model; simulate production systems and their processes. We can also:

- Optimize material flow.
- More efficient utilize the resources.
- Improve logistics processes.

The procedure of saw blades production

Saw blades are mainly used for quick and simple sawing of wood. Their production will be described in the following steps:

1. The first step in producing a saw blade is the movement of the steel sheets of the desired thickness to a laser device which cuts out from the steel sheet a toothed disk in the basic shape of the saw blade (Figure 2).
2. The next step is the manual selection of individual discs from steel sheet (Figure 3).
3. Then follow the manual insertion of the cut-out discs into the slotting machine and the grooving on both sides of the disc. This grooving prevents

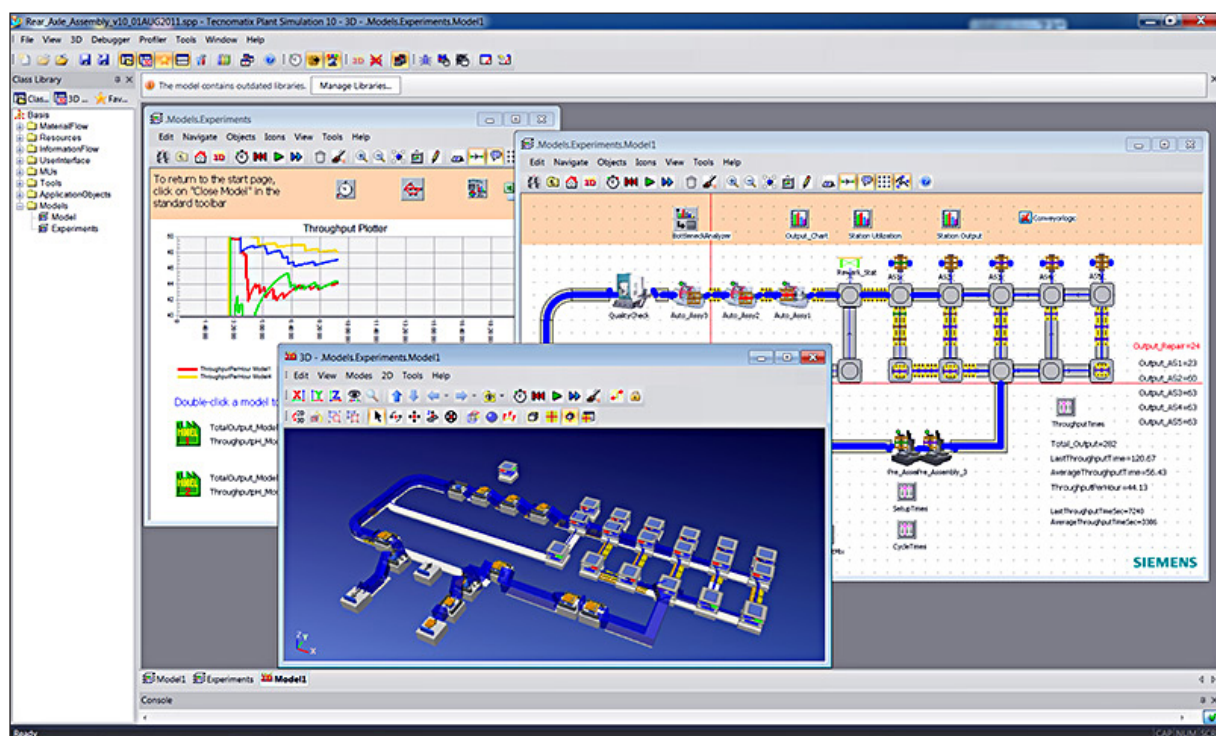


Fig. 1. Working environment in Plant Simulation

vibrations during cutting, which is extremely important for straight cutting with saw blades.

4. The manual measurement of disc grooves unevenness is shown in Figure 4.
5. Later is performed rolling of the saw blades to compensate the unevenness of the disc.
6. Polishing of saw blades for removal of all impurities from previous production is shown in Figure 5.
7. Then follows burning of the saw blades in the furnace, which achieves a high hardness of the discs, takes about 24 hours.
8. Carbide tips on the teeth of the discs are in the meantime controlled by the laser whether they



Fig. 2. Laser cutting machine

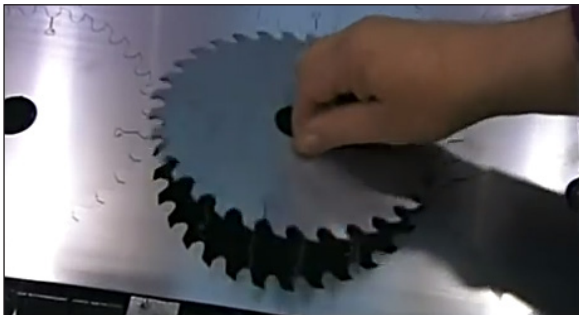


Fig. 3. Manual selection of individual discs from steel sheet



Fig. 4. Manual measurement of disc grooves unevenness

are correctly set for the next step, as shown in Figure 6.

9. Then, one of these carbide tips is grasped by the robot and transferred to the nozzles that eject the flux on it. Another robot places a metal solder on the flux and thus the carbide tip is delivered to the saw blade. Hard soldering melts resistive wires and flux. This process joins the carbide tip to the saw blade (Figure 7).
10. The next step in the production is to place the saw blade on the shaft. The disc is there slowly rotated while sanding through the spray nozzle (Figure 8). With this process, the saw blade is devoid of all impurities and has a specific structure.
11. In this step, each saw blade is tapered by grinding. The individual teeth are moved by



Fig. 5. Polishing of saw blades



Fig. 6. Carbide tips check laser control

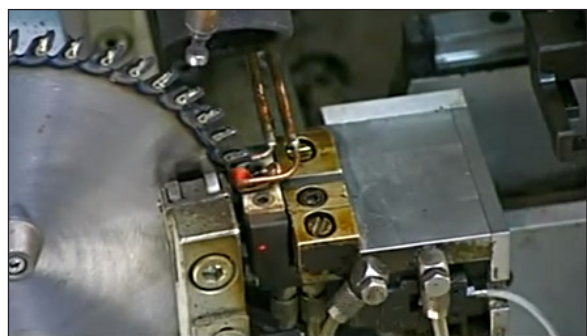


Fig. 7. Hard soldering of carbide tip and saw blade

a mechanical finger. With the further grinding wheel is grinded the outside edge of the teeth (Figure 8). Next starts the grinding of the front of each tooth to achieve a sharp edge.

12. Then starts manual knocking out of the unevenness of the saw blade and when the disc has been knocked out, the worker has to check the wheel (Figure 9).

13. The last step in the production is to check the teeth of the disc with a computer. The camera scans each tooth step by step and the records are sent to the computer. The computer examines whether the cutting angle and shape of the wheel's teeth meet the required quality (Figure 10).



Fig. 8. External grinding of saw blade teeth



Fig. 9. Manual knocking of saw blade unevenness



Fig. 10. Computer control of saw blade

Proposal of simulation solution for selected production process in Plant Simulation

Inputs will represent the following 5 specific items:

- Steel plate.
- Carbide tips.
- Trucks.
- Flux input.
- Solder input.

It will be also necessary to create individual workplaces for activities that occur within the production process:

- Laser cutting.
- Grooving the disc.
- Measurement.
- Rolling.
- Polishing.
- Burning.
- Laser check.
- Application of flux (or assembly).
- Location of solder (or assembly).
- Sanding.
- Teeth grinding.
- Knocking out.
- Computer teeth control.
- Packaging.


In the simulation we will use conveyors and trucks to move between workplaces, so we will create a conveyor and truck object. The track is necessary to move the truck. In the Mobile Units folder, you'll find the following items:

- Saw blade.
- Carbide tips.
- Truck.
- Flux.
- Solder.

According to layout of the production hall, we place individual objects in the Plant Simulation workspace (inputs, objects representing processes, output). Future simulation functionality will be ensured using the object Connections. Between the workplaces according to the hall design, we deploy conveyors or the road for the truck movement. The next step is to set each object and then start of the simulation.

After these settings, we'll look at the timing of individual objects located in the workspace. The input of the Steel store will be the beginning of the simulation run, so all times will be 0. For the input of the truck we will mark Creation time 0:01, which is 1 second.

Table 2. Basic statistical output from Plant Simulation

Object	Name	Mean life time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Saw blade	Disc after soldering	14:24:1654	81	10	95.66%	3.88%	0.46%	72.90%	

program opens the new window and we can see statistics about:

- The working time of individual machines.
- The material flow passing through the individual simulation objects.
- The robot rotation time.
- The setting times.
- The waiting times.
- The unused time.
- The output (pending and working time, number of outputs, number of outputs per hour).

From these different statistics, we first introduce material flow statistics (Table 3) in objects where you can see the amount of material inputs into individual program objects (devices). Table 3 doesn't contain data about all objects that are in the model. Through this table we demonstrate that Plant Simulation (when it is properly used)

can provide users a lot of necessary statistical and mathematical data that they would otherwise have to calculate using different methods.

We also introduce Table 4, which shows the individual working times of the objects

Proposals for improvement of saw blade production

The production of saw blades is partly automated, but there are still places in production that could be improved. The possibilities for improving the process are clearly seen in the following places:

- Transport of material in the production hall between workplaces through the truck.
- Manual measurement of the unevenness of saw blade grooves.
- Manual feeding of saw blades into the machine at some workplaces.

Table 3. Statistical material flow data

Object	Number of entries	Number of exits	Minimum contents	Maximum contents	Relative empty	Relative full
Steel store	84	84	0	1	97.81%	-
Road	1938	1937	0	1	50.00%	-
Road 1	1937	1937	0	1	50.00%	-
Truck	1	1	0	1	100.00%	-
Transfer station	84	84	0	1	97.08%	-
Transfer station 1	84	84	0	1	97.08%	-
Buffer	84	84	0	1	98.25%	1.75%
Road 2	2255	2254	0	1	50.11%	-
Road 3	2254	2254	0	1	50.13%	-
Transfer station 2	84	84	0	1	97.08%	-
Transfer station 3	84	84	0	1	97.08%	-
Truck 1	1	1	0	1	100.00%	-
Grooving	84	84	0	1	91.25%	-
Buffer 1	84	84	0	1	98.24%	0.00%
Road 4	2700	2700	0	1	50.21%	-
Road 5	2700	2699	0	1	50.24%	-
Truck 2	1	1	0	1	100.00%	-
Transfer station 4	84	84	0	1	97.08%	-
Transfer station 5	84	83	0	1	97.09%	-
Unevenness measuring	83	83	0	1	92.80%	-
Rolling	83	83	0	1	93.05%	-
Polishing	83	83	0	1	82.71%	-
Road 6	3372	3371	0	1	50.28%	-

Table 4. Statistical data about working time

Object	Portion	Count	Sum	Mean Value	Standard Deviation
Steel store	0.00%	0	0.0000	0.0000	0.0000
Road	47.08%	2022	3:46:00.0000	6.7062	1.3520
Road 1	47.08%	2021	3:45:59.0000	6.7091	1.3463
Truck	0.00%	0	0.0000	0.0000	0.0000
Transfer station	2.92%	84	14:00.0000	10.0000	0.0000
Transfer station 1	2.92%	84	14:00.0000	10.0000	0.0000
Buffer	0.00%	0	0.0000	0.0000	0.0000
Road 2	46.97%	2339	3:45:27.0000	5.7832	1.0704
Road 3	46.96%	2338	3:45:24.0000	5.7844	1.0696
Transfer station 2	2.92%	84	14:00:0000	10:0000	0.0000
Transfer station 3	2.92%	84	14:00:0000	10:0000	0.0000
Truck 1	0.00%	0	0.0000	0.0000	0.0000
Grooving	8.75%	84	42:00.0000	30.0000	0.0000
Buffer 1	0.00%	0	0.0000	0.0000	0.0000
Road 4	46.88%	2784	3:45:00.7500	4.8494	0.8111
Road 5	46.86%	2783	3:44:55.2500	4.8492	0.8126
Truck 2	0.00%	0	0.0000	0.0000	0.0000
Transfer station 4	2.92%	84	14:00:0000	10:0000	0.0000
Transfer station 5	2.91%	84	13:57.0000	9.9543	0.3273
Unevenness measuring	7.20%	83	34:35.0000	25.0000	0.0000
Rolling	5.76%	83	27:40.0000	20.0000	0.0000
Polishing	17.29%	83	1:00.0000	1	0.0000
Road 6	46.63%	3455	3:44:46.0000	3.9039	0.5745
Road 7	46.82%	3454	3:44:44.0000	3.7844	0.5745
Truck 3	0.00%	0	0.0000	0.0000	0.0000
Transfer station 6	2.88%	83	13:50.0000	10.0000	0.0000
Transfer station 7	2.88%	83	13:50.0000	10.0000	0.0000
Buffer 2	0.00%	0	0.0000	0.0000	0.0000
Burning	12.97%	83	1:02:15.0000	45.0000	0.0000
Hard soldering	0.00%	83	0:0000	0.0000	0.0000
Sanding	34.58%	83	2:46:0.0000	2:00.0000	0.0000
Teeth grinding	69.03%	83	5:31:19.2168	3:59.5086	4.4765
Knocking out	17.08%	82	1:22:00.0000	1:0.0000	0.0000
Control of saw blade	42.71%	82	3:25:00.0000	2:30.0000	0.0000
Packaging	17.08%	82	1:22:00.0000	1:00.0000	0.0000
Saw blade	0.00%	81	0.0000	0.0000	0.0000
Line	100.00%	1	8:00:00.0000	8:00:00.0000	0.0000
Conveyor	100.00%	1	8:00:00.0000	8:00:00.0000	0.0000
Conveyor 1	100.00%	1	8:00:00.0000	8:00:00.0000	0.0000
Road 8	47.38%	2811	3:47:24.0000	4.8538	0.6001
Road 9	47.36%	2810	3:47:20.0000	4.8541	0.7995
Transfer station 8	1.42%	82	6:50.0000	5:0000	0.0000
Buffer 3	0.00%	0	0.0000	0.0000	0.0000
Laser cutting	11.67%	84	56:00.0000	40.0000	0.0000
Conveyor 2	100.00%	1	8:00:00.0000	8:00:00.0000	0.0000
Laser control	61.29%	2531	4:54:11.0000	4.9989	0.0673
Conveyor 3	100.00%	1	8:00:00.0000	8:00:00.0000	0.0000
Line 1	100.00%	1	8:00:00.0000	8:00:00.0000	0.0000
Flux application	24.50%	3528	1:57:36.0000	2.0000	0.0000

Table 4. Cont. Statistical data about working time

Line	24.48%	3525	1:57:30.0000	2.0000	0.0000
Conveyor 4	100.00%	1	8:00:00.0000	8:00:00.0000	0.0000
Flux input	0.00%	0	0.0000	0.0000	0.0000
Robot	15.33%	7057	1:13:35.3244	0.6257	0.0000
Solder input	0.00%	0	0.0000	0.0000	0.0000
Robot 1	15.32%	7051	1:13:31.5704	0.6257	0.0000
Buffer 4	0.00%	0	0.0000	0.0000	0.0000
Saw blade input	0.00%	0	0.0000	0.0000	0.0000
Truck 4	0.00%	0	0.0000	0.0000	0.0000
Transfer station 9	1.42%	82	6:50.0000	5:0000	0.0000
Buffer 4	0.00%	0	0.0000	0.0000	0.0000

We suggest conveyor belt (Figure 13) for transport between workplaces, which would save time for workers, remove inter-operational warehouses and thereby make production more transparent.

The cost of the conveyor depends on its length and width. The width of the conveyors would be equal (700 mm). This improvement would increase the flow of production. Conveyors would be placed instead of trucks between the following objects:

- Steel store and laser cutting (6 meters).
- Laser cutting and grooving (6 meters).
- Grooving and unevenness measuring (6 meters).
- Rolling of discs and polishing (5 meters).
- Teeth grinding and knocking out (5 meters).

Manual measurement of the unevenness of saw blade grooves is work-intensive and lengthy, so it would be profitable to buy a laser device for measuring unevenness (Figure 14). This would shorten production time, making work easier for workers, because it is a monotonous and hard-working job for eyes.

The laser distance sensor will be between the grooving and rolling operation. A belt conveyor is placed between these operations according to the new design. At the edge of the belt conveyor

a laser sensor would be mounted to measure the groove diameter (Figure 15).

In Plant Simulation, we will not add this laser sensor as an object, because the time of the groove distance measurement takes only a few seconds, which doesn't have a significant effect on the simulated process. In Figure 16 there is a simulation section that relates to grooving



Fig. 14. Example of laser device for measuring unevenness



Fig. 13. Example of conveyor belt



Fig. 15. Measuring the saw blade diameter

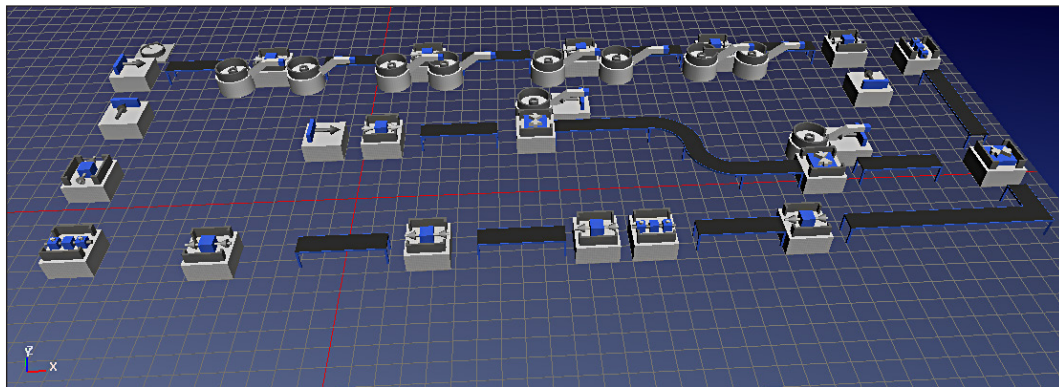



Fig. 20. 3D simulation model after the proposed improvements

Table 5. Basic statistical output after implementation of improvements

Object	Name	Mean life time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Saw blade	Disc after soldering	13:47:9665	79	10	97.89%	2.11%	0.00%	79.09%	

implementation of the improvements (Table 5) with the data before improvement (Table 2).

After comparison, we found out that the number of outputs (saw blades):

- Increased by 2 pieces in 8 hours.
- The percentage of production time increased to 97.9%.
- Storage times were reduced to 0%.

CONCLUSION

This simulation model is a simplified version of saw blade production because it is not possible to look at all the settings, all the times, stoppages, etc. But Plant Simulation offers a wide range of simulation options, so detailed simulation is not a problem.

Businesses that need to find improvements in processes can this program undoubtedly help and can helping them to become market leaders if they will apply findings from simulations to practice. A disadvantage for some businesses may be the difficulty of program control or the lack of necessary objects in the object library for a 3D model, although these objects can be gradually added.

Our simulation model improve some crucial performance indicators in this production process of saw blade and the most important are that the output of production process increased by 2 pieces in 8 hours, also the percentage of production time increased to 97.9% and on the other hand storage times were reduced to 0 %.

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