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MODELING AND SIMULATING PRODUCTION PROCESSES WITH THE USE OF THE FLEXSIM METHOD

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The steel industry is committed to integrating digital concepts into its production and organization to be more competitive in the context of globalization. Approaches to optimizing simulations have been developed in the steel sector. In this article, a model was built and a simulation was carried out using the FlexSim program. The simulation made it possible to identify weak points in the production process of galvanized profiles, which will enable the introduction of corrective actions that will eliminate emerging discrepancies in the future. Therefore, the proposed model can reliably simulate the behavior of multi-process operations in the steelmaking process.

Keywords: steel, galvanized profiles, production, simulation, quality.

INTRODUCTION

The Polish steel industry has been developing very dynamically in recent years. Definitely faster than in other European countries. As a result, in 2021 Poland, in terms of steel consumption, became one of the three largest markets in the European Union. The rapidly growing demand for metallurgical products, but also the collapse of imports from across the eastern border, showed how insufficient the production potential of Poland is. In order to meet the entire demand of the economy for steel, the domestic industry should significantly increase its production capacity. This would change the structure of supplies, causing distributors and recipients to turn more towards the domestic steel industry. In addition, the rapid development of technology in the steel sector requires the integration of digital transformation, which will increase competitiveness in the context of globalization. Due to the complexity of production processes, the use of new technologies may result in the optimization of the entire steel production. Combining process automation, information technology and connectivity, the digitization of steel production can go beyond conventional automation of industrial production. In the future, the intelligent combination of different tools, such as factory and laboratory experiments, physical modeling and, above all, computer modeling, will play a significant role in the digitization process in the steel sector. The use of digital technologies allows the implementation of new processes throughout the value chain, from production and sales to services. In this respect, digitization means a holistic approach that covers all areas and functions of a company in order to exploit its digital potential and analyze every step of its value chain. For this reason, it should be emphasized that digitization is not a simple transition from „analog" to digital data. It is networking between business processes, creating efficient interfaces and integrated data exchange and management. Approaches to optimizing simulations have been developed in the steel sector. In particular, the study of potential changes in projects and operations is the goal of the development of decision support systems.

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DIGITAL TRANSFORMATION IN THE STEEL INDUSTRY

Simulation of warehouse processes in the steel industry allows you to build a virtual model of a real warehouse and test different variants of operations in a low-cost way, the higher the awareness of logistics processes and their importance for the organization, the greater the importance of simulation at the design stage. As a rule, large organizations with separate independent logistics departments expect warehouse processes to be simulated before they are physically launched in the warehouse. The simulation allows you to check what resources are actually necessary to achieve the intended goals. During the design phase, decision makers assume certain performance metrics [1]. Unfortunately, these are just assumptions resulting from mathematical calculations. Logistics systems are characterized by volatility. In the simulation, you can study the impact of variability on the functioning of the warehouse. Not all processes run perfectly, there are failures, unplanned delays in delivery or any other random event. The simulation model allows you to check such situations and prepare for their occurrence. Simulation models are also used to check whether the planned warehouse equipment (conveyors, rotary tables, racks, forklifts or AGVs) will meet the assumed expectations and allow for optimal performance [2]. The main goals of the simulation are to increase the planning accuracy, ensure transparency, understand material flows, identify "bottlenecks", optimize the strategy, as well as obtain guidelines and experience for the rapid implementation of the system implementation and its stable operation [3]. Simulation is related to defining, designing and constructing a general model and its detailed forms, describing the course of the experiment, preparing and analyzing the data on which the model operates, as well as analyzing and interpreting the results of the experiment [4]. Each simulation is a model or representation of the system. A useful model does not have to represent every detail of the system exactly. Including too many details in the model will make it inefficient and complicated [5]. The optimal model building consists in determining the level of detail that is sufficient to effectively solve the problem, because this is the purpose of using this tool [6].

PRODUCTION OF GALVANIZED PROFILES

The production of galvanized profiles begins with the design of the tools that will be used to profile the steel, Figure 1.

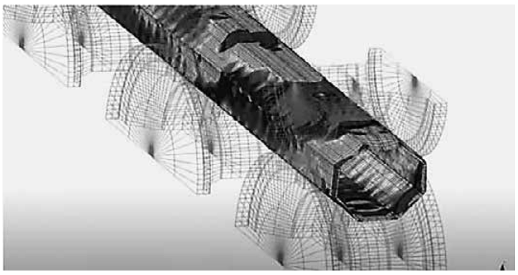

Figure 1 Profiling simulation [7]

Galvanized steel is the main raw material from which profiles are made. Steel coils are delivered from the steelworks, and each of them weighs about 10 Mg. The thickness of the sheet is from 1 to 5 mm. The layer of zinc coating is from 7 to 30 μm. The width of the sheet is about 1 250 mm, so it should be cut into strips from which the profile can be produced. The coil of steel is placed on the decoiler of the slitting line. After unrolling, the sheet goes to the section where the cutting knives are located. Up to 30 tapes can be made from one coil. The width of the tape needed to produce the profile ranges from 40 to 500 mm. The loop bottom is necessary to equalize the different winding speeds. Finished tapes are collected at the end of the line. The finished tape is delivered to the profiling line. The first process consists in smoothing the unevenness of the sheet by using a straightening machine. In order for the production to run smoothly, the ending strip is welded to the material from the next coilThe unrolled sheet goes to the accumulator, which is the buffer of the entire line, and then the material is continuously fed to the profiling part. At subsequent forming stations, the tape is gradually bent and in this way the desired shape of the profile is obtained. Depending on the type of profile, there can be from 5 to 15 bends. After the frames, the profiler, and at the point where the two bent parts of the profile meet, are welded with high-frequency current. After welding, excess material is collected with cutting knives. The next step is to protect the weld area with a zinc coating. Then the profile goes to the cooling chute where a special emulsion receives part of the heat generated during the process. This is a necessary procedure before the calibration stage, in which the profiles are straightened and get their final dimension. After calibration, the operator visually checks the quality of the weld and verifies the dimensions of the profile. The next step is to cut the profiles to the desired length using a flying saw. Then the profiles should be dried, and the table ensures the gravitational outflow of the emulsion that remained in the profiles after the subsequent stages of the process, Figure 2.

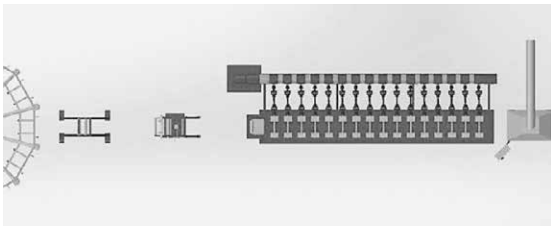

Figure 2 Profiling line [7]

Then two operators transfer the profiles to the storage table and form packages. The profiles are packed using plastic separators, thanks to which they will not touch each other. This prevents the formation of white corrosion. The finished package goes to the warehouse.

SIMULATION

The built model includes the operation of entry and unloading. The production process concerns the production of closed galvanized profiles with a round cross-section. The profiles were made of galvanized sheet, which effectively and permanently protects the structure against corrosion. Galvanized profiles are used wherever there is a need to increase the durability of the structure. The method of obtaining a profile with a circular cross-section was cold rolling. Three products were processed in the warehouse (profiles with a diam-

Table 1 **Parameter setting**

Name	Property	Data
Source	Inter-arrivaltime	exponential(0, 5, getstream(current))
Product_1	Process Time	10 s
Product_2	Process Time	15 s
Product_3	Process Time	18 s
Quality control	Process Time	4 s

eter of ø 27 x 1, ø 30 x 1, ø 40 x 1), which, after the cutting operation, were placed by the operators on the storage table and formed packages. Table 1 shows the product processing parameter settings.

The first stage of the work was to build a model based on the current layout, Figure 3.

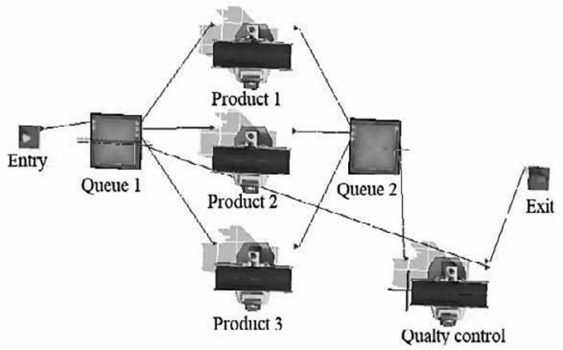

Figure 3 Magazine layout [7]

After the profiling process is completed, the products are delivered to one quality control station in order to check their correctness. If the product is well made, it will be delivered to the next stage of the process, and if not, it will be returned to the process again. The model includes a source, i.e. an order generator, three production lines and a quality control station.

Arrival of goods: The time interval for the arrival of the four kinds of goods is the exponential – exponential (0,5 getstream (current)). Figure 4 shows the processing parameters of three products with a diameter of ø 27 x 1, ø 30 x 1, ø 40 x 1.

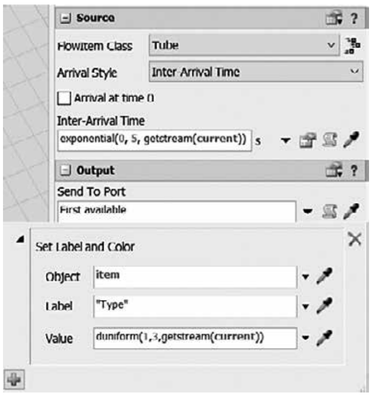

Figure 4 Product Parameters [7]

The four types of goods are used in red, green and blue.

Process 1~3: The processing time of the incoming inspection is subject to exponential (0; 10; 15; 18) distribution.

Queue: the goods are processed by the processor, which are transported to the appropriate location by transporter. It is assumed that 80% of the products are correct.

```
Object item = param(1);
Object current = ownerobject(c);
/***popup:Percentage:valuestr=Port*/
/**By Percentage*/
int stream = /**\nStream number: *//***tag:stream
*//**/getstream(current)/**/;
double randomnum = uniform(0,0, 100,0, stream);
double total = 0,0;
/***tagex:data*/
total += /**\nPercent: *//**/80/**/;
if (randomnum <= total)
return /** Port: *//**/1/**/;
total += /**\nPercent: *//**/20/**/;
if (randomnum <= total)
return /** Port: *//**/1/**/;/***/
```

The next stage is the quality control of the products, 20 % of the defective products marked in color (Product_1 - orange, Product_2 - black, Product_3 - pink) are returned to the process, Figure 5.

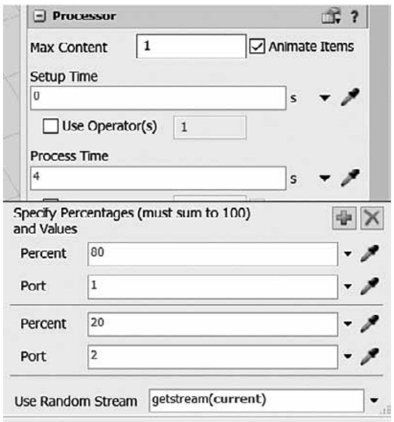

Figure 5 Quality control parameters [7]

The simulation time was set to one working shift, i.e. 28 800 s, and an additional warmup time parameter was used, i.e. the period during which the line does not work as if it were working in normal conditions, for example by changing the machine. During this time, the line does not reach its optimum capacity. The warmup time option allows data from this period not to be included in the statistics, Figure 6.

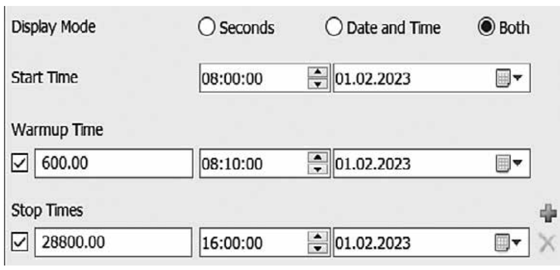

Figure 6 Simulation settings [7]

ANALYSIS OF THE RESULTS

The simulation was performed for 28 800 s, i.e. 8 hours, and a bottleneck was observed on the Product_1 and Product_2 machines, Figure 7. In addition, a graph of queue occupancy over time highlighted issues with

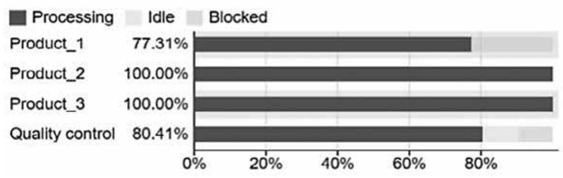

Figure 7 Use of machines [7]

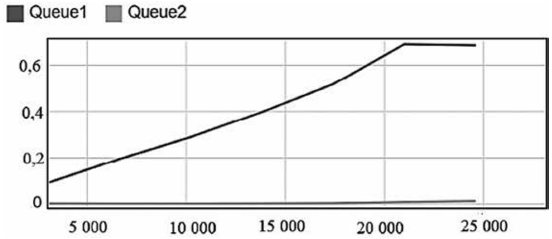

Figure 8 Use of queues over time [7]

long waiting times, Figure 8. The maximum capacity that reaches the first line is 500 pieces, while the second line only 33 pieces. Most products await processing. Total production per shift is 4 477 pieces.

It should be noted that the simulation model reflects reality to the extent that it has received accurate data. The simulation result is directly proportional to the data that will be used in the model. The simulation made it possible to identify weak points in the production process of galvanized profiles, which will enable the introduction of corrective actions that will eliminate any incompatibility in the future.

SUMMARY

Digital technologies are used to increase the flexibility and reliability of processes and improve the quality of products. In addition, they can be used to monitor and assess the environmental performance of processes, improve the control of production and auxiliary processes affecting the environment, and provide key performance indicators for efficient use of resources. In the case under consideration, the computer simulation method enabled the development of an effective model reflecting the functioning of a company producing closed galvanized steel profiles. For the purpose of optimizing the system in the manufacturing industry, the following were analyzed in the simulation studies: the duration of the entire technological process, the time of rebuilding the rolling mills, the time of downtime, the degree of use of equipment for the production process. On the basis of he simulation, bottlenecks and long waiting time for processing. The use of simulation tools enables virtual mapping of the real system, analysis of real data, conducting simulation experiments and selecting the best solution confirmed by the results. The future expectations of digitization in the steel industry include the optimization and interaction of individual production units throughout the entire production chain and beyond. This will ensure the highest quality, flexibility and productivity.

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Note: Nowak P. is responsible for English language, Katowice, Poland