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APPLICATION OF TECNOMATIX PLANT SIMULATION FOR MODELING PRODUCTION AND LOGISTICS PROCESSES

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Abstract. The main objective of the article was to present the possibilities and examples of using Tecnomatix Plant Simulation (by Siemens) to simulate the production and logistics processes. This tool allows to simulate discrete events and create digital models of logistic systems (e.g. production), optimize the operation of production plants, production lines, as well as individual logistics processes. The review of implementations of Tecnomatix Plant Simulation for modeling processes in production engineering and logistics was conducted and a few selected examples of simulations were presented. The author's future studies are going to focus on simulation of production and logistic processes and their optimization with the use of genetic algorithms and artificial neural networks.

Keywords: computer simulation, Tecnomatix Plant Simulation, modeling, digital model.

JEL Classification: C61, L23.

1. Introduction

In the contemporary, dynamic changing world, access to production data in real life is necessary to properly plan, simulate and supervise production. Companies operating in different sectors of the economy are more and more commonly using IT solutions to optimize logistic systems by improving the handling of materials and performance parameters. Computer simulations are the techniques and tools most frequently used in broadly understood production engineering, logistics or industrial engineering.

Along with the technological progress in the field of information technology and very rapid enhancing computing power, increases also the popularity of methods based on computer simulation (see Smith 2003). Moreover, to follow the technological and economic changes and dynamic developing global trends, the companies must react in a cost-effective, efficient and fast way (see Gola, Konczal 2013). To remain competitive, companies must design manufacturing systems that not only produce high-quality products at low costs, but also allow for rapid response to market changes and consumer needs (see Gola, Świc 2012).

Identifying errors in the planning phase is much cheaper for a company than doing that after the start-up of a project or its full implementation. Performing a computer simulation makes it possible to assess whether the project was designed properly and is being carried out as it should. Simulation provides a comprehensive perception of the studied process or product, allows to conduct multi-criteria analysis, and to test many scenarios. That is why computer systems are becoming necessary tools which support the design and improvement of business processes.

The terms "simulation" and "model" are often used in the work, hence it is necessary to provide their definitions. Quoting Bangsow (see Bangsow 2010) simulation is a representation of a real system including its dynamic processes in a digital model, allowing the transfer of conclusions to the reality. In a broader meaning, simulation means the preparation, implementation and evaluation of specific experiments with the use of a simulation model. Model is a simplified copy of a planned or real system, including its processes, in another system (see Bangsow 2010).

Regarding simulation, it is recommended to apply the following methodology presented at the Figure 1 (see Bangsow 2010):

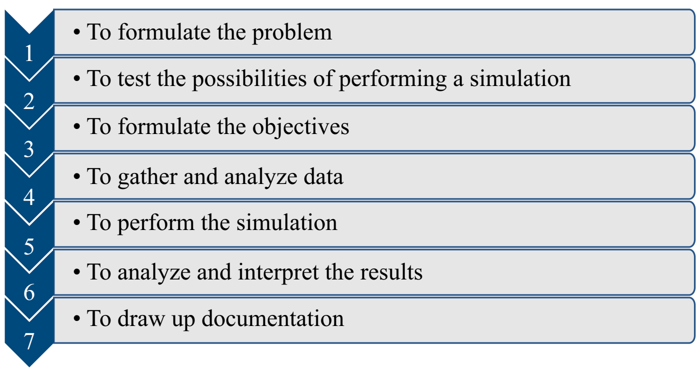

Fig. 1. The methodology of conducting simulation
(source: own study on the basis of Bangsow 2010)

Thus, computer simulations should be understood as methods which allow to test the planned solutions in a digital, virtual model before they are implemented in the real world. The article discusses the possible applications of Tecnomatix Plant Simulation software to simulate production processes and emphasizes the advantages of applying such simulations. It also introduces some integrated optimization tools and advanced analytic tools to optimize the throughput and operation of production plants and individual logistics processes and minimize work-in-process.

Tecnomatix Plant Simulation is an object-oriented 3D program used to simulate discrete events, which allows to quickly and intuitively create realistic, digital logistic systems (e.g. production) and thus test the properties of the systems and optimize their performance. The application is manufactured by the German company Siemens PLM Software, which is the leading global supplier of software for PLM (Product Lifecycle Management) and MOM (Manufacturing Operations Management). The solutions provided by Siemens as part of Smart Innovation Portfolio help production companies optimize digital enterprises and implement innovations. Digital models make it possible to perform experiments and test "what if" scenarios without disturbing the work of production systems or, in the case of the planning process, long before their assembly. Preliminary definition of the libraries of factory and logistic facilities makes it possible to create simulation models in an interactive way (see Siemens 2016).

Advanced analytic tools, such as bottleneck analysis, statistics and charts, can be used to evaluate different production scenarios. The results ensure information necessary for quickly making good decisions at early stages of production planning. In addition, this way it is possible to optimize material flow, the use of resources and logistics at each level of planning – beginning with global production facilities, through local enterprises, up to individual lines.

Tecnomatix Plant Simulation application is available in: English, German, Japanese, Hungarian, Russian and Chinese. It is also possible to efficiently switch from one language to another. A very important feature of the program is the possibility to model and simulate processes following the paradigms of object-oriented programming. The following features of such programming need to be mentioned (see Bangsow 2010):

- inheritance – it is possible to create new classes on the basis of existing ones. The original class is called the base class, and the derivative one is the subclass. This property is important e.g. when designing a production hall. If several machines (workstations) are of the same type and have the same properties, then instead of defining each of them individually, we can only define the base machine (base class), and define the settings of the other machines (subclasses) by inheriting the properties from the base class;
- polymorphism – classes and methods may be redefined, which allows to build complex models with a very transparent structure in a quick and simple way;
- hierarchy – complex models can be designed on several logically connected levels (working windows). This property enables to implement two most popular strategies used in information processing and design: "Top-Down" and "Bottom-Up".

Tecnomatix Plant Simulation provides effective and simple analytic tools which allow the detection of bottlenecks (Bottleneck Analyzer), tracking material flow (Sankey Diagrams) and identification of resource excess (Chart Wizard). A very important advantage of this program from the point of view of the author's scientific interest is that it provides integrated optimization tools. These include mainly:

– GA Wizard – an optimizing simulation model using genetic algorithms;
– Layout Optimizer – which enables minimizing transportation costs using genetic algorithms;
– Neural Network – which makes it possible to identify connections between input and output parameters and which provides projections with the use of artificial neural networks;
– Experiment Manager – used to create scenarios or evaluate relations between two input parameters.

Tecnomatix Plant Simulation allows also to perform statistical data analyses (e.g. studying dependence and independence, regression, data fitting, ANOVA etc.). Furthermore, it is possible to import data from other systems, programs or databases, e.g. Access, Oracle, Excel, SAP, AutoCAD. A very important advantage of the program is also the tool used for original algorithms and scripts programming (Method). The built-in language SimTalk, with the syntax based on Basic, is used for this purpose.

2. Literature analysis

The analysis of the literature of the subject gives us relatively few publications which discuss the application of Tecnomatix Plant Simulation in production engineering and logistics. What is more, most of them are absent from the Web of Science database. Still, they refer to interesting solutions and lead to interesting conclusions. Most articles are by European researchers from: Slovakia (see Filo *et al.* 2013; Kliment, Trebuna 2014; Kliment *et al.* 2014), Poland (see Danilczuk *et al*. 2014; Gola, Świc 2012; Gola, Konczal 2013; Kłosowski 2011; Kostrzewski 2013), Bosnia and Herzegovina (see Jovisevic *et al.* 2014; Borojevic *et al.* 2009), the Czech Republic (see Boruvka *et al*. 2011) or Germany (see Gutenschwager *et al.* 2012; Kuehn 2006).

Simulation modeling is commonly used in manufacturing and it enables solving various problems. The simulation can be applied when a new facility is planned or the existing one should be optimized. In those cases the simulation helps to optimize the times (processing time, failure time, set-up time, recovery time, etc.), the throughput of the plant, determine the size of buffers and the number of machines.

The research conducted by Danilczuk, Cechowicz and Gola (see Danilczuk *et al.* 2014) from Lublin University of Technology focuses on the application of Tecnomatix Plant Simulation in the analysis of efficiency of a production line machining a specific kind of parts as part of a technological process which involves two operations and five technological procedures. The system was simulated and analyzed in a production process involving two, three, or four stages. The influence of failure-related machine stoppage on the efficiency of the whole production line was shown. Such a workstation blocks the next machines, so it is a bottleneck of the process. An experiment like this is a signal for the company that certain actions should be taken to eliminate the effects of temporary unavailability of the workstation. The machine can be modernized (or replaced by a new one), or so-called buffers can be used to temporarily exclude it from the process. Computer simulation made it possible to determine the size of the buffer and properly plan its location, which was essential from the point of view of the best use of space in the production hall (see Danilczuk *et al.* 2014).

Boruvka, Manlig and Kloud (see Boruvka *et al.* 2011) discussed an example of computer simulation performed so as to analyze the capacity of production lines, and verifies how failures of individual workstations affect the whole production and efficiency of the production line. Besides, an experiment was carried out to determine the minimum number of pallets necessary to ensure the maximum use of production lines. Using specific examples, it was shown that the elimination of 5% of bottlenecks leads to approx. 5% increase of production (see Boruvka *et al.* 2011).

An interesting application of Tecnomatix Plant Simulation software was introduced by Borojevic, Jovisevic and Jokanovic (see Borojevic *et al.* 2009). The work presents the outcome of simulation of production and assembly of crankshafts for saw engines. Computer simulations allowed to identify production process bottlenecks, to show the lack of efficiency of certain workstations, and to minimize the duration of the whole process. On the basis of the conducted analyses it was possible to introduce buffers storing the manufactured elements, to eliminate inefficient workstations, to reduce the time of transporting elements between the workstations, and to introduce extra machines. These actions considerably reduced the time of processing elements at each workstation and led to optimizing the duration of the whole production process (see Borojevic *et al.* 2009).

Tecnomatix Plant Simulation was used by Moscow Domodedovo Airport for modeling air cargo handling, passenger flows in the international terminal as well as various terminal performance scenarios. The main objective was to model the handling of incoming air cargo in order to identify bottlenecks and to improve overall efficiency. Tecnomatix Plant Simulation enabled to conduct essential improvements to airport workflows, including check-in planning, equipment for check-in, luggage claim areas, the locations of stores, buses, gates, passenger routes across the terminal and boarding management etc.

3. The example of Tecnomatix Plant Simulation application

Let's consider the example of production line shown in Figure 2. It is a simple digital model representing the process of nails production, designed by the author with the use of the Tecnomatix Plant Simulation program.

In the developed model, steel wire is collected from the stock, then at the first workstation it is cut (the disassembly process) into 100 elements ("Wire cutting" machine). The duration of wire cutting is 10 seconds (100 elements, 0.1 second per nail). The unused parts of steel wire are removed from the process as a separate out-

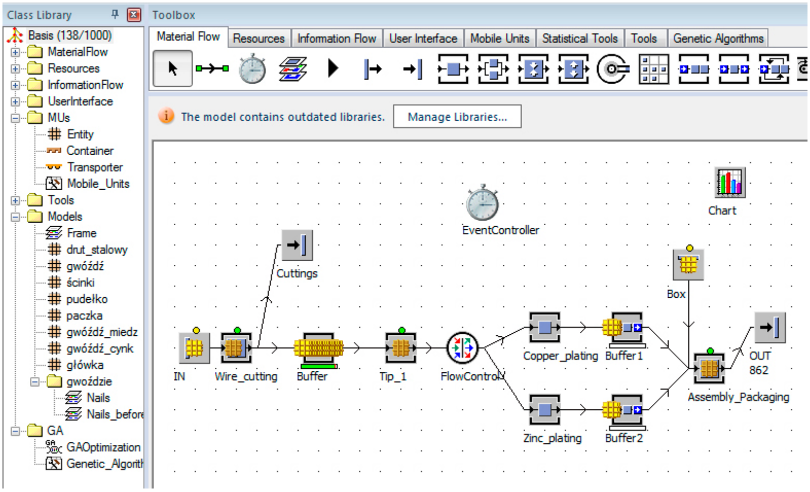

Fig. 2. Example of production process designed using Tecnomatix Plant Simulation

put ("Cuttings" workstation). After the cutting, these elements go to the station called "Tip" in the model, where the nail tips are sharpened and the heads are formed. The time of sharpening each nail tip and of forming each nail head is 10 seconds. The set-up time after the first action is 20 seconds.

Further, half of the nails are copper plated ("Copper plating" machine), and the other half are zinc plated ("Zinc plating" machine). The working times of these machines are 2 seconds per nail. The movement of the elements along appropriate paths is defined using a FlowControl object.

After copper or zinc plating, a nail is stored in a buffer with the capacity of 4,000 pieces ("Buffer1" and "Buffer2" stations, respectively). From the buffers, the nails go to the Assembly workstation, where they are packaged in boxes containing 50 copper plated nails and 50 zinc plated nails each. The machine used to package the nails ("Assembly_Packaging" workstation) is fed with boxes from an extra source, i.e. the "Box" workstation. The assembly time is 1 minute. A ready packet containing a total of 100 nails in a box is then directed to the process output.

In addition, the appropriate statistic was defined at the model output, which summarizes the manufactured and assembled elements. Within 24 hours of technological process, the production capacity for machine and workstation settings defined this way is 862 boxes of nails. Figure 3 presents the performance charts of individual workstations in the analyzed production process.

Statistical analyses of work at each workstation performed after the whole production process showed that only 10% of the wire cutting machine capacity was actually used. This station is blocked by the "Tip" machine, which is the bottleneck in this process.

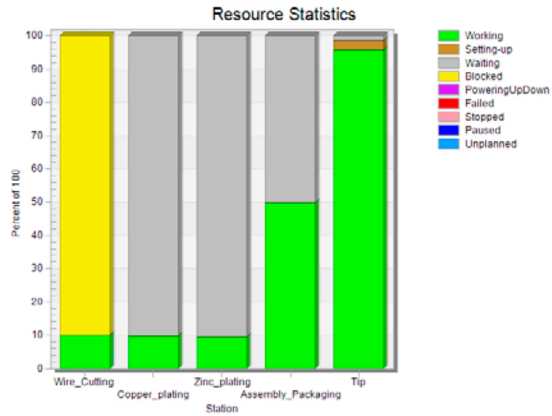

Fig. 3. Statistics concerning the work of machines in the discussed production process

The research question was formulated as follows: *what are the bottlenecks of the production process and how to increase the throughput of the plant*?

The results of author's experiments showed that increasing the process flow capacity is possible e.g. by adding another, parallel workstation for sharpening the cut nails. Settings of the extra machine are the same as of the main one: the process duration is 10 seconds, and the set-up time lasts 20 seconds. The result of the simulation of introducing an extra nail sharpening workstation into the discussed production process is shown in Figure 4. This solution produced very satisfying effects, as it allowed the increase of production up to 1,438 boxes of nails within 24 hours.

Processing times and setup times of individual workstations after introducing an extra sharpening machine into the discussed production process are shown in Table 1.

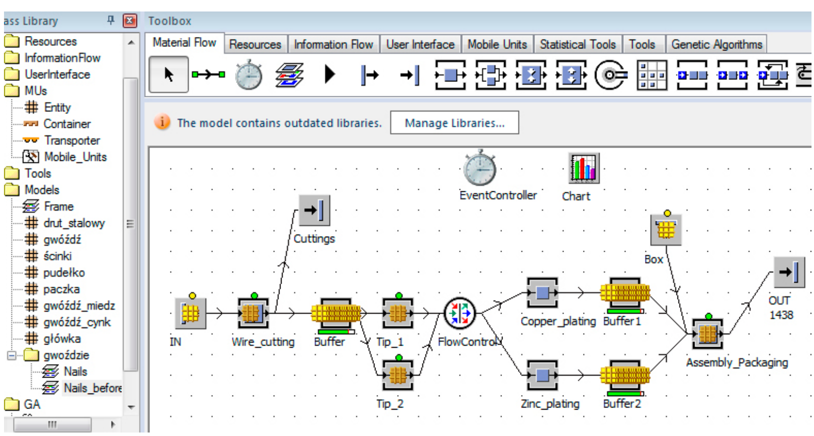

Fig. 4. Change of production volume after adding the "Tip" workstation

Table 1. Processing times and setup times of machines

Operation	Machine	Setup time [sec]	Processing time [sec]
Cutting	Wire cutting	0	10
Tipping	Tip_1	20	10
Tipping	Tip_2	20	10
Plating	Copper plating	2	0
Plating	Zinc plating	2	0
Assembly	Assembly_Packaging	0	60

Figure 5 presents the statistics concerning the work of machines after adding an extra sharpening workstation. The wire cutting machine is working all the time now and 100% of its' capacity was actually used. This machine is not blocked by the "Tip" workstation any more.

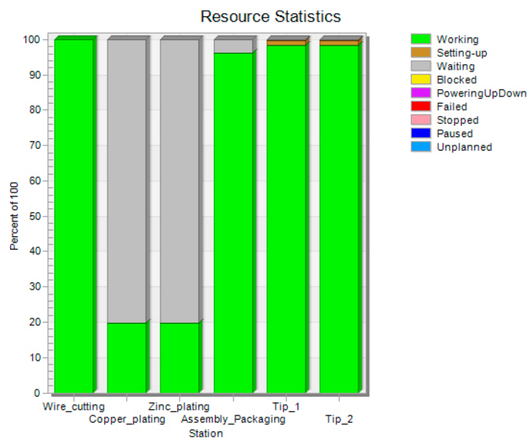

Fig. 5. Statistics after adding "Tip" workstation

The effect of shortening the time of assembly of one box from 60 to 30 seconds was also analyzed. This would make it possible to increase the production capacity even up to 1,726 pieces within 24 hours. Thus, in the analyzed process it would be worthwhile to modernize the existing workstation at which the final product is assembled.

4. Conclusions

Computer simulations using IT tools have recently become necessary activities supporting the design of new production and logistic systems or streamlining the existing ones. Simulation methods are also used to evaluate different aspects of production systems. Repeatability is a significant feature of computer simulation. Thanks to determining a certain number of parameters and assigning them specific numerical values, the same process can be repeated many times. In real life conditions, such procedures could not be performed (Kłosowski 2011).

Computer simulations performed with the use of IT tools ensure the optimization of work and performance of whole production plants, production lines, as well as individual logistics processes. Digital models of logistic systems enable enterprises to carry out simulations without interrupting the work of real systems. Furthermore, thanks to testing different scenarios, it is possible to choose the best strategy ensuring the increase of efficiency and quality and lowering production costs (Borojevic *et al*. 2009).

Different types of simulation, for example discrete events, can be applied in digital models to various planning tasks and stages to improve the product and process planning at all levels of the whole production process. The combination of simulation and optimisation techniques allows for advanced approaches for planning and improving the product development and production planning processes (see Kuehn 2006).

This paper introduced the implementations of Tecnomatix Plant Simulation for modeling the process of nails production. The conducted simulations pointed the bottlenecks of the whole production process and allowed for experimenting some optimizations and introduced the possibilities of increasing throughput of the plant. By adding an extra nail sharpening workstation into the discussed production process it would be possible to increase the whole process flow capacity. This solution produced very satisfying effects, as it allowed the increase the production up to nearly 70% within 24 hours.

The analysis of the previous applications of Tecnomatix Plant Simulation to model and simulate production processes allows to regard it as an effective IT tool, used e.g. for increasing the efficiency of the existing system, optimizing resource consumption, limiting stocks and shortening the production time.

The author's recent research interests include implementation of simulations and digital models for assessing the condition of manufacturing companies. The author's future studies are going to focus on simulation of production and logistic processes and their optimization with the use of genetic algorithms and artificial neural networks. Those implementations with artificial intelligence tools will be the fundamental basis for the author's further commitments.

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