OPTIMIZATION OF METALLURGICAL PROCESSES USING DYNAMIC SIMULATION

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Abstract

In today's fiercely competitive market, companies have to try to find ways how to succeed and how to keep their position among successful businesses. More and more ways, methods, procedures and tools for improving the functioning of technological and organizational processes have been searched and tried. The use of computer simulations when designing manufacturing systems or their management in practice is one of the ways how to examine the behavior of industrial processes or systems in various conditions without increased risk. With their help, it is possible to find optimal parameters that can bring the desired benefits once they have been applied in practice. It is not only their possible prediction but also the possibility of their use in various areas of industrial practice which can be considered an advantage. This article deals with an example of the use of simulation in a company which is engaged in processing of metallurgical materials. The simulation model of material flow was developed to determine the bottlenecks and the best solution for material flow with respect to contractors from the previous operation. Verifying the results of their own computer simulation with results achieved in practice, we can confirm the appropriateness of the use of computer simulations in the optimization of manufacturing processes and systems in practice.

Keywords: Optimization, dynamic simulation, manufacturing processes

1. INTRODUCTION

In recent years, the global economy has been growing with an unprecedented dynamism and in its comprehensiveness with all the inputs and outputs. This economic growth is associated with development of existing and new technologies, discoveries of new materials and machinery equipment. On the market there are emerging new products, their life cycle is shortening and their comprehensiveness is increasing.

The present dynamically changing market environment is forcing companies to respond to changes and customer requirements faster and in a more targeted way. On the one hand, time brings big business opportunities, but on the other hand, these opportunities bring with them a greater uncertainty and many risks. In an effort to minimize the risk of wrong decisions, the company executives are constantly forced to seek appropriate solutions in all business processes. A relatively large and stable interest on the part of corporate executives can be observed in the field of the modernization of process control systems, then in development of new products and also in cost reduction. Simulation systems are one of many options that can be used in decision-making processes connected with design and optimization of manufacturing processes and systems.

The simulation can be understood as performing of experiments using a computer model that mimics the functioning of real processes and systems in order to analyse their behaviour under various conditions. This is a set of complex numerical and logical relationships that can be evaluated without the need of real implementation in practice. Simulation is also referred to as a modern method for the analysis of complex corporate processes that contain elements of random and dynamic behaviour. This is a very successful method of analysis of business processes, which can be used to find the optimal process parameters, with regard to the criteria required. The applications in practice have shown that businesses that use simulation to optimize their business processes, reach financial, material and personnel savings. [8].

Formerly, the simulation modelling only was used in the automotive and aerospace industries, but today is used in many other areas, e.g. in medicine, machinery engineering, including the metallurgy industry.

The scientific objective of the issue under solution can be seen especially in the possibility to verify TOC (Theory of Constraints) methodology when addressing the bottlenecks in metallurgical production. This article gives an example of using a simulation model of material flow in the section of the forge shop, created based on the determination of bottlenecks. The most suitable variant of material flow was verified with respect to suppliers from previous operation.

" Company profile: it is a significant engineering company with its own steel production that focuses on the delivery of heavy steel castings, crankshafts, equipment for steelworks and rolling mills, equipment for forming and rolled hoops for the railway industry. Their efforts are focused on increasing the share of manufacturing and supplies of products with high added value". [2]

2. METHODOLOGICAL BASE - THEORY OF CONSTRAINTS (TOC) AND DYNAMIC SIMULATION

As already has been mentioned in the introduction, TOC (Theory of Constraints) methodology is going to be used in connection with the verification by using simulation of problems being solved in the metallurgical enterprise. By integrating TOC principles within the organization can be achieved the synergic effect that ultimately can lead to maximum satisfaction of customers, employees and other stakeholders. Many authors confirm that this concept can be successfully applied in all sectors of production and services at different levels of detail. [3, 4]

2.1. Theory of Constraints (TOC)

The basic idea of Theory of Constraints (Theory of Constraints) TOC is focused on searching bottlenecks, maximization of flow and minimization of inventories and costs. This theory works on the principle of the weakest link of the chain, which is the workplace with the lowest-capacity, which determines the rhythm of production. Such a workplace constituting a bottleneck must be firstly identified and then fully exploited. If operation of a production line is controlled according to the workplace with the lowest capacities, then all other workplaces must ensure the supplies for such bottleneck, in order to avoid its lack of work. The performance of production quite effectively can be increased by strengthening the workplace with the lowest production capacity. Stopping any machine in the production process outside the narrow site does not constitute any problem in the production system, because no flow limitation occurs. "*One hour that was lost in the bottleneck means a loss to the entire enterprise. Conversely, one hour that was lost somewhere else does not mean any loss.*"[5] Nevertheless is necessary to monitor the achieved capacities at all workplaces, because if the capacity of the bottleneck does not differ much from the capacities at workplaces in the manufacturing process at other location, it can easily happen that by strengthening of the original bottleneck will be created a new bottleneck that already means a crucial problem in system. [6]

2.2. Dynamic simulation

Predictive technology and simulation methods are entering increasingly into the attention of experts in many different industries. Nowadays, the companies are expected to respond quickly to constant changes, to provide high-level services as this significantly influences sustainability and strengthening the corporate competitiveness. Under conditions of strict monitoring of costs it is necessary to verify the various options in planning the systems and seek and find new and innovative, as far as possible successful solutions. Each request for changing technological or organizational processes entails a certain risk. Dynamic simulation using Witness program helps to reduce this risk by enabling to model the work environment and simulate the consequences of different decisions and a number of variants, which can then be compared and then to select optimal solution before actual implementation. [1]

In the professional literature we can find a wide range of definitions for simulation. By R. E. Shannon it was defined as follows: "*Simulation is the process of creating a real system and conducting experiments with this model for the purpose of achieving a better understanding the system that is under study, or for the purpose of assessing different variants of activity of system*." [7]

Another similar definition of simulation according to O. J. Dahl sounds: "*Simulation is a research method whose essence lies in the fact that the dynamic system that is under examination is replaced by its simulator and experiments are carried out with this simulator, in order to gain information about the original investigated system.*" [4]

Simulations allow us to create models of systems that do not yet exist. The advantage is, that we can simulate any idea, thus even at the first attempt suggest a system that will suit us. Very short time of simulation allows us to track the actions in progress in relatively short period of time, and thus evaluate several different variants of the proposed issue. The system allows us at any time to stop the simulation, change the necessary parameters and then continue in simulation. We can immediately monitor the effects of the required changes and their consequences. [8]

Simulation originated from the Monte Carlo method, and was separated from this method into an independent discipline. The author of Monte Carlo method is considered Stanislaw Ulam, a Polish mathematician, who along with John von Neumann worked during World War II in the United States in development of nuclear weapons. Ulam invented this method probably within examination of the probability of winning at cards. [4]

2.3. Methodical process of simulation

The principle of the simulation is described in **Figure 1**. At the beginning it is necessary to describe the system, then to its structure and function, find a solution to the given problem or estimate the future behaviour of the model. If a problem is found and solved, then follows design and verification of the functionality of newly set model structure.

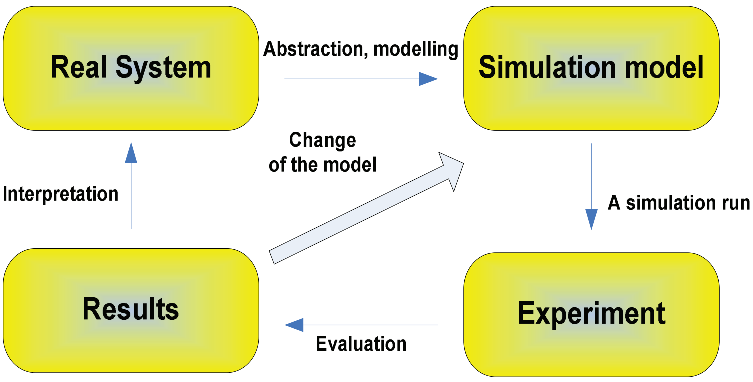

Figure 1 Principle of the simulation [7]

When designing a simulation model it is necessary to proceed according to the following steps:

- recognition of problems and setting goals - it is necessary properly formulate the problem and set the achievable and measurable goals,
- creation of a conceptual model - preparation of model according to a real process,
- data collection - simulation requires relevant data, then follows setting up the input parameters, starting the simulation,
- creation of a simulation model - checking of the conceptual model,
- verification and validation of the model - check of proper transcription of functioning of the real system into simulation program, verifying that the simulation model is in line with reality,

- carrying out of experiments and analysis of results - the creation of variants,
- documentation of the model - description of structures of model, development of model, results of experimenting for a future application.

3. THE CASE STUDY OF USE OF DYNAMIC SIMULATION IN PRACTICE

In following lines there will be described practical use of dynamic simulation carried out on the basis of analysing the material flow in the forge shop. The simulation was aimed at finding bottlenecks and determination of the best suitable variant for the material flow, in consideration of suppliers from previous operation. The paper presents a summary and an example of computer simulation in a section of forge shop in an environment of Witness simulation program. All parameters, that influence the flow of material in operation, are incorporated here.

Input parameters

- manufacturing capacities of individual workplaces - the furnaces for heat treatment, burning equipment, presses, etc.,
- shift operation at individual workplaces,
- technological procedures of products and their thermal diagrams with regard to the product type and material,
- size of production with respect to composition, suppliers for a given section of operation.

Within the model is possible to monitor individual furnaces together with other production sections and operations in progress in these sections, bound to a specific product differentiated by an icon. The fulfilment of individual furnaces, their spare capacity and utilization of other workplaces are tabulated. Set of variables allowed us changing times of processing the finished products at individual workplaces (time of stay in furnaces, time of burning, etc.). Thus we simulated the possibility of adding different products with the same technology into groups and ensured a better utilization of the furnaces.

Factors influencing the production

As it is apparent from the analysis model, production process is rather complicated especially for the following reasons:

- diverse assortment of input material from several suppliers,
- finished products have different technological processing depending on the contract, material type and other parameters given by the specific character of production,
- insufficient awareness on input materials, complicated planning of the entire course of production with a view to optimal utilization of production equipment,
- the possibility of occurrence of hidden failures during processing, the necessity to repeat some operations, extension of time needed for finishing products
- the occurrence of defects - up 90% of bars and blocks have to be straightened, which constitutes delays, reduces the throughput of furnaces, disturbs the smooth flow of products,
- waiting for acceptance inspectors and for test results - production delays up by three weeks.

On the basis of input parameters it was designed the simulation model for operation of the forge shop, which is schematically illustrated in **Figure 2**.

On the basis of simulation of a given section of the forge shop and the associated data collection, the operation "burning the ends and milling", through which pass all middle pieces and blocks, seems to be a bottleneck in production process. This operation it is time-consuming (at larger pieces it takes the whole working shift), and therefore it is important good planning previous operation (warm-up time for burning and exploitation of furnaces).

The quality furnaces constitute another bottleneck. When processing medium pieces it is needed sufficient capacity of furnaces for tempering. Otherwise it is need annealing and subsequent tempering, which represents a time delay and capacity reduction low quality furnaces.

Given the difficulty in obtaining data, also the flow of information between suppliers and the forge shop can be considered to be a bottleneck. So a long-term planning with regard to the optimal utilization of available technology is not possible.

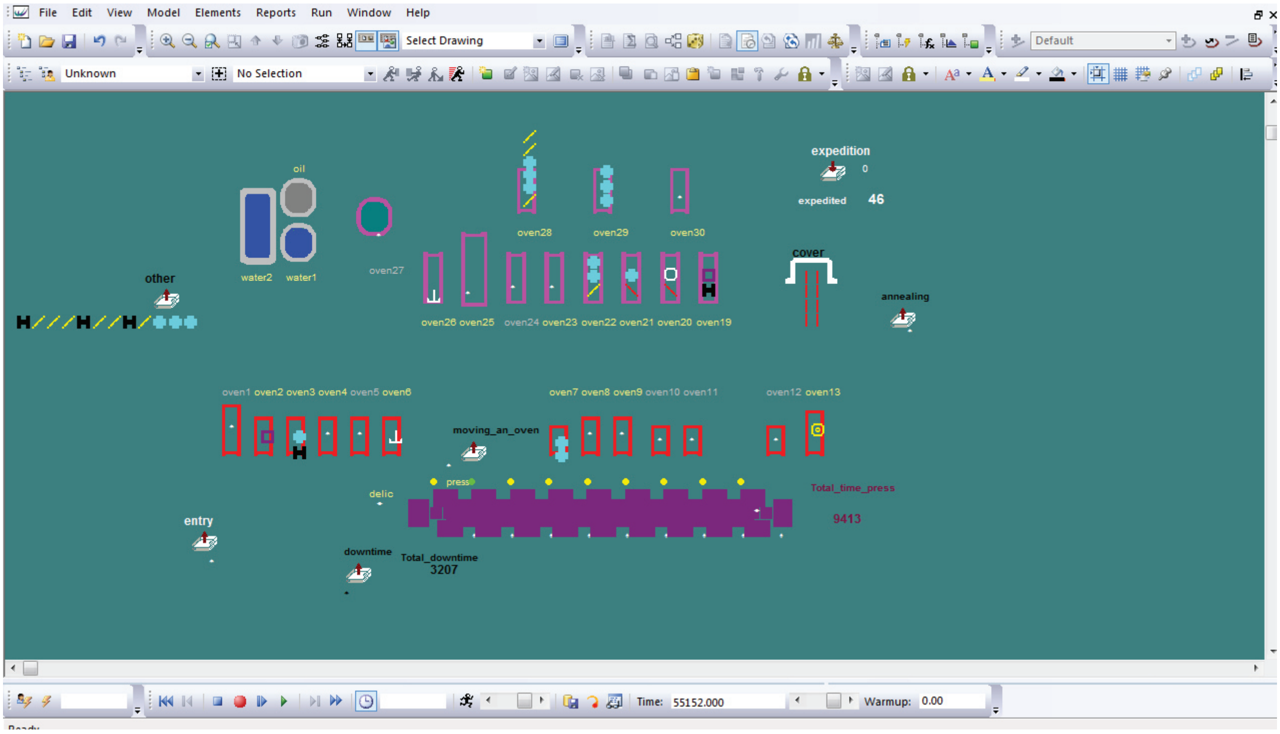

Figure 2 Schematic model of a section of forge shop in Witness simulation program

Results of simulation and conclusions

Within the optimization of material flow in the section of forge shop by means of simulation in Witness program and after finding the bottlenecks, there could be drawn the following conclusions and recommendations:

1. in case of planning of input ingots was increased the number of dispatched products by 9.5%,
2. the exploitation of the press was increased by 7.2%, the total number of forged products by 7.7%,
3. within simulation was also verified the possibility of putting the furnace no. 1 into operation. It was found that after connecting the furnace no. 1, the time of stay of the products in furnaces in the pressing shop was reduced by 3%. Also was shortened the manufacturing time of the propeller shaft at average by 54% and were improved the quality parameters of propeller shafts.

Increase in the throughput of section of the forge shop can be achieved by using an appropriate and correct planning of the entire production flow. This can be improved due to a timely awareness on incoming products and current work in progress in given section and also previous workplaces at a supplier. Just so we can plan the flow of products with the aim of the best exploitation of available capacity of furnaces, in order to ensure the best throughput rate of products in individual operations. The possibility of monitoring of work in progress helps ensure the instant changes on inputs so as to avoid overloading of production flow and related inefficient use of available production capacities.

4. CONCLUSION

The simulations include a significant advantage against the real systems, as they allow experimenting and have a significant degree of variability and repeatability. Dynamic simulations have a great potential in terms of scope and possibilities of use. They can be used not only in the field of designing of manufacturing processes and their optimizing, but simulations may become an interesting solution also in the field of planning and management of production. Simulations are one of the possibilities how to verify the intended changes in the manufacturing process or how to set the optimal conditions of the system, namely without any greater risk.

The case study was focused on the manufacture of metallurgical products in the section of forge shop. It was proved that the practical use of the simulation model on the basis of a real manufacturing process allows us very reliably to plan an optimal exploitation and filling of furnaces and thus increase the throughput of the input material in the material flow. When using this model, when it is possible to monitor the inputs and work in progress of individual products, the company has the option to interactively use the proposed model for planning and management of production. By verifying several options the company can select such one, which will effectively utilize the production equipment (ovens, presses) in the section of the forge shop, thus ensuring production of contracted orders.

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