MODELLING AND SIMULATION OF PERMEABILITY OF HEAT TREATMENT OF FORGED PIECES

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Abstract

Increased utilization of production capacities has a positive impact on competitiveness of a company both in the area of cost savings and in customer service. The effort to increase the utilization of production capacities should be primarily focused on bottlenecks which limit the production capacity of the entire production system. The objective of this article is to propose and evaluate possible measures leading to increased permeability of heat treatment of forged pieces process. The proposed measures result from an analysis of a concrete forging process where heat treatment had been identified as the bottleneck. Dynamic and stochastic simulation technique is applied in order to evaluate their impacts. The article describes the construction of the simulation model of a forging process, testing and validating the model, design of the experiment, conducting the experiments, evaluating the results, and implementation. The simulation model includes all technological operations from forging of pieces on a forging press, through flame cutting of the front parts of forged pieces, their tagging, cooling on cooling beds, heat treatment in two furnaces, repeated cooling, straightening and hardening to shot blasting. Twenty five simulation experiments combinations of possible measures have been identified, realized and evaluated. Modelling and simulation of the process uses WITNESS 2007 software tool. The realized experiments demonstrate the opportunities to increase the permeability of heat treatment and thus the entire forging process by up to 70%.

Keywords: production capacity, forging, heat treatment, dynamic simulation

1. INTRODUCTION

Metallurgical companies facing globalized and highly competitive market environment look for ways how to increase their competitiveness. Efficient utilization of production capacities is one of them. Positive effects of improved utilization of production capacities on competitiveness of metallurgical companies can be seen mainly in the following areas:

- Reduction of the unit production costs which makes it possible to cut the prices of metallurgical products or to increase company profit
- Shortening production lead time, which provides opportunity to cut delivery time and to increase reliability of supplies
- Free capacity for production of products with high added value which may require larger capacity
- Boosting the ability of flexible reaction to demand fluctuations caused, for example, by seasonal effects

The effort focused on increasing capacity should primarily deal with bottlenecks limiting production capacity of other devices linked with them, as well as the entire production system [1]. In metallurgical companies the capacity bottlenecks are mainly represented by the basic production devices.
Capacity of the bottlenecks can be increased with the aid of investments aimed at technology improvement and at increasing the performance of the equipment in question. However, this solution should only be taken after all measures not requiring large investments have been expended [2].

The objective of this article is to propose and evaluate possible measures leading to increased permeability of heat treatment of forged pieces process. The proposed measures result from an analysis of a concrete forging process where heat treatment was identified as a bottleneck.

2. METHODOLOGY

Many specific features which can be summarized in the following points are typical for metallurgical processes [3]:

- Very large production assortment (shape, size, structure, physical, chemical and other qualities)
- Production batch economy
- Low degree of freedom among the individual processes
- Various technological and logistics characteristics of follow-up processes
- Great number of production links
- High capital demands
- Trouble-free supply and removal of material in case of continuous processes
- Large material flows, and necessity of holding large volume of raw materials

In order to analyse such complex production and logistics systems, it is useful to apply computer simulation [4, 5]. Computer simulation is a method which uses computer model of company process to conduct experiments with the aim of achieving model parameters that are later applied back on the examined process [6]. With regard to time playing a key role in analysis of permeability of heat treatment and with regard to the fact that the forging process is influenced by several stochastic effects, dynamic and stochastic simulation was selected.

3. EXPERIMENTAL WORK AND RESULTS

Permeability of heat treatment was analysed using methodology for application of dynamic simulation in metallurgical processes [7]. Modelling and simulation was conducted in WITNESS 2007 software tool. Experimental work and main results are summarized into the following points:

- Construction of the simulation model
- Testing and validating the model
- Design of the experiment
- Conducting the experiments
- Evaluating the results
- Implementation

3.1 Construction of the simulation model

The simulation model of a forging process includes all technological operations from forging of pieces on a forging press, through flame cutting of the front parts of forged pieces, their tagging, cooling on cooling beds, heat treatment in two furnaces, repeated cooling, straightening and hardening to shot blasting.

Data necessary for construction of the model have been gathered from technical and technological documentation of the company, information system, operational records, time studies and consultations with the workers. Data regarding operation layout, technical parameters of production and manipulation equipment, production technological procedures (above all forging and heat treatment), quantity and structure of manufactured assortment, duration of technological and manipulation operations, breaks in
activities (for example time needed for conversion and breakdowns of equipment) are among the most important ones. Statistic processing has been carried out in case of stochastic quantities. It was focused on excluding measurement errors (for example unrealistically long forging time) and on setting the average values and probability distributions.

Simulation model of a forging process created in the environment of simulation tool WITNESS 2007 is illustrated in figure 1.

![Simulation model of forging process](image)

**Fig. 1** Simulation model of forging process

### 3.2 Testing and validating the model

Testing and validating the model was done by means of simulation of current situation of the researched process for the quantity, structure and sequence of production assortment input related to the monitored period of time. The total simulation production time has proven sufficient conformity between the model and the real system. The simulations have also proved that heat treatment of forged pieces is the bottleneck. The main reasons could be summarized this way:

- Certain production assortments must pass through heat treatment process more times (according to the technological procedures)
- When the forging or straightening press are idle (mainly during the time when the equipment is being rebuilt), the forged pieces can not be charged into furnace, which causes decreased utilization of their capacity
- Method of linking the individual technological operations by conveyors has prevented parallel use of both furnaces for various production assortments (with various technological procedures of forging and heat treatment)

### 3.3 Design of the experiment

The workers’ experience in the process and the outcomes of simulations of current situation focused on monitoring the utilization degree and scope of non-efficient time of basic production activities served as the main foundation for defining the possible measures leading to increased permeability of the process.
Eight proposed primary measures which could lead to increased permeability of forging process represented the outcome of this activity:

A) Contraction of heat treatment time
B) Contraction of time necessary for forging press conversion
C) Contraction of time necessary for straightening press conversion
D) Change of input material in case of selected forged pieces assortment which would make it possible to shorten the forging time and to eliminate forged pieces straightening
E) Keeping stock of goods in process which would make it possible to increase capacity utilization of furnaces
F) Building second input feeding conveyor for charging forged pieces into furnaces
G) Building second conveyor and cooling bed for output of forged pieces from the furnaces
H) Adjustment of straightening press enabling parallel straightening of forged pieces from both furnaces

By combining these eight basic measures, the total of twenty five real options for increasing the permeability of forging process have been created.

3.4 Conducting the experiments

The proposed options were used in simulations with quantity, structure and sequence of input of production assortment corresponding with the monitored period of time. Monthly permeability of forging process, resulting from the average monthly number of forged and heat treated forged pieces, was set as the main entry parameter of dynamic simulation. The other monitored parameters of the model were the usage rate of basic technological equipment and the inventory level of products in process which is limited by the size of the storage areas. Examples of graphical outcomes of the above mentioned parameters are illustrated in figure 2.

3.5 Evaluating the results

Comparison of permeability of forging process for the individual options is summarized in figure 3. It became obvious during the simulation that five combinations of basic measures had excluded each other. From the evaluation of the remaining twenty options is clear it was possible to achieve increased permeability of heat treatment and thus the entire forging process by 37 – 76 %. When the benefits of the individual options (mainly in the area of additional revenues) and their realization costs have been considered, the option combining measures B), C), E), G) and H) was selected. The selected option was supposed to bring 72% increase in permeability of the forging process (marked as option 11b in figure 3).
3.6 Implementation

After suitable option have been selected, potential suppliers of equipment were addressed with the inquiry to specify the technical parameters of the selected solution. On the basis of the gathered information, there were adjustments of conveyors layout, storage areas and system of organization of the forging process. The planning stage finished when the realization schedule had been put together, the suppliers had been selected and the project documentation elaborated.

The realization stage included reconstruction of the forging process and launch of the field test. After the initial problems had been eliminated, regular operation was launched. The permeability of the forging process has risen by 70% as early as after the first month, which confirmed the construction of the created model had been correct.

4. CONCLUSION

The presented example has proven that by using suitable decision support systems it is possible to judge and find significant potential for increased utilization of production capacity in metallurgical production. Modelling and dynamic simulation of processes represent suitable tool for complex metallurgical processes. The solution acquired using analytical approach would be based on simplified presumptions not reflecting real functions of the researched processes. Significant benefit of dynamic simulation application on metallurgical productions lies in the fact that model is built from the perspective of practice and its visualization enables the managers to be directly engaged in search for suitable solutions.

REFERENCES


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