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Research Article

EXAMINATION OF THERMAL WORK OF ELECTRIC CHAMBER FURNACE TO THERMAL PROCESSING

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ABSTRACT
The improvement of effectiveness of work furnaces depends on increasing the efficiency as well as the decrease the elementary consumption of energy. The character of the analyzed electric chamber furnace to thermal processing in work was introduced. over the discussed results concern the efficiencies, consumption of electric energy as well as the coefficient of elementary consumption of energy. The improvement of coefficients of furnace solutions were proposed.

Keywords: heat treatment, heating costs, heat consumption.

INTRODUCTION

One of the basic factors that determine the price and, consequently, the competitiveness of the product is the energy efficiency of the manufacturing process. The attempts should be made in any areas for which fuel and energy consumption is important to incessantly strive for reduction in energy intensity of production processes.

Reduction in energy intensity of the production process can be achieved in a number of ways, e.g. modernization of current furnaces, which are an integral part of any heat treatment department. The basic aim of such a modernization is improvement in efficiency of furnace work, which manifests mainly in the increase in their capacity, fuel efficiency (reduction in unit energy consumption) etc. The decision about starting such initiatives should be made after the analysis of thermal work of the furnace.

INDICES OF THERMAL WORK OF FURNACES

Evaluation of the efficiency of current heat-generating equipment is based primarily on the results of thermal measurements. The results of thermal examinations are usually presented in a form of balances. The balance-based approach has numerous advantages, including [1, 2]:

- it allows for correctness of measurements and calculations,
- it removes the necessity of dealing with processes inside the system analysed by the balance,
- it facilitates unequivocal calculation of the efficiency of the process and relative loss that occurs in the process.

The basis for ensuring proper thermal balance is the principle of energy conservation, which says that the general equation of the balance can be expressed mathematically as [3]:

$$E_d = \Delta E + E_w \tag{1}$$

where: E_d – energy supplied to the system,
E_w – energy released from the system,
ΔE – change in energy of the system.

Energy balances are most often prepared with respect to the unit of charge mass and time unit. In industrial energy sector, the important condition of evaluation of the quality of utilization of energy in the processes is the index of unit energy consumption with respect to the unit of the final effect in the process [4]. For electric furnace, the index of unit heat (energy) consumption is calculated from the relationship:

$$WJZE = \frac{Q_{elek.} \cdot 3600}{m}, \text{ kJ/kg} \qquad (2)$$

where: Q_{elek} – electric energy consumption, kWh,
m – charge mass, kg.

The index of unit heat consumption reflects energy intensity of the heating process, and, consequently, the quality of furnace operation. This affects the cost of the heating process, which is determined based on the current prices of electricity.

FURNACE SPECIFICATIONS

The examined resistance chamber furnace (PEKtw 1000/4) is installed in the department of heat treatment of machine parts. The department is a separate part in the technological centre of the enterprise. Electric chamber bogie hearth furnace PEKtw-1000/4) is a furnace designed for heat treatment processes, mainly for annealing at the temperature of up to 1000 ºC in air atmosphere.

Design of the furnace is presented in Figure 1. With high-quality temperature controllers, recorders and other control components, the furnace is qualified for performance and monitoring of the above technological processes. Distribution of heating elements in all the walls of heating chamber, gates and in the hearth guarantees demanded distribution of temperature in the working space of the furnace. Heating elements are made of Kanthal AF resistant strips in a corrugated shape.

Thermal insulation (brickwork) was made of high-class insulation materials in a form of mats and fibre boards and conventional ceramic materials. Furnace hearth was made of high-quality conventional refractory and insulation materials with durability suitable to handle charge mass [5].

Fig. 1. Design of electric chamber furnace with a bogie hearth

Technical specifications of the furnace are presented in Table 1.

Table 1. Technical specifications of the furnace [5]

Maximum charge mass	25000 kg
Furnace dimensions:	
width	6450 mm
height	6780 mm
length	7480 mm
Maximum operating temperature	1000 °C
Rated power	690 kW

ANALYSIS OF HEATING PROCESS

Any heat treatment operation is characterized by a heating curve adjusted to the material and type of operation. Figures 2–4 presents selected heating curves for the furnace analysed in the study.

Operation 1 is normalizing the rods with diameter of 60mm and total mass of 1600 kg. Charge temperature was increased linearly up to the value of 860 °C for 4 hours. Then, the charge was held for 2 hours at this temperature, and, after 1.2 hours, it was cooled to the temperature of 700 °C.

Operation 2 concerned interoperational annealing. The charge was provided by 2 rods with diameter of 400mm and length of 4 m. The mass of the cylinder was 3944 kg. Charge temperature was increased linearly up to the value of 550 °C for 3 hours. Then, the charge was held for 3 hours at this temperature, and, after 4 hours, it was cooled to the temperature of 350 °C.

Operation 3 was stress relief annealing of the structure after fusion welding. The charge was a post with a mass of 3600 kg. Charge temperature was increasing up to the value of 620 °C for 6.5 hours. Then, the charge was held for 3 hours at this temperature, and, after 18.5 h it was slowly cooled to the temperature of 200 °C.

ANALYSIS OF FURNACE OPERATION

Furnace capacity and electric energy consumption was determined for heat treatment operations. The results are presented in Figures 5 and 6.

The analysis of the above figures leads to the conclusion that operations of heat treatment

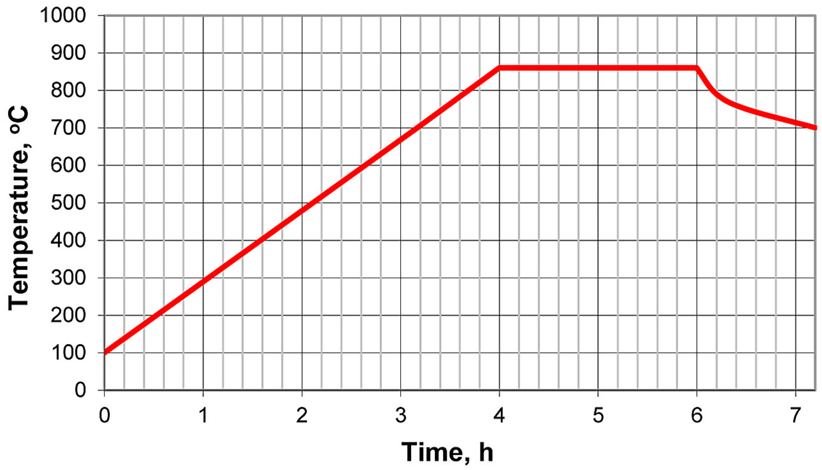

Fig. 2. Heating curves for the normalizing (operation 1)

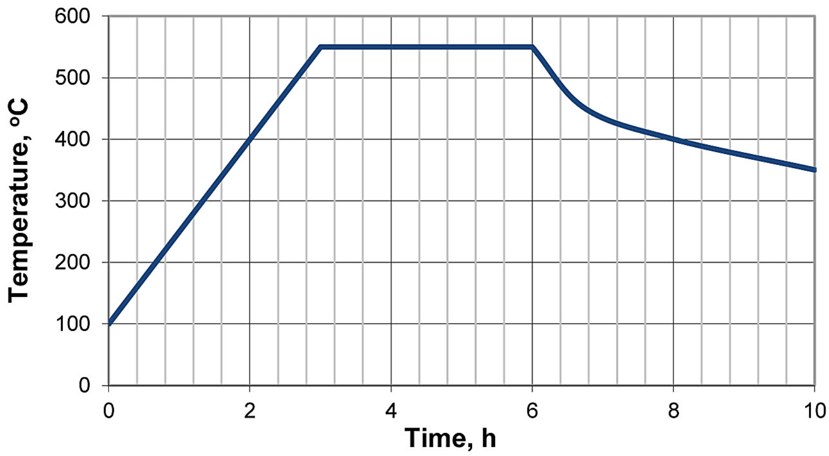

Fig. 3. Heating curves for the stress relief annealing (operation 2)

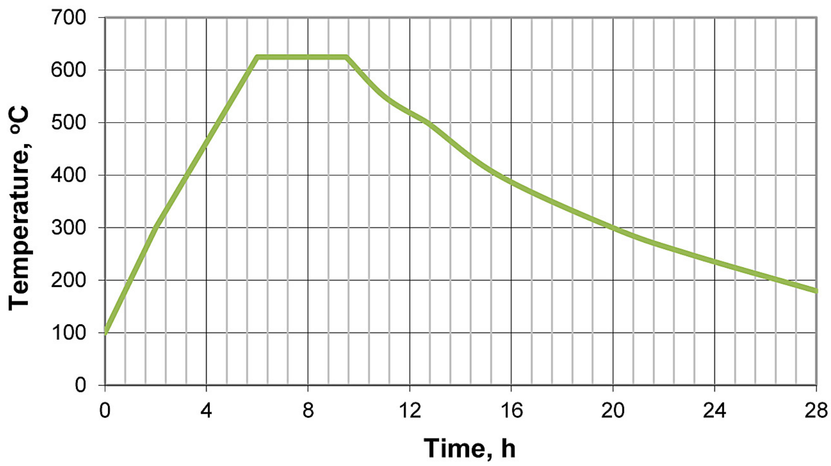

Fig. 4. Heating curves for the interoperational annealing (operation 3)

in the resistance chamber furnace are characterized by low capacity. This results from the specific nature of the heat treatment, also from the character of the department and its profile. Similar situation is observed for energy consumption.

The highest energy consumption can be observed for operations of interoperational annealing (operation 2) characterized by the lowest capacity. Comparison of operation 1 and 2 reveals that, despite substantially higher annealing temperature, with insignificantly longer duration of

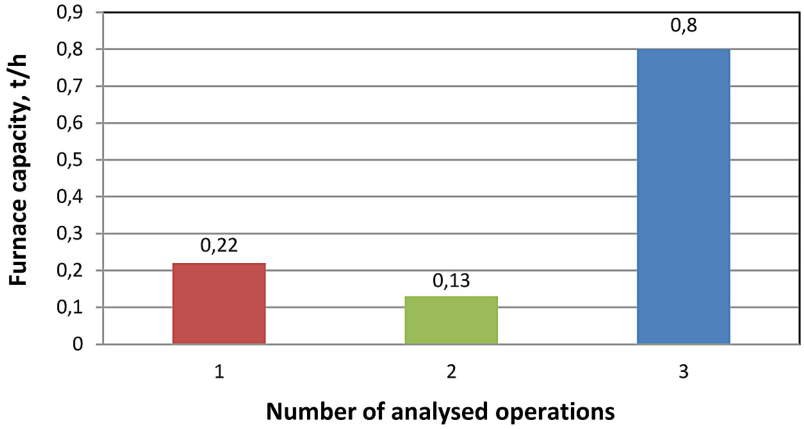

Fig. 5. Furnace capacity for the operations analysed in the study

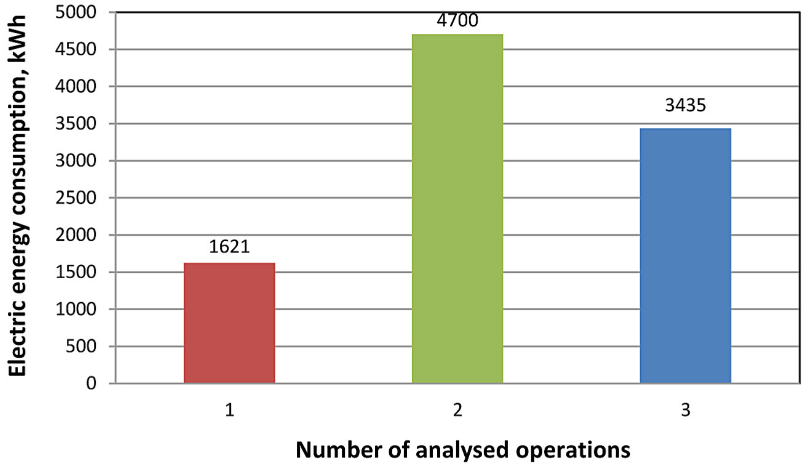

Fig. 6. Electric energy consumption for the operations analysed in the study

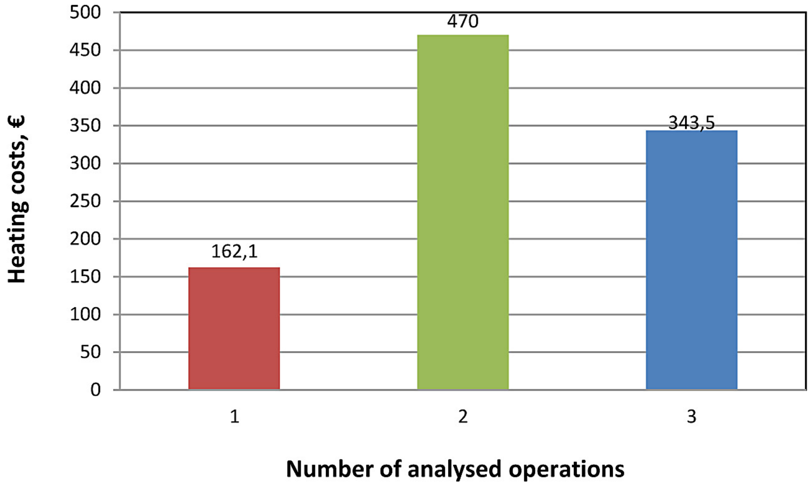

Fig. 7. Heating costs in the operations analysed in the study

the process, normalizing operation is characterized by substantially lower energy consumption. This results from the geometry of the annealed charge. In the case of normalizing, charge was provided by rods with small diameters, whereas in the case of interoperational annealing, the diameter of the rods was by nearly 7 times higher. Energy consumption has an effect on annealing costs of individual operations, which is presented in Figure 7.

Calculation of the heating costs were based on the electricity price of 100 €/MWh [6]. The

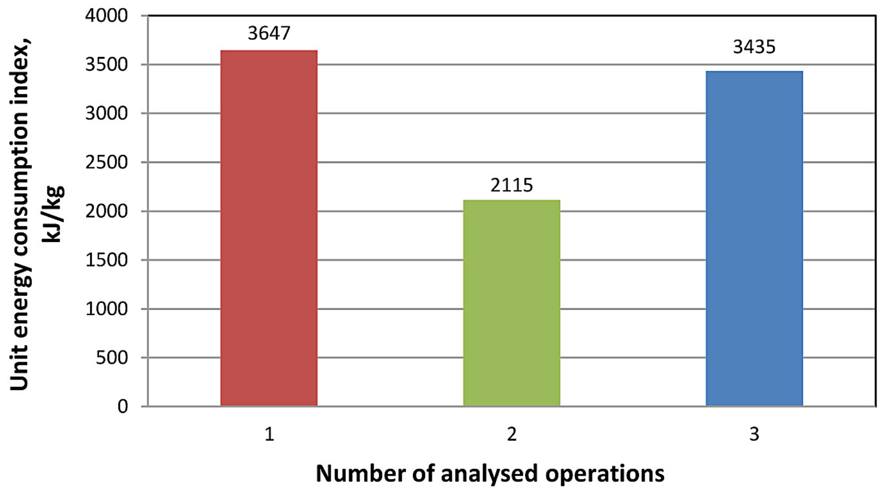

Fig. 8. Unit energy consumption index for the operations analysed in the study

costs of heating are correlated with energy consumption. Unit energy consumption index is presented in Figure 8.

Analysis of Figure 8 reveals that operation 1 (normalizing) is characterized by the highest value of the index. A slightly lower index was found for operation 3 (stress relief annealing). Despite almost twice higher energy consumption, values of unit energy consumption index for these operations are nearly comparable. This is caused by the fact that normalizing was carried out for the charge with over twice higher mass compared to stress relief annealing, with operation time being four times shorter. Furthermore, in order to heat the charge for normalizing, it was necessary to supply substantially more energy due to higher temperature the operation occurs at.

CONCLUSIONS

Chamber furnaces for heat treatment have a specific character since, despite the seasonal operation they are designed for, each heating should be adjusted to specific temperature conditions of the charge. Furthermore, an important role is also played by operation time, which depends not only on the type of treatment but also on geometrical dimensions (charge mass). This causes that it is very difficult to operate the furnace for varied heating parameters which follow one after another.

The results obtained for unit energy consumption index and heating costs lead to investigations of opportunities for the improvement of furnace operation organization, which is likely to contribute to a more efficient operation. Improved furnace operation can be achieved without much financial expenses. It is suggested that furnace operation is organized so that:

- operations of heat treatment should be planned in advance and performed in „blocks" for heating that requires similar temperature parameters,
- heating should be carried out so that it allows for rational utilization of furnace heating power,
- heating with reduced capacity requires changes in heating technologies [7, 8]. However, in the case of processes of heat treatment, the necessity of maintaining heating curves causes that reduction in energy consumption can be improved through better utilization of the working space of the furnace.

With regard to the character of the department the furnace operates in, this can be difficult to be achieved, but not impossible. With adequate financial resources, the implementation of the information system IFS [9, 10] can be proposed, which would substantially allow for planning furnace operation.

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