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# THE EFFICIENCY INCREASING OF THE ENERGY CONSUMPTION OF INDUSTRIAL HEAT TECHNICAL EQUIPMENT

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## ABSTRACT

*In the paper the positive experience of "KAPRONI" Ltd. – Kazanlak by the building of a system for complex technological and energy control in the thermal production of the company is described. The equipment includes electrical furnaces for hammering, stamping and heat treatment, thermal baths, foundry furnaces, etc. The juice of the system is the realization of a distance control of the high-temperature processes in the different types of units, whereupon the consumed electric energy is determined by a regressive equation in dependence from the observed temperature. The using of similar solution simplifies the system and saves resources for expensive apparatuses for energy control.*

*The furnaces for gas carburizing and hardening are chosen to illustrate the expediency of the using the system. Data obtained at production conditions are given. The usefulness of the system consists in the founding of optimal energy regimes for working of the equipment, in the creating of a requirements for energy consumption according to the arts of manufactured production and in the introduction of indexes for energy efficiency and for technological loading of the aggregates. The effect of the system applied is essential on account of the dimension and the energy capacity of the units in the thermal productions. The relative error in the determination of the consumed electric energy by the system doesn't exceed 5 % and in the predominant number of cases it is between 2 and 3 %. The system is unique for Bulgaria, it has an universal character and can be applied in other metallurgical and industrial enterprises.*

*Keywords:* *energy efficiency, normalizing of the energy consumption, control on the consumption, accurate reading, optimizing, planning.*

## INTRODUCTION

The necessity of development of effective methods for energy control imposes as one of the basic ways for remaining and for adaptation to the market requirements of the metallurgical and the machine-building plants in our country. For the Bulgarian industrial production the low competitive power is a fact [1, 2]. This is caused mainly by the insufficient application of advanced methods for management and technical insurance of the production.

This work presents the results from the putting into operation of a system for complex technological and energy control in the thermal production of "Kaproni" Ltd. – Kazanlak, Bulgaria (former "Hydravlica"). The tasked problems before it are to insure energy-founded technological regimes of the equipment and a continuous monitoring of their implementation. The waited results from the applying of the system are [3]:

- the expenditures reducing for electric energy with about 3 %;

• insurance of possibility for perspective planning of the expenditures for electric energy according to the arts of manufactured production;

• introduction of indexes for an energy efficiency and a technological loading of the equipment;

• creating of a new organization for control of electric energy with an application of flexible methods for stimulation.

## EXPERIMENTAL

One of the main production units in "Kaproni" Ltd. – Kazanlak, Bulgaria is the heat treatment shop, whose technological scheme is shown in Fig. 1. As a basic object for monitoring and energy optimization is chosen one of the furnaces for gas carburizing and hardening (position 1 in Fig. 1).

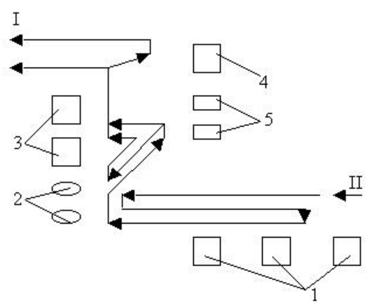


Fig. 1. Technological scheme of the heat treatment shop
I – semi-manufactured articles; II – finished production; (1 – furnaces for gas carburizing and hardening; 2 – washing-machine; 3 – annealing furnaces; 4 – aggregate for heat treatment with high frequency electricity; 5 – refrigerator).

The scheme reflects the transport of the semi-manufactured articles from their entry in the shop to their dispatching. The equipment of the shop is mainly thermal, thus allowing its including in a common technological and energy control both individually or for the whole shop.

In Fig. 2 is presented a principle scheme of the system for complex technological and energy control. It includes a computer 1 with special developed for that purpose software, concentrator 6, to whom consequently are connected up to 32 pieces thermoregulators 5 and a cable net 4. An electrometer 3 with a monitoring function using the concentrator 2 is plugged to the computer.

The registration of the experimental data occurs as follows: one from the thermoregulators of the system

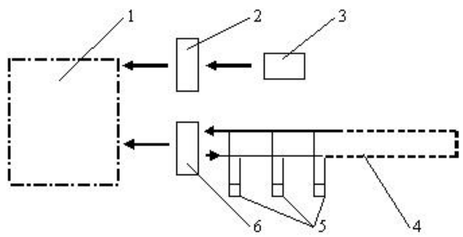


Fig. 2. Principle scheme of the system for complex technological and energy control (1 – computer; 2 – concentrator for electrometer; 3 – electrometer; 4 – cable net; 5 – thermoregulators (up to 32 pieces on distance to 500 m); 6 – concentrator for thermoregulators).

is switched on the furnaces for gas carburizing and hardening. The outgoing signal from it by means of the software of the system is changed into a temperature graph, which is transformed through the established regressive equation into energy one. The incoming signal parallel from the electrometer is also changed into an energy graph. In this way it is given a possibility for comparing of the obtained graphs and for determination of the accordance grade between them.

## RESULTS

A key-role in the software of the system has the mentioned regressive equation, which is necessary for calculation of the effective electric power of the heaters *P*, kW according data for the observed technological temperature in the corresponding furnace *T*, °C. The common form of this dependence is:

$$P = f(T). \qquad (1)$$

The consumed electric energy *E*, kJ, for a definite period of time $\tau_1 \div \tau_2$, s, is given with the equation:

$$E = \int_{\tau_1}^{\tau_2} P(\tau)d\tau\,. \qquad (2)$$

Two possible temperature regimes for work of the thermal equipment are existing – a steady, when the assigned and the observed, i. e. measured temperatures are identical, and unsteady, when they are different. The last situation comes into being by assigning of new working temperatures by loading in the furnace of cold semi-manufactured articles, etc.

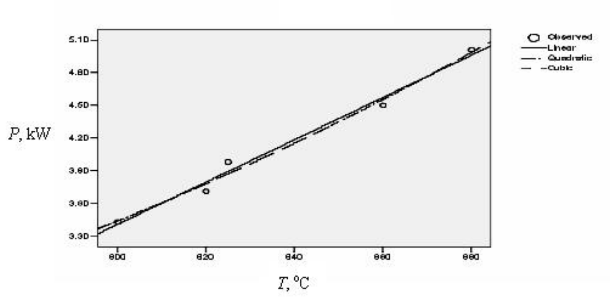


Fig. 3

Fig. 3. Comparison between the experimental obtained and the predicted by the separate equations values of the effective power of the furnace.

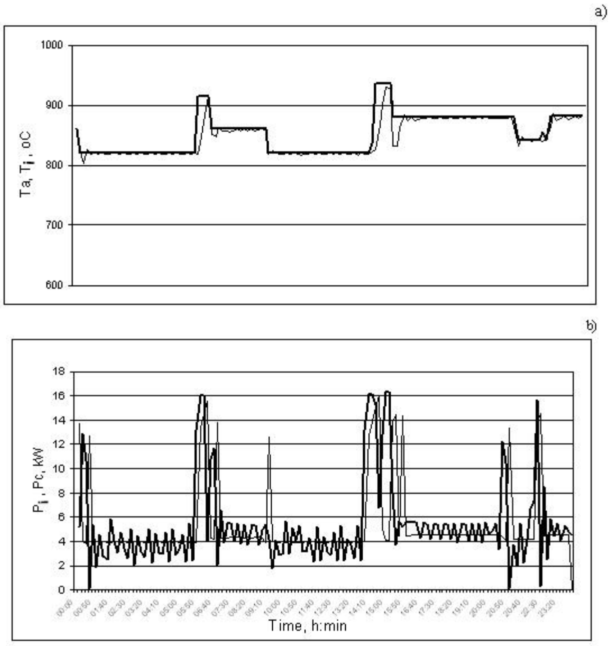


Fig. 4. Results from supervision during 24 hours of:
a) assigned ($T_i$) and observed ($T_i$) values of the furnaces temperature; b) observed ($P_i$) and calculated ($P_c$) values of the effective furnaces power.

The experimental data used for the searched regressive equation at the furnace work in steady temperature regime, are collected during 11 days and nights over fixed intervals of time equal to 10 min. In Fig. 3 are shown the so called "heavy points", that are obtained by averaging of all the 864 observed couple of values of $T$ and $P$ by steady temperature regime of the furnace.

For establishment of an appropriate regressive equation on the basis of the results are used the commonly accepted principles and methods for regressive analysis of experimental data [4, 5], as well as a package of applied software "SPSS" for their statistical processing. Three types of dependences reflecting the obvious mode of (1) were obtained. The common form of the most complicated one from them is the following:

$$P = b_0 + b_1 T + b_2 T^2 + b_3 T^3 \ , \qquad (3)$$

where with $b_0 \div b_3$ are marked the empirical coefficients in each correlation, whose values are presented in Table 1.

The corresponding dependences are graphically shown in Fig. 3. Obviously the three equations ensure enough high and practically equal accuracy (the curves corresponding to the quadratic and to the cubic expressions are coinciding at the chosen scale). Their statistical verification also shows that their correlation coefficients varying within the boundaries of $0{,}993 \div 0{,}994$ are significant and with a probability over 95 % it can be affirmed that the established dependences describe adequately the experimental data in the whole working range 800 °C $\leq T \leq$ 900 °C. The linear equation can be used by necessary from accidental engineer estimations at the real production conditions. When such calculations are doing by means of a computer in the borders of the system for control, it is preferred the cubic equation, which ensures relatively higher accuracy.

The obtained results for one from the working days of the furnace are given in Fig. 4a and Fig. 4b. With a dense line in the upper graph is shown the assigned temperature $T_a$, and with a thin – the observed one $T_i$ °C. In Fig. 4b with a dense line is presented the observed power $P_i$, and with a thin – the calculated $P_c$, W. In the graphs very clear can be seen the periods of work of the furnace in an unsteady regime. By it $T_i$ with

Table 1. Values of the coefficients in equation (3) for the three types of dependences.

| Type of the equation | Coefficient | | | |
|---|---|---|---|---|
| | $b_0$ | $b_1$ | $b_2$ | $b_3$ |
| Linear | -12,100 | 0,019 | – | – |
| Quadratic | 14,090 | -0,040 | $4.10^{-5}$ | – |
| Cubic | 2,275 | 0 | $-1{,}5.10^{-5}$ | $2{,}1.10^{-8}$ |

some retardation catches up with $T_a$. In the same moment it observes a peak in both compared values of the power. From Fig. 4b makes an impression also the good coincidence between the observed and the calculated curves in the whole examined period of time.

## CONCLUSIONS

A system for distance temperature control on the work of the whole thermal equipment in one large machine-building company was created. In it is successfully experimented a module for energy control by means of which the consumed electric energy is determined through the established regressive equation in dependence from the observed furnace temperature.

The work of the system results into the application of measures for finding of optimal energy regimes for exploitation of the equipment. Consequently, it can be achieved a reduction of the electric energy consumption with about 3 %.

The successful inculcation of the system insures the possibility for conversion of the electric energy consumption into a continuous controlled production indicator and creates preconditions for its perspectively planning on the different arts of fabricated products as well as for an introduction of indicators for its quantitative estimation and comparison with data for similar aggregates work.

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