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The Dependence of the Heat Energy Consumption upon the Working Intensity and the Frequency of the Isolation Maintenance of a Pusher-type Furnace

Ovisnost utroška toplinske energije od intenziteta rada i učestalosti održavanja izolacije potisne peći

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The paper covers investigations of the specific heat energy consumption dependence upon the productivity and frequency of the isolation maintenance in a pusher-type furnace of a strip and billet rolling mill.

U okviru ovog rada istraživana je ovisnost specifičnog utroška toplinske energije od produktivnosti i učestalosti odražavanja izolacije na primjeru potisne peći u valjaonici traka i gredica.

1 Introduction

Systematic decreasing of the fuel consumption per unit of a product should be one of the most important tendencies in Yugoslav rolling mills. However, the dynamics of the specific fuel consumption decreasing has recently been stopped in some heating furnaces and has assumed, for the various reasons (mostly objective), an inversed trend. Thus, even a decreased working intensity of heating furnaces leads to an increased specific fuel consumption. This often happens to appear in the rolling mills mentioned, especially lately. This is the reason that the paper deals with the investigation of the specific heat energy consumption dependence upon the productivity of heating furnaces and, especially, upon the frequency of isolation maintenance on the example of one of the two pusher-type furnaces of a Sisak Ironwork's strip and billet rolling mill (Sisak, Croatia).

2 Heat energy balance and fuel consumption

Rough values for specific fuel consumption decreasing in the case of increased working intensity of heating furnaces can be obtained by heat energy balance[1,2]. The total heat energy consumption ($\sum E_i$) can be derived into two groups:

1. one depending on the mass of steel being heated in a certain heating furnace:
   - heat energy of steel being heated (E_1),
   - heat energy of scrap developing in the course of steel heating (E_2),
   - heat energy losses (through the walls to the outside, by cooling water etc.) independently to the mass of steel being heated (E_3);
2. one depending on the level of fuel utilization in a certain heating furnace:
   - heat energy losses because of mechanical unburning, incomplete chemical combustion and by fuel gases going out (E_4).

Obviously, it is (per unit share)

$$E_1 + E_2 + E_3 + E_4 = 1 \tag{1}$$

First, let's take that a quantity of conditional fuel X_n is consumed to heat a mass of steel M_n, i.e.

$$E_1X_n + E_2X_n + E_3X_n + E_4X_n = X_n \tag{2}$$

If the intensity of steel heating increases z times, the consumption of the conditional fuel increases up to the value of X_z, and the equation (2) takes the following form:

$$z(E_1 + E_2)X_n + E_3X_n + E_4X_z = X_z \tag{3}$$

From the equation (3) we can now derive a quantity of the conditional fuel X_z, i.e.

$$X_z = X_n\left(\frac{z(E_1 + E_2) + E_3}{1 - E_4}\right) \tag{4}$$

Based on these, it is possible to define a decrease of the specific fuel consumption, as a result of the intensity of steel heating increased z times, as follows:

$$\begin{aligned}\Delta x &= \left(\frac{X_n}{M_n} - \frac{X_z}{M_z}\right)\cdot 100 = \\ &= \left(\frac{X_n}{M_n} - \frac{X_z}{zM_n}\right)\cdot 100 = \\ &= \left(\frac{X_n}{M_n} - \frac{X_n\left(\frac{z(E_1+E_2)+E_3}{1-E_4}\right)}{zM_n}\right)\cdot 100 = \\ &= \frac{X_n}{M_n}\left(1 - \frac{z(E_1 + E_2) + E_3}{z(1 - E_4)}\right)\cdot 100 \end{aligned} \tag{5}$$

Consequently, as a result of the increased working intensity of the heating furnaces, i.e. the process of steel heating being intensified z times, the the specific fuel consumption (in %) will be decreased in a ratio:

$$\left(1 - \frac{z(E_1 + E_2) + E_3}{z(1 - E_4)}\right)\cdot 100. \tag{6}$$

3 Main characteristics of a pusher-type furnace

A three-zonal pusher-type furnace observed, designed by American Rust Furnace Co., was built in the year 1972. Beginning from the charging side the furnace has a preheating zone, a heating zone and a soaking zone. In the preheating and heating zone a charge was heated both from the upper and the lowes side, whereas in the zone of soaking it was heated only from the upper side. Burners were installed laterally on the furnace, above and below the charge in the preheating and heating zone. In the preheating zone five burners were installed above the charge and five burners below the charge. Two burners were installed above the charge on one side and three on the other side of the furnace. The burners were also installed below the charge, but placed inversely to those above the charge. In the heating zone six burners were installed above the charge and six burners below the charge. On each side of the furnace three burners were placed above the charge and three below the charge. In the soaking zone six burners were placed on the frontal side of the furnace. Otherwise, the furnace is not of a conventional profile and is of a conventional temperature regime[3]. By operating measurements it was found that the firing from the lower side and that from the upper side have the equal efficiency. The furnace profile, as well as its main dimensions are presented schematically in **Fig. 1.**

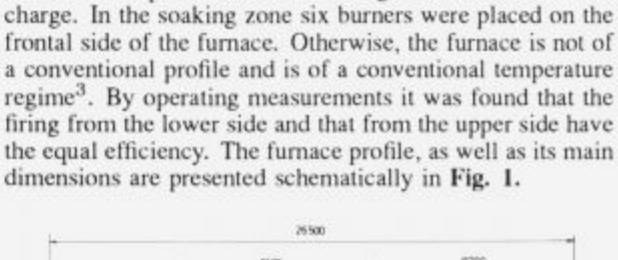

Figure 1. Schematic presentation of a pusher-type furnace profile.
Slika 1. Shematski prikaz profila potisne peći.

During the energetic balancing slabs of St 12 (per DIN) quality, dimensions of 430 × 190 × 3800 mm and mass of 2500 kg singly were heated in the pusher-type furnace. The furnace was fired by natural gas having the heating value of 37300 kJ/m^3. Gas consumption was 2347 m^3/h, and consumption of air necessary for its combustion was 24286 m^3/h. Air temperature at the metal recuperator exit was 300°C. According to the request of the rolling mill train the furnace productivity was kept at 37 t/h, and the slabs were heated up to the final temperature of 1230–1250°C. However, the furnace was designed to achieve the productivity of 67 t/h when heating slabs of stated quality and dimensions. This shows that the coefficient of capacity utilization of the furnace was about 0.55, which indicates that working intensity of the furnace can be increased 1.81 times.

4 Fuel consumption dependence upon the productivity and frequency of a pusher-type furnace maintenance

For a calculation of the specific fuel consumption decrease heat energy consumption in a pusher-type furnace was found.The heat energy consumption (per single items) in the furnace when heating the slabs of the stated quality and dimensions is given in **Table 1.**

Table 1. Heat energy consumption in a pusher-type furnace when heating slabs of St 12 quality and dimensions of 430 × 190 × 3800 mm

Heat energy consumption items	Quantity of heat energy	
	MW	%
E_1	8.998	33.32
E_2	-	-
E_3	6.108	22.61
E_4	11.902	44.07
$\sum E_i$	27.008	100.00

The following step enables to find out how much the specific fuel consumption decreases if the working intensity of the furnace increases 1.81 times.

Applying the equation (6) we get that the specific fuel consumption decreases for 18.09%, providing that, as stated, the working intensity of the pusher-type furnace increases 1.81 times, i.e.

$$\left(1 - \frac{1.81 \cdot 0.3332 + 0.2261}{1.81(1 - 0.4407)}\right) \cdot 100 = 18.09\%$$

The value obtained also anables calculating the specific fuel consumption in the case that the furnace works full capacity. Results of such a calculation show that the specific natural gas consumption in the furnace decreases from 63.43 to 51.96 m^3/t, corresponding to the decrease of the specific heat energy consumption from 2366 to 1938 kJ/kg, i.e. for 428 kJ/kg.

To get a real picture of the dependence of the specific heat energy consumption upon the working intensity of the puscher-type furnace, a three-years period of the furnace work has been analyzed. Only the data referring to the furnace work during the St 12 quality slabs of 430 × 190 × 3800 mm dimensions being heated were delt with. The dependences of the specific heat energy consumption upon the furnace productivity being got that way are presented in a form of a diagram in **Fig. 2.**

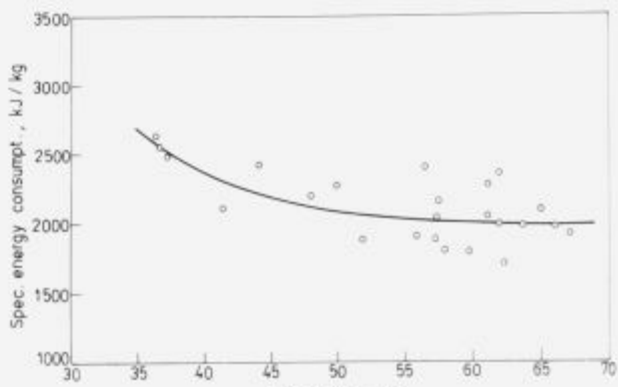

Figure 2. The dependence of the specific heat energy consumption upon the pusher-type furnace productivity.
Slika 2. Ovisnost specifičnog utroška toplinske energije od produktivnosti potisne peći.

Volume in m^3 refers to a normal state.

Comparing the calculated values for the specific heat energy consumption with those obtained by operating measurements for the stated quality and dimensions of the charge, the results of which are presented in a form of a diagram in **Fig. 2,** we can see that the differences are relatively small. Considerable differences are the consequence of including a consumption of natural gas for "blank" firing to the operating data on the natural gas consumption. Also, the changes of energetic losses per items of energetic balance, in the course of the furnace utilization for its isolation reparation between the two stoppings, can bring to some bigger differences between the calculated and operating values for the specific heat energy consumption in a certain furnace productivity.

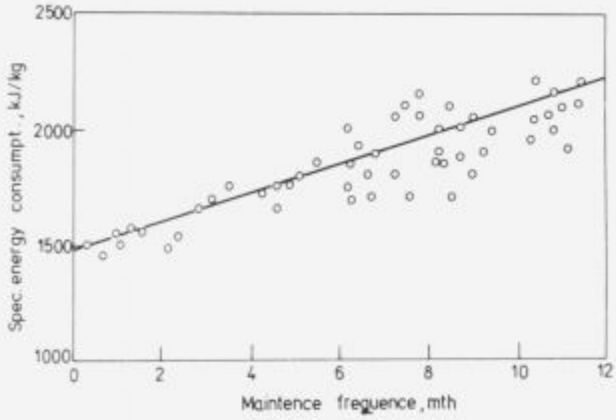

Figure 3. The dependence of the specific heat energy consumption upon the frequency of the isolation maintenance and the pusher-type furnace floor cleaning.

Slika 3. Ovisnost specifičnog utroška toplinske energije od učestalosti održavanja izolacije i čišćenja poda potisne peći.

The analysis carried out for the furnace work between its last two stoppings, because of the beam cleaning and of the isolation reparation, showed that with the productivity of 50 t/h (realized annual productivity) the specific heat energy consumption increases from the initial 1480 to the final 2240 kJ/kg, in other words the average value is 1860 kJ/kg (**Fig. 3**). Beside others, the course of that is almost up to 80% of refractory mass falls off the skid carrier so that energy losses by cooling water are considerable[4]. The increase of isolation maintenance frequency, as well as that of beam cleaning from the layers, to the half of time (6 months) of the previous (12 months) would decrease the average heat energy consumption from 1860 to 1670 kJ/kg (**Fig. 3**), i.e. for 190 kJ/kg.

However, for a rather long period of time in some western countries a quartal frequency of pusher-type furnaces[5] maintenance has been practised, so regarding to this, there are no reasons to make the first step in our strip and billet rolling mills as well.

5 Summary

Results obtained analytically show that the specific heat energy consumption decreases for about 18% if the productivity of the pusher-type furnace observed increases from 37 to 67 t/h. Also, the operating data analysis of the furnace work does not show significant deviations from the results obtained analytically. However, because of the lack of coordination between pusher-type furnaces and rolling mill train capacities, even in normal production conditions it is impossible to realize. The same way, the increase of the pusher-type furnace isolation maintenance frequency and that of the layers removal from the floor to the period of 6 from so far 12 months, would decrease the specific heat energy consumption for about 10%. This can be realized successfully by better month and week planning of rolling, which would assure heating of the charge having the same quality and dimensions in the course of a few weeks. In such a case it could be possible to stop one of the furnaces if another's passing capacity per hour would satisfy the requests of the rolling mill train. Such periods sometimes occure now, too, as well as those in which plans of rolling change from shift to shift together with plans of heating.

6 References

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