

Metal loss reduction in the continuous furnace with a mechanized hearth due to the increase in uniformity of billet heating

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Abstract. The analysis of the negative influence of the uniform heating of billets along the length in the continuous furnaces with a mechanized hearth on the work of heating furnaces, rolling mill and the quality of metal products is given. The influence of the non-uniformity of heating on metal loss is investigated. Based on the experimental data analysis of temperatures measurements of billets surface heated in the walking-hearth furnace, a statistical analysis was carried out and the equation of regression of the temperature distribution along the length of the billet was obtained using the least squares method. It is established that an increase in the non-uniformity of surface billet heating leads to an increase in the metal loss, and this dependence has a nonlinear character.

1. Introduction

Slabs and square billets are heated in the continuous furnaces of various designs before rolling. The most promising of them are continuous furnaces with a mechanized hearth (furnaces with a walking hearth FWH and furnaces with walking beams FWB). One of the important indicators of the quality of metal heating [1] in furnaces, along with the absence of cracks from temperature stresses [2], is the uniformity of temperature distribution along the thickness, length and perimeter of billets. A high heating non-uniformity of metal along the length of the billet is typical for continuous furnaces with a mechanized hearth, which is caused by gaps between the elements of the walking hearth or water-cooled walking beams [3, 4].

In FWH the appearance of local areas on the workpiece with a reduced temperature (“dark spots”) may be due to imperfection of the design or technical condition of the water closures. For example, in case of unsatisfactory operation of hydraulic locks, depending on the pressure regime in the furnace, atmospheric air can get inside through the gaps between the walking elements of the hearth, which causes cooling of the part of the workpiece located above the gap.

In FWB dark spots appear at the contact points of billets with water-cooled beams, and the magnitude of the uniformity largely depends on the design and material of the riders installed on the beams.

It is typical that the non-uniform heating of billets also appears during the rolling process. When fixing the currents I of the rolling mill engines, low-frequency oscillations are clearly visible, the number of which corresponds to the number of local sections of rolled products with a lowered temperature, and the magnitude of the load fluctuation depends on the magnitude of the temperature fluctuation.



High temperature non-uniformity along the length of billets has a number of negative consequences, negatively affecting the operation of heating furnaces, rolling mill and the quality of metal products:

- the non-uniformity of geometric dimensions and the mass of the running meter along the length of the workpiece;
- periodic increase in rolling forces and, as a result, an increase in the probability of rolls breakage;
- increase in the power consumption for rolling profiles;
- elimination of the possibility of expanding the assortment due to rolling high-precision and lightweight profiles, stable performance of finished rolled products in the field of negative tolerances;
- creates fluctuations in mechanical characteristics of rolled products along the length of the workpiece;
- complicates the setting of the mill, which leads to an increase in rejects and second-class quality in the geometric dimensions of profiles;
- increased metal loss and fuel consumption during heating.

The lower the metal temperature in the area of the dark spot, the higher the metal resistance to the plastic deformation, the force P of the mill and the energy consumption for rolling. A decrease in the temperature, for example, of 3ps steel from 1300 to 1150 °C, leads to an increase in the resistance of the steel plastic deformation and, accordingly, the rolling forces by 1.55 times on average by approximately 3% per 10 °C. In this regard, the need to obtain the required mass-average final temperature of metal (to roll dark spots) leads to the inevitability of raising the heating temperature of the rest of the workpiece with no dark spots. This leads to a general increase in the metal loss, steel decarburization, worsens the operating conditions of the furnace hearth lining, reduces the service life of the furnace.

Figure 1 shows schematically the dependence of the rolling forces and load of the stand motors on the workpiece temperature for various temperature non-uniformity along the workpiece length. At the same average metal temperature a more uniform heating (figure 1, c) leads to a lesser probability of grain growth, overheating, steel burning and melting of scale. It allows the cobbing to be intensified and the productivity of the rolling process to be increased. High non-uniformity of heating (figure 1, a), on the contrary, increases the probability of heating failure, leads to considerable fluctuations in the forces of the mill and the load of electric motors.

2. Methods of research

In the present work, the effect of non-uniformity of workpiece surface heating on the metal loss is investigated. Based on the experimental data of temperature measurements of the workpieces surface heated in the furnace with a walking hearth of one of the Russian metallurgical enterprises, statistical analysis was carried out and the equation of regression of the temperature distribution t over the length l of the workpiece was obtained using the least squares method:

$$t = t^{\circ} + A \cdot \cos(B \cdot l) \quad (1)$$

where t° – the average surface temperature of the workpiece, °C; A and B – empirical coefficients depending on the heating mode and the number of gaps between the elements of the hearth (heat dissipation sector).

3. Results and discussion

For example, figure 2 shows the results of one of the statistical processing options. In equation (1), $t^{\circ} = 1214$ °C; $A=60$; $B=3.76$. The maximum value of the surface temperature is 1274 °C, the minimum is 1154 °C, the temperature difference Δt is 120 °C, respectively. The dependence has the form of a cosine wave. The ends of the billet are characterized by a higher heating temperature and the number

of temperature minima (dark spots) corresponds to the number and location of gaps between the elements of the hearth that have a cooling effect.

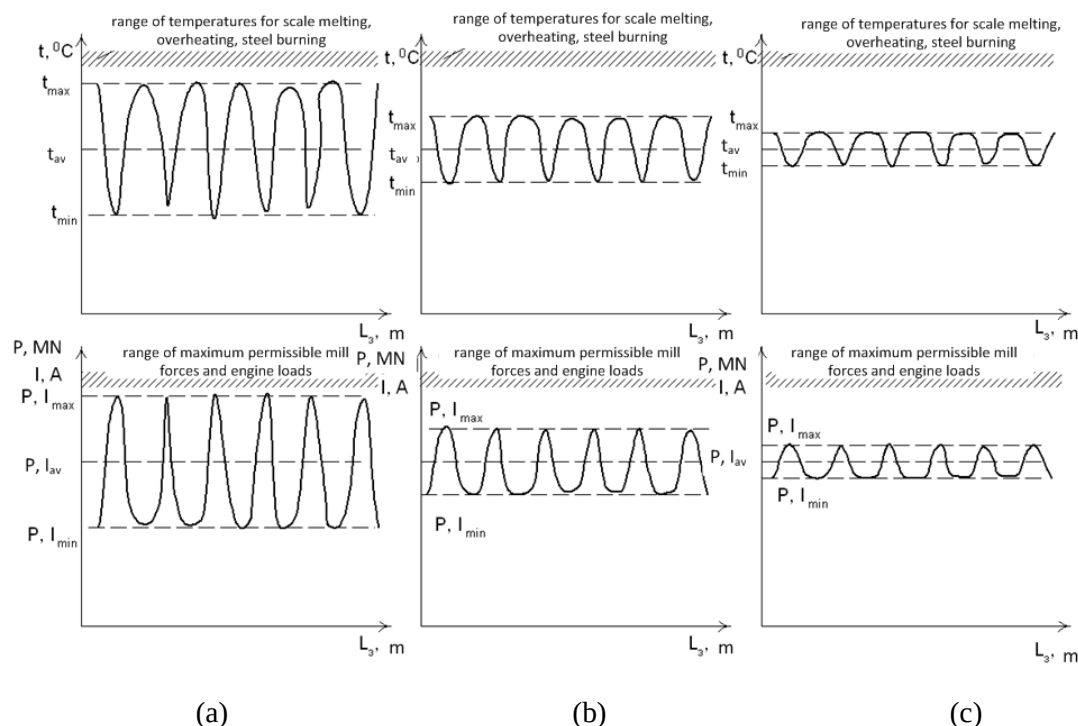


Figure 1. Dependence of rolling forces and loads of stand motors on the workpiece temperature for various temperature non-uniformity along the workpiece length.

Using equation (1) and the data on kinetics of oxidation of siliceous spring steels [5 – 10], an assessment of the effect of heating non-uniformity on metal loss was made. Comparative calculations were carried out holding steel 60S2KhA at the appropriate temperature along the length of the billet for 1 minute.

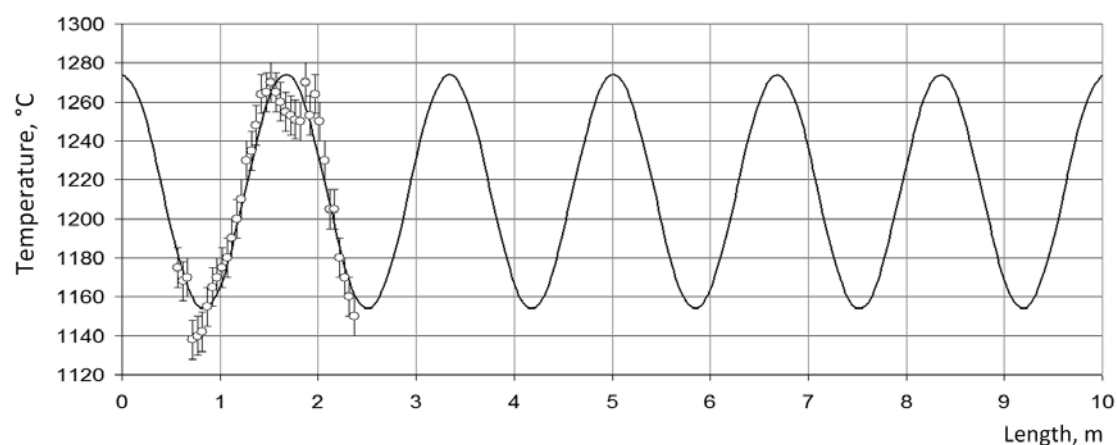


Figure 2. Temperature distribution along the length of the workpiece (points – experimental data, solid line – calculated).

Figure 3 shows the results of the study. It is established that an increase in the heating non-uniformity of the billet surface leads to an increase in metal loss, and this dependence has a nonlinear

character. With an average temperature 1214 °C and a temperature difference 100 °C, the metal loss increases by almost 2% compared to non-uniformity heating, and at a drop of 200 °C by 7%.

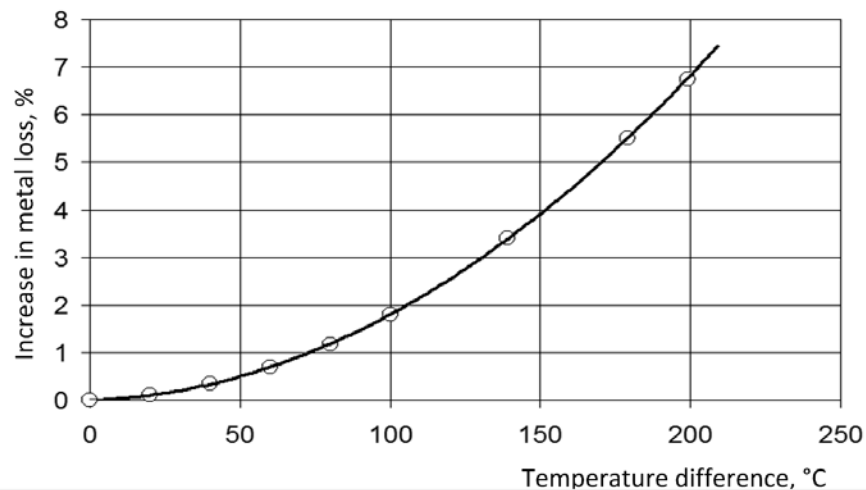


Figure 3. Dependence of the increase in metal loss on non-uniformity of heating of the surface workpiece.

4. Conclusion

It is established that an increase in the heating non-uniformity of the billet surface leads to an increase in metal loss, and this dependence has a nonlinear character.

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