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Research and substantiation of production and application of nickel-free electrical steels for the grate bar

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Abstract
The analytical research results of replacement possibility of expensive high-alloy nickel-chromium steels by sparingly alloyed nickel-free ones alloyed by nitrogen are shown. The interrelation of increase of operational steel properties for the grate bar of the roasting and sinter machines is shown.
Key words: CONVEYOR-TYPE MACHINE, PELLET FIRING, AGGLOMERATE SINTERING, GRATE BAR, ELECTRIC STEEL, ALLOYING, SCALE

The modes of high-temperature hardening of pellets and agglomerate are thermal-cycle and are conductive to intensive breakdown of parts of firing and pallet cars of conveyor-type machines. The grate field consisting of cast gate bars is subjected to the greatest wear. The costs of gate bars replacement are reflected in prime cost of raw materials pelletizing and are equal to 0.008-0.009 kg/t (according to agglomerating plants of Kryvyi Rih) and 0.011-0.018 kg/t (according to "Northern GOK" and "CGOK" roasting plants of Kryvyi Rih and also PGOK).

In papers [1-3], it was noted that high-alloy nickel-chromium steels mainly of austenite-ferritic class: 40H24N12SL for grate bars of pellets firing machines and 75H28N2SL for sintering machine, are used.

In order to increase the processing properties of steels, which operate at high-temperature zone and in aggressive media, the number of scientists [4-7] proposed them to be alloyed with nitrogen.

The theory main problems, technique of processing and application of nitrogen-containing corrosion-resistant nickel-chromium and chromium-manganese steels are analyzed by V.A. Grigoryan and colleagues [7].

In order to ensure the steel corrosion resistance, the nitrogen is added instead of nickel in the ratio 1:27. The steady nitriding of liquid melt is one of the main objectives of nitrogen-containing corrosion-resistant steels production. Process of stabilization of liquid melt nitriding is considered on the basis of the absorption mechanism of nitrogen from nitrogen-oxygen gaseous phase by steel [7]. This mechanism essence consists in existence of gas-metal of nitrogen active forms in the border area including the forms of CN, NO_x, etc.

The process of deoxidation and inoculation of corrosion-resistant alloys on the basis of chrome and nickel by aluminum and titanium was investigated in the paper [8]. The authors proved that the optimum concentration of aluminum is changed from 0.15 to 0.65% and the titanium concentration - from 0.07 to 0.37% with the chrome content increase from 15 to 40%. The increase in concentration of aluminum and titanium is followed by the increase of plastic characteristics and corrosion resistance of alloys.

A number of researchers [9, 10] established the possibility of the sparingly alloyed heat-resistant steels and alloys production. New composition of the steel grades 10H14G14N4T, 10H14AG15 and other was developed, and also researches of chemical and phase composition of scale and layers under oxide were conducted.

The researches results showed that the chrome content on the metal surface and in scale is changed slightly in the steels with manganese. The manganese content in scale decreases (10.5% and 4.6% respectively). Advantage of the chrome-manganese steels with nitrogen is associated with not only the increase of scale protective properties, but also with nitrogen interference in scale formation; this prevents the chrome from burn-off.

According to O. Kubashevsky and B. Gopkins [11], and also to the results of our researches of grate bars operating conditions [12-14], the composition and structure of the formed scale have significant impact on their resistance. The positive effect on the heat resistance of aluminum and silicon steels is noted [15]. In accordance with [16], aluminum and silicon increase the steel stability against the impact of aggressive media including the sulfur at high temperatures.

On the basis of the analysis of papers [9, 17, 18], it is possible to formulate the basic principles of the heat-resistant steels alloying for grate bars of conveyor-type machines when iron ore concentrates pelletizing, namely the replacement of high priced nickel with austenite-promoting elements manganese and nitrogen is basically possible [10]. The chrome content should be not higher than 15%, and the carbon content – not less than 0.2% in order to obtain the austenitic structure [17]. It is reasonable to alloy the steel with aluminum and silicon, and also with titanium for further increase of the steel heat resistance. The last is added in heat-resistant steel for grain refining and carbon fixation into the high-heat carbide TiC [18].

We developed the steel 30H14G8AYu2TL with the following chemical composition, %: Cr – 14-16; Mn – 6-8; Al – 1.5-2.5; C – 0.2-0.4; Si – 0.5 – 1.5; Ti – 0.03 – 0.1; N – 0.15 – 0.2. This steel composition is protected by the patent of Ukraine [19].

The steel phase composition for grate bars 40H24N12SL, 75H28N2SL and the developed steel 30H14G8AYu2TL is shown in Fig. 1. Considering that when calculating of nickel and chrome equivalent content according to Sheffler diagram (see Fig. 1), the content of such elements as nitrogen and aluminum is not considered, the calculation of nickel and chrome equivalent content for the developed steel is carried out according to P. N. Bidulya formulas [15], where the content of nitrogen (under calculation of the nickel equivalent content), as well as of aluminum (under calculation of the chrome equivalent content) is considered.

$$Ni_{eq} = \%Ni + 30\%C + 0.5\%Mn + 12\%N \quad (1)$$

$$Cr_{eq} = \%Cr + \%Mo + 1.5\%Si + 0.5\%Nb + 0.8\%W + + 1.5\%V + 4\%Ti + 3.5\%Al \quad (2)$$

For the steel according to the patent [19], the equivalent content of Ni_{eq} = 16.9 and Cr_{eq} = 21.7 calculated by formulas (1) and (2) corresponds to the austenitic structure according to Sheffler diagram (see Fig. 1), while currently applied steels 40H24N12SL and 75H28N2SL are of two-phase austenite-ferritic composition.

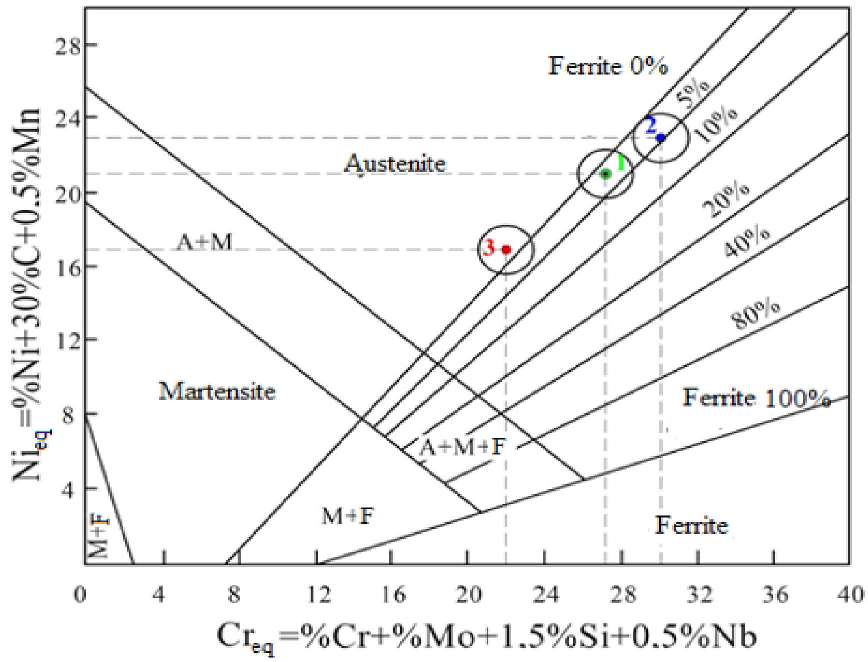

Figure 1. Phase composition of steel for grate bars of roasting and sinter machines at various values of the chromic and nickel equivalent (Sheffler diagram):
A – austenite; M – martensite; F – ferrite; 1 – steel 40H24N12SL;
2 – steel 75H28N2SL; 3 – steel 30H14G8AYu2TL

Conclusions

1. The possibility of nitrogen use when production of nickel-free steels operating in the conditions of pellet firing and agglomerate sintering is shown on the basis of the analysis of earlier researches, and also the nitrogen absorption mechanism by liquid melt from the nitrogen oxygen gas environment.

2. Possibility of the steel heat resistance increase for production of grate bars of roasting and sinter machines due to steel alloying with aluminum and titanium is shown.

3.The nickel-free heat-resistant steel for grate bar was developed by steady austenitic structure obtaining due to alloying by manganese and nitrogen, and also by the oxide layer of difficult chemical composition obtaining on grate bar surface; this prevent the grate bar from further destruction.

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