SUMMARY

Gezenzvey Yu. I. Technological effectiveness of the use of fine-grained heat-resistant steels in the constructions of blast furnace casings. – Qualifying scientific work. A manuscript.

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The work deals with solving the applied problem of lengthening the cycle of trouble-proof work of blast furnace casings at the expense of domestic high-strength rolling usage. The task was solved by creating temperature-deformative regimes of plate rolling from steel 10Г2ФБЮ to form in polygonal austenite structure heterogeneous nucleation of ferrite. It leads to the formation of highly dispersed ferrite-perlite structure that keeps a high level of power, plasticity and heat-resistance of plate, while being exploited under the conditions of elevated temperatures.

The urgency of the work is conditioned by the analysis of expediency of application of high-strength steels in the construction elements of blast furnace casings. In general cost of produced and mounted building steel construction, the cost of metal rolling is 60…70%, thus the application of technological and high-strength types of rolled metal and steel types causes the reduction of the construction prime cost. The expansion of steel range that enables to increase technological effectiveness of steel constructions as for not only weight minimization but also optimization of the criteria of corrosion resistance and fire resistance with their effective usage in bearing metal structures of different buildings and structures is one of the primary tasks of material science.

It should be stressed that steels used nowadays as materials for the constructions of blast furnace complexes do not fully meet the requirements to the constructions of such purpose. Plate metal-roll produced by domestic metallurgical factors has a great variety of power and plastic peculiarities along, across and at the

thickness of the sheet. The value of power characteristics along the rolling direction in comparison to Z-direction can differ in 1,5…2 times. Anisotropy of power and plastic characteristics is the result of ferrite-perlite stripes presence in the metal-roll structure. This structure heterogeneity together with the formation of axial liquation zone increases the risk of the destruction of the construction that works under a significant temperature influence, which occurs in blast furnace casings.

That is why the researches aimed at improving the structural state of high-strength micro-alloyed steels by means of creating temperature-deformative regimes of plate rolling for further exploiting under the local influence of elevated ones is a burning issue both from the scientific and economic sides.

The aim of the work is to improve the structural state of high-strength micro-alloyed steels of elevated power to lengthen the cycle of trouble-proof work of blast furnace casings.

The object of the research is the formation processes of structural state and the complex of properties of low-carbon low-alloy steels at exploiting under elevated temperatures.

The subject of the research is the interconnection between the morphology of structural state that is formed under the condition of elevated temperatures of exploitation as well as a certain complex of properties.

The work applies modern methods of structure research, thin structure and a complex of properties of low-carbon low-alloy steels, in particular: light microscopy (optical microscope Neophot 20); scanning electron microscopy (scanning electron microscope PEM-106И); diffraction electron microscopy (transmission electron microscope ПЕМ-125К); general methods of quantitative and semi-quantitative metallographic analysis. To define the complex of mechanic properties, traditional methods of static and dynamic testing as well as the methods of testing the mechanic characteristics under elevated temperatures were applied. While doing the research, all-round evaluation of the influence of temperature-deformative conditions of structural state formation after landfill controlled rolling on the possibility of lengthening trouble-proof work of blast furnace casings was conducted.

The information-analytical review showed that in general cost of produced and mounted building steel construction the cost of metal-roll is 60…70%, hence the application of technological and high-strength types of metal-roll and steel types causes the reduction of the prime cost of the constructions. The expansion of steel ranges that enable to increase technological effectiveness of steel constructions as for not only weight minimization but also the optimization of the criteria of corrosion resistance and fire resistance with their effective usage in bearing metal structures of different buildings and structures is one of the primary tasks of material science.

The work presents the grounds for the choice of the material for constructional elements of blast furnace casings. According to the results of comparative analysis of the usage of two different steels of power class C245 and C460 in bearing structures of the frame, it is shown that the effectiveness of C460 steel application in the constructions is almost 34%. Thus, while designing constructive elements of blast furnace casings, it can become efficient to use steel types with elevated level of properties.

Based on this, the work researched the structural state of steels that are most often used as a material for constructive elements of blast furnace casings. The comparative analysis of structural state on the cross section of the sheet of low-carbon low-alloy steels after the traditional and landfill controlled rolling was carried out.

The analysis of the thin steel structure after hot rolling enabled to find out that for Ст3 the main structural components are polyhedral ferrite and perlite. Ferrite grains with moderate density of dislocations are observed. Perlite areas consist of several colonies (3-10 mkm in size) with different orientation of cementite plates. For steel 09Г2С, ferrite grains have the right polyhedral shape. Perlite dispersed (S0=0,2 mkm) thickness to 0,02 mkm; cementite has a shape of thin plates, large perlite colonies disoriented one towards another.

The peculiarity of the steel10Г2ФБ structure (production technology – controlled rolling) is the presence of perlite stripes. To define the distribution of perlite stripes, a complex was conducted.

The analysis of the results of metallographic researches on the intersection of the sheet proved the presence of perlite stripes along all the intersection of the sheet thickness of the samples. Thickness and density of perlite stripes increases. It can be explained by the presence of the zone of axial liquation close to the center of the sample. Herewith, the sizes of perlite colonies almost do not change from the surface of the sample to its center.

Steel 10Г2ФБЮ after landfill controlled rolling has a ferrite-perlite structure. Herewith, perlite stripes brike into separate colonies. A ferrite component has polyhedral ferrite grains, inner volumes are also separated by low-angle boundaries into sub-grains not only in near-surface layers but also in the central part of the sheet. In fact, the sizes of perlite colonies increase from the surface of the sample to its center. It should be stressed that the gap between the fragmented perlite colonies is filled with a milder phase – ferrite. Grinding of perlite stripes is done by the way of increasing the number of places of ferrite component origin at the stage of austenite deformation.

The results of the research of alloying elements distribution at the intersection of thick sheets that are produced according to the technological scheme of controlled rolling (steel 10Г2ФБ) and landfill controlled rolling (steel 10Г2ФБЮ) showed that for steel 10Г2ФБЮ there is a more uniform distribution of alloying elements across the cross section of the sheet in comparison to steel 10Г2ФБ.

To estimate the interconnection between the morphology of the structural state and the property complex formed under elevated temperatures, the work investigates the influence of temperature on a structural state and a property complex of low-carbon low-alloy steels.

The complex of the researches carried out showed that mechanic characteristics of the presented steel types under the temperature elevation to

+800°C dramatically decrease. For instance, the yield strength boundary for steel 10Г2ФБЮ decreased in 6,3 times, and temporary rupture resistance – in 7 times. Herewith, a higher value of the yield strength was observed for steel 10Г2ФБЮ (73 МПа); less than this value in 1,6 times for steel 09Г2С (63 МПа). A minimal boundary of yield was observed for steel Ст3сп (37 МПа). Thus, testing of low-carbon high-strength steel samples 10Г2ФБЮ under the temperature +800°C proved that the material of blast furnace casing produced from this steel type will be more fireproof than from other steel types (Ст3сп and 09Г2С).

A joint analysis of the results of metallographic researches of the influence of temperature elevation on the morphology of the structural state of low-carbon low-alloy steels showed that for steels Ст3сп and 09Г2С under temperature elevation from 20°C to 600°C, the percentage of structural components does not change as well as their geometric size. Under temperature elevation to 800°C, the geometric size of perlite colonies decreases, which proves the processes of perlite decay. For steel 10Г2ФБЮ, a similar interconnection between the testing temperature and the parameters of structural state was observed.

The complex of the researches of testing temperature influence on the parameters of structural state and the property complex of low-carbon low-alloy steels showed that temperatures under which low-carbon low-alloy steels can be exploited are conditionally divided into two levels: temperature below which there are no significant changes in a structural state; temperature under which there are significant changes in a structural state happening that lead to the reduction of load-bearing capacity of structures. The presence of two temperatures is connected both with the development of diffusion processes and with the ability of the structure to resist the influence of temperature tension (so-called structural stability).

Structural stability of the steel under temperature elevation is conditioned by the processes that bring the system closer to the position of thermodynamic equilibrium in comparison to the state of the system under low temperatures (structural state under room temperature), namely: the processes of

recrystallization, coagulation of the carbon-nitride phase. As a result, exactly the processes mentioned become of great importance while defining the ability of using the materials under elevated temperatures.

The expediency of using low-carbon low-alloy steel 10Г2ФБЮ produced according to the technological scheme of landfill controlled rolling while reconstructing blast furnace casing and aspiration equipment of the foundry yard was proved.

The analysis of steel 10Г2ФБЮ usability checks after landfill controlled rolling in the constructions of blast furnace casing by means of imitating modelling of temperature influence showed that heat treatment led to the formation of structural state that is characterized by the appearance of separate disperse perlite colonies. The ferrite phase both in near-surface layers and inside the cross section is characterized by a certain variety of grains that is the consequence of recrystallization processes. Besides ferrite and perlite, the structure of metal-roll appears to have separate areas with bainite structure after imitating heat treatment. Hence, this steel type was used while reconstructing the blast furnace casing (proved by the act of implementation).

The analysis of the possibility of using high-strength steels 10Г2ФБЮ in the constructions of steel bunkers for the metallurgical industry under high technological loads and low temperatures showed that if to compare a bunker from steel С255 with that from 10Г2ФБЮ, material weight saving was: casing – 38,9%; stiffeners – 36%; bunker beams – 37,8%. Overall saving of metal-roll for a single bunker capacity was more than 4 t. For the bunker compartment, total theoretical saving of metal-roll exceeds 16 t, which in the prices of 2019 makes about 0,5 million UAH.

Key words: landfill controlled rolling; blast furnace casings; structural state of low-carbon low-alloy steels; mechanic properties under elevated temperatures.