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DEOXIDATION IMPACT ON THE IMPURITY INDEX OF HEAT RESISTANT STEEL 40H15N7G7F2MS

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Preliminary Note – Prethodno priopćenje

Analyzing failure causes of the parts made of heat resistant steel shows that one of the defining factors impacting the properties is concentration of harmful impurities both dissolved in steel and being in the form of nonmetallic inclusions. The latter, in turn, is considerably defined by the process of steel deoxidation.

Keywords: alloy steel, heat resistant, ferrosilicon, barium, metallographic, modifying.

INTRODUCTION

Heat resistant steel 40H15N7G7F2MS is used for producing fasteners, exhaust valves, steam pipes and the steam-superheating pipes, some parts of engines working at the temperature 600 ^{0}C. In the course of operation it shall possess a certain limit of long durability and good impact strength to resist sign-variable loads connected with pressure changing. The chemical composition of the alloy is given in Table 1.

Table 1 **Chemical composition of 40H15N7G7F2MS alloy / wt. %**

C	Cr	Ni	Si	Mn	Other elements
0,38-0,47	14 -16	6 - 8	0,9 -1,4	6 - 8	1,5 – 1,9 V 0,65 – 0,85 Mo

In recent years abroad and in Kazakhstan there become widely spread steel modifying and alloying with calcium- and barium-containing alloys [1, 2]. If alloys with calcium are used widely and for a long time, the impact of barium alloys on the steel properties and microstructure has not been studied sufficiently.

Alkaline earth metals and rare earth metals are widely used as components of high refining properties which allow controlling the nature, shape and distribution of non-metallic inclusions.

Kazakhstan has sufficient reserves of barite ore which in their properties, chemical composition and reserves can serve as a reliable ore basis for industrial production of barite alloys.

Comparison of physicochemical properties of calcium and barium suggest that the effects of barium on the liquid metal must be more efficient and therefore its effect on the formation of the microstructure and properties of the alloy after crystallization must be more powerful [1,2].

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Nonmetallic inclusions are the result of the number of physical and chemical phenomena proceeding in the melted and hardening metal in the course of its production. A larger or a smaller number of inclusions exists in any steel according to its structure and conditions of production. Usually the number of nonmetallic inclusions in steel does not exceed 0,1 %. However in connection with their small sizes the number of inclusions is, on the whole, very large.

Nonmetallic inclusions in steel are foreign matters breaking the uniformity of its structure therefore their impact on mechanical and other properties can be considerable. It is obvious that for heat resistant steel the main indicator of quality are heat resisting properties, however at this it is necessary to consider also other mechanical properties, especially such an important indicator of plasticity as impact strength. Meanwhile, it is the size, the form, the nature, as well as the nature of nonmetallic inclusions arrangement that exert the decisive impact on this parameter.

EXPERIMENTAL PART

Equipment and tools

The main objective of the study is studying the ferrosilicon barium introducing impact on the steel metallurgical quality, in particular on the number and distribution of nonmetallic inclusions.

Ferrosilicon barium is a ferroalloy containing 57 – 60 % of Si, 15 – 22 % of Ba, the rest if Fe. In this work for a metallographic study there were used samples made of steel 45H2SFL when modifying with ferrosilicon barium of Fs65ba15 grade. The alloy was obtained according to the technology developed at the Chemical and Metallurgical Institute n.a. Abishev (Karaganda, Kazakhstan) [3, 4].

Melting the experimental samples was carried out in the UIP-25 furnace at the KSTU engineering profile research laboratory of complex development of mineral resources, ferrosilicon barium was introduced several minutes prior to the end of melting. The additional deoxidation of steel was carried out with silicon. After cooling standard metallographic specimens were made of the obtained samples. As a standard there was used the specimen of 40H15N7G7F2MS steel deoxidated only with silicon.

Nonmetallic inclusions, their form and the nature of distribution were studied according to the standard techniques, the index of impurity was determined by the formula:

$$I = \frac{b\sum a_i \cdot m_i}{l} \tag{1}$$

where b is the scale division of the ocular scale at the given magnification in mcm;

a_i is the average value of inclusion sizes in the divisions of the ocular scale;

m_i is the number of the given group inclusions;

l is the counting length in mcm.

The results of the carried out studies are presented in Table 2.

Table 2 **Modifying impact on nonmetallic inclusions distribution**

Specimen number	Additive / %	Index of impurity I_{over}*10^{-3}		
		Boundary	Dendrites axes	Total
1	Standard	1,85 / 62	1,27 / 40,7	3,12 / 100
	FS65Ba15 / %	Boundary	Dendrites axes	Total
2	0,05	1,02 / 52,8	0,91 / 47,2	1,93 / 100
3	0,10	0, 68 / 38,4	0,65 / 61,6	1,33 / 100
4	0,20	0,68 / 50,0	0,68 / 50,0	1,36 /100
5	0,30	1,12 / 47,25	1,25 / 52,7	2,37 / 100
6	0,40	0,95 / 35,3	1,74 / 64,7	2,47 / 100

Note: numerator: absolute values, denominator: relative percent.

As it is seen from the data of the Table, the minimum nonmetallic inclusions impurity index and the maximum value of impact strength are present for samples modified with 0,1…0,2 % ferrosilicon barium (samples 3, 4).

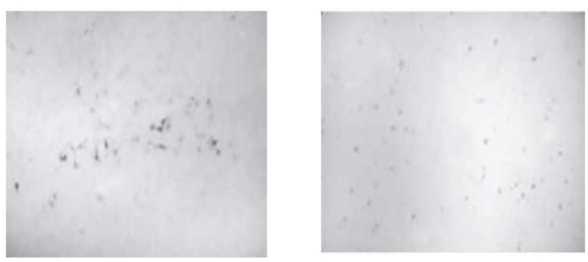
Figure 1 shows a general nature of the distribution of non-metallic inclusions in steel after deoxidation by ferrosilicon barium.

In the steels deoxidized by conventional methods most of the inclusions (more than 60 %) is placed on the grain boundaries. This are defective component, as at these areas accumulate increased number of dislocations are becoming stress concentrators duce to the higher content of non-metallic inclusions. Modifying by ferrosilicon barium leads to the redistribution of non-metallic inclusions between the axes of the dendrites and the volume of grain. This phenomenon can lead to ambiguous results. On the one hand, cleaning of grain boundaries should lead to lower stress levels and, consequently, to an increase in toughness. On the other hand, for high-temperature materials any grain growth constraints result in increased high-temperature strength, which underlies the theory of high-temperature steel alloying. Under optimal additives of ligature, about 35% of the inclusions stay on the borders of the cast grains with barium.

The nature of non-metallic inclusions was determined by Hitachi 8000 electron microscope and microscope TescanVega // LSU (KSTU) with a resolution of 0,5 nm with microanalysis system INCA Energy350 and nitrogen energy dispersive spectrometer INCA PentaFETx3.

Studies of the nature of nonmetallic inclusions showed that steel in all the variations of modifying has MeC and Me3S-type carbides, sulfides, and oxysulfide-type complex phases. With the increase of the additive of ferrosilicon barium greater number of inclusions acquired a rounded shape (Figure 2).

Microprobe analysis of globular non-metallic inclusions which are not carbide phase showed the presence in their composition of barium, aluminum and sulfur. Lack of silicon in the composition of globular inclu-



a b

Figure 1 Distribution of nonmetallic inclusions in the source (a) and experimental steel (b) x 200

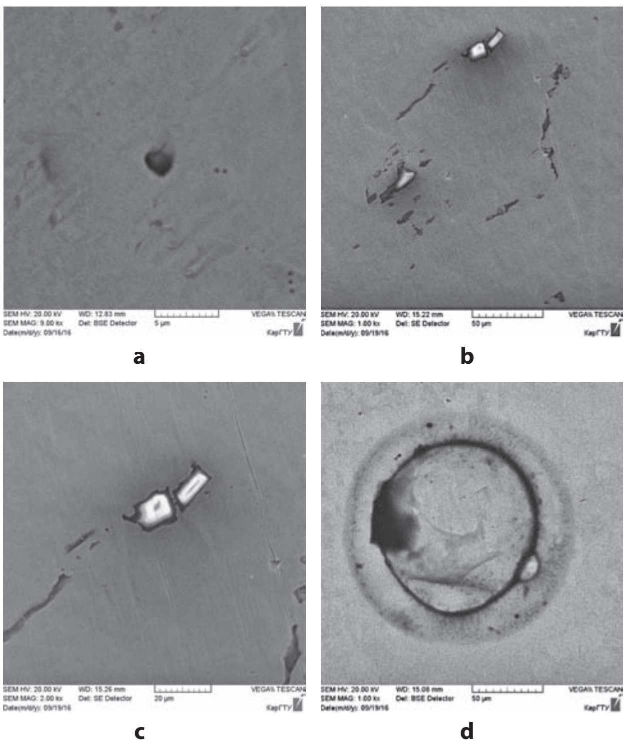


Figure 2 Distribution and form of nonmetallic inclusions
a - rounded shape of the carbide
b - the presence of hair-like cracks
c - oxysulfides
d - layered structure of the carbide

sions with barium confirmed the endogenous nature of their formation. Such inclusions precipitate in the initial crystallization stage in the middle and are located in the middle of the grain resulting purification of the cast grain boundaries.

The mechanism of effect of the ferrosilicon barium during modifying the steel on the distribution of non-metallic inclusions and hence on the properties is as follows [1,5,6]. According to the classical theory of crystallization, kinetics of primary crystallization process depends on two main parameters: the rate of formation of nuclei of future crystallization centers and the rate of their growth. Both of these parameters are a function of the melt supercooling, the value of which is determined by the rate of cooling or heat sink intensity. Randomly formed in a supercooled melt phase in the result of fluctuations, solid particles are firstly initial nuclei and only later, upon subsequent cooling of the melt, become real nucleating seeds of solid phase and crystallization centers if their size reaches a critical value.

When adding into the source iron melt a siliceous modifier containing active elements such as calcium, barium or rare earth metals, the latter react with the iron components to form oxides, sulfides, and carbides. Thermodynamic analysis of the interaction reactions of, for example, barium, at melt temperatures shows the greatest affinity of barium for oxygen, then for sulfur and for carbon.

When adding ferrosilicon barium into the steel, alloy particles after melting enter into an active interaction with the base metal. It must be taken into consideration that iron and silicon are dissolved in the steel, and the remaining insoluble barium particles are of high reactivity and react with oxygen and other elements. During this, interfacial tension dramatically lowers which can lead to self-dispersion of Ba particles to very small sizes, up to nanoparticles.

RESULTS AND DISCUSSION

As a result of these processes, in the steel for a very short period of time equal to the time of presence of Ba therein a finely grained self-organizing system of Ba particles is formed the behavior of which determines the character of the modification process. It is the emergence of myriad of Ba micro- and nanoparticles in the metal melt at local adding of modifiers allows explaining and understanding the possibility of changes in the microstructure and properties of the total volume of liquid steel, which will further affect the change of finished product properties.

Atoms or nanoparticles of barium in the metal and when entering the slag-meta border are combined with adsorbed surfactant metalloids (O, S and P) and as compounds BaO, BaS, Ba3, P2 pass into slag. Because of the small size they are easily absorbed by the slag contributing to a reduction of oxygen, sulfur and phosphorus content in the steel [1].

An interesting question is possible content of the remaining barium in steel. Given the high degree of recovery of additive 70 – 80 % by analogy with other ferroalloys, the presence of barium tracks in steel can be expected. It should be noted that most of the works connected with the study of barium in steel [1,6] note the complexity of determining small concentrations of barium. The present study uses Perkin-Elmer atomic adsorption spectrophotometer allowing to determine the concentration of Ba of 0,001 % and above. However, it did not be find Ba traces in the samples.

In this regard, changes in the structure of the molten steel under the modification by ferrosilicon barium during the crystallization leads to a change of the microstructure and properties of metal that can be inherited after thermal hardening operations.

The proposed hypothesis explains fairly well the experimental data on the nature of non-metallic inclusions and changes in some of the mechanical properties of steel modified by ferrosilicon barium.

CONCLUSION

The studies found that the using ferrosilicon barium as a deoxidizer reduces non-metallic inclusion impurity index.

Adding of ferrosilicon barium increases the plastic properties of the metal matrix and a more favorable form of nonmetallic inclusions, which should enhance the operational durability of steel as a whole.

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