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STUDYING OF PROPERTIES AND MICROSTRUCTURE OF 30 CrMnV9 STEEL ON WEAR RESISTANCE

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The properties and microstructure of 30 CrMoV9 steel after its treatment with ferronickel and ferromanganese with the aim of increasing the content of nickel and manganese in steel were studied. After the trial smelting, the samples were tested in four parameters: hardness, ultimate stress limit, wear resistance, and toughness. Experimental studies have shown that changing the composition of steel with increasing the nickel content up to 0,5 – 0,7 % and manganese up to 1,5 – 1,8 % leads to increasing strength, hardness and wear resistance of steel with slight decreasing its toughness.

Key words: 30 CrMnV9 steel, wear resistance, strength, toughness, microstructure.

INTRODUCTION

One of the trends in the development of wear-resistant materials is improving the composition and properties of the alloy based on steels being improved [1-3]. This circumstance is caused by the fact that Hardox steel of various grades (Sweden) occupies the dominant position in this sector of the market because it possesses extremely high wear-resistant properties. A high level of properties is achieved, first of all, due to the purity of the charge materials, the balanced composition and the proper heat treatment. The cost of this steel is high enough, moreover, it is unprofitable to be used as a material for producing parts by casting.

These factors determine searching for steel that are analogues comparable after additional treatment with the properties of the standard.

The scientific rationale for the use of improved steels as wear-resistant materials is based on the Charpy principle. According to this principle, the structure of wear-resistant materials should consist of a strong, hard but rather tough matrix with uniformly spaced solid inclusions, preferably of a spheroidal shape. In the structure of steels being improved, such a matrix is a doped α-solution, and solid inclusions are carbides and other possible interstitial phases.

In previous studies 30 CrNiMo8 steel deoxidized with ferrosilicon boron was considered as an analogue [4]. The results of the experiments show that the composition and properties of 30 CrNiMo8 steel after deoxidation with ferrosilicon are close to the composition and properties of Hardox steel due to introducing boron micro-quantities into the composition.

Another analogue can be considered 30 CrMoV9 steel that is used for manufacturing parts of diesel engines, possesses wear-resistant properties and heat resistance up to 450 ^{0}C. Compared to Hardox steel, 30 CrMoV9 steel has a higher chromium content and does not contain boron. However, in the composition of 30 CrMoV9 steel there is vanadium that forms hard and resistant carbides of the MeC type; in addition, the presence of vanadium contributes to grinding the grain, which further strengthens the structure. Taking into account these features of the vanadium effect, it can be assumed that the presence of vanadium in the composition compensates for the absence of boron.

A disadvantage of 30 CrMoV9 steel in this aspect is also a low content of nickel and manganese in the composition, though they play an important role in forming the alloy properties. Nickel does not form carbides and, therefore, does not affect hardness, but at the same time it increases the matrix toughness and partially reduces the temperature threshold of cold brittleness. Manganese forms cementite carbides that strengthen the matrix. Thus, the presence of nickel and manganese in the composition of the steel in a given quantity (0,5 – 0,7 % and 1,5 – 1,7 %, respectively) is necessary, since these elements form the properties of the alloy matrix.

EXPERIMENTAL STUDIES

Equipment and tools

The objective of this study was to determine the possibility of adjusting the composition of 30 CrMoV9 steel by additional alloying in order to give it wear-resistant properties.

For alloying there was used FeNi20LC grade ferronickel (ISO 6501:1988), deoxidation was performed

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with FMn90 grade ferromanganese (GOST 4765-91). The charge was calculated in such a way that nickel and manganese were present in the composition in the amount of 0,5 – 0,7 % and 1,5 – 1,8 %, respectively, with the degree of elements assimilation of 80 %. For better dissolution ferroalloys were ground to the fraction of 200 μm with the content of this fraction of at least 70 %. Melting was carried out in a UIP-25 laboratory furnace with an improved water cooling system, the melting weight was 3,0 kg. The basis was 30 CrMoV9 steel, ferronickel was injected 15 minutes before the end of smelting, 5 minutes before casting, deoxidation was carried out with ferromanganese. At the end of melting and complete cooling, the chemical analysis of the melted alloy was performed on the NITON XL2–100G spectrometer. The results are presented in Table 1.

Table 1 **Chemical composition of the samples / %**

Sample number	1	2	3
Element	Hardox 500 (reference)	30H3MF without alloying	30H3MF after alloying
C	0,27 - 0,35	0,28	0,32
Si	0,7	0,35	0,6
Mn	1,6	0,5	1,7
Ni	0,6	0,2	0,55
S	0,025	0,02	0,025
P	0,025	0,02	0,025
Cr	1	2,5	2,3
Mo	0,6	0,3	0,28
B	0,003 -0,004	-	-
V	-	0,12	0,1

It can be seen from the data of Table 1 that the content of such elements as Si, Mn, Ni after the proposed treatment reaches the content of these elements in the standard. The absence of boron in sample No. 3 is compensated for by the increased chromium content and the presence of vanadium. The disadvantage of the obtained alloy is a lower content of molybdenum compared with the standard, which must be taken into account when assigning a heat treatment mode, since molybdenum prevents the development of temper brittleness.

Discussion of the results.

From the experimental melting there were prepared samples for heat treatment. The classic mode of heat treatment of 30 CrMoV9 steel is quenching at 870 ^{0}C in oil with subsequent tempering at 620 ^{0}C in water. Due to the fact that the composition of steel has changed, accordingly, the heat treatment mode should change.

In connection with increasing the carbon and manganese content that forms cementite-type carbides, it is advisable to somewhat increase the quenching temperature. When assigning a heat treatment mode, it is also necessary to remember that 30 CrMoV9 steel is prone to type II temper embrittlement. Increasing the content of Si and Mn in the Cr-Mn-Si combination, as in this case, increases this tendency. The presence of Mo is a favorable factor in the fight against tempering fragility, although its amount presence is lower than in the standard.

To prevent the development of temper brittleness, the following heat treatment modes were considered: quenching at 890 ^{0}C in oil with subsequent tempering in the range of 450 – 550 ^{0}C, cooling in cold water. The choice of a lower tempering temperature is due to the desire to avoid a range of temper brittleness and to increase the matrix strength properties.

The required toughness of the matrix should be provided by an increased content of Ni in the adjusted composition. After heat treatment the samples were examined for hardness, ultimate strength, and wear resistance. The samples hardness was determined on the VH1150 hardness tester, strength on the INSTRON testing machine, wear resistance on the TABER ABRASER 352G wear test instrument. There were used abrasive discs made of tungsten carbide S-35. The test results are shown in Table 2.

The data in Table 2 show that increasing the content of manganese and nickel in 30 CrMoV9 steel due to additional alloying and deoxidation leads to increasing hardness, strength and wear resistance. These parameters become comparable with the parameters of Hardox 500 steel. However, Sample No. 3 has, at high hardness and wear resistance, very low toughness, which is undesirable, since parts made of this steel experience impact loads in addition to abrasive ones (Figure 1).

Such a sharp decrease in toughness can be explained by the significant segregation of alloying elements along the grain boundaries, which increase the thermodynamic activity of impurities and their inflow to the boundaries (Figure 2a). The microstructure of all the

Table 2 **Testing results for experimental samples**

No	Sample	HB	Ultimate strength limit / MPa	Wear resistance, x10^{-4} / g	KCU / kJ/m^2
1	Hardox 500 steel	425	1 250	26	-
2	30Х3МФ reference (without additional treatment), quenching at 890 ^{0}C in oil, tempering at 450 ^{0}C in water	328	980	38	930
3	30Х3МФ after additional treatment: quenching at 890 ^{0}C in oil, tempering at 450 ^{0}C in water	452	1 380	23	670
4	30Х3МФ after additional treatment: quenching at 890 ^{0}C in oil, tempering at 500 ^{0}C in water	434	1 305	31	830
5	30Х3МФ after additional treatment: quenching at 890 ^{0}C in oil, tempering at 550 ^{0}C in water	421	1 180	32	860

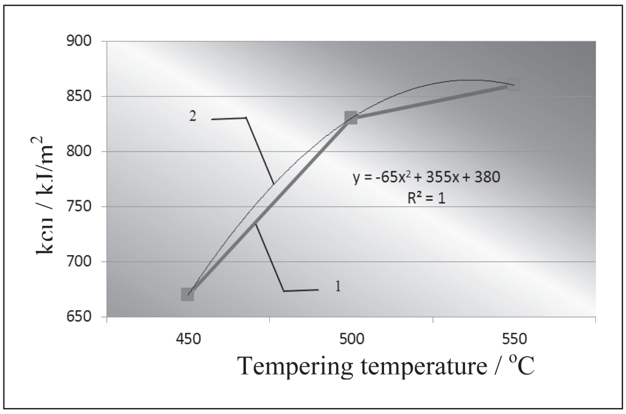

Figure 1 Sample toughness dependence on the tempering temperature. 1 – theoretics; 2 – experimental.

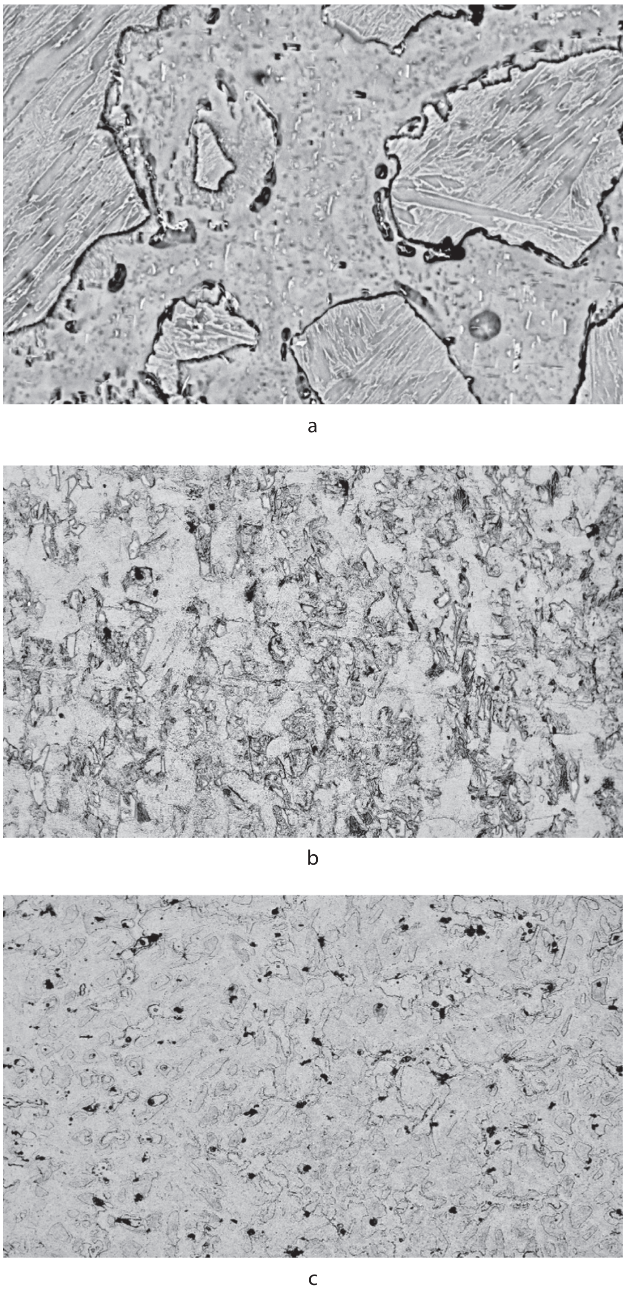

Figure 2 30H3MF steel microstructure: a – sample No. 3, segregation of inclusions at the boundaries, x 1500; b – sample No. 2 (pilot), x 500; c – sample No. 4, x 500

samples after heat treatment is represented by a sorbitol-like mixture of different dispersity with pronounced inclusions of carbides (Figure 2).

The overall increase in strength properties of 30 CrMoV9 steel after additional doping is explained by increasing the content of manganese and nickel. Manganese forms additional carbides of the Me3S type that harden steel. Increasing hardness and strength with a relatively low drop in toughness (by about 8 – 10 %) is ensured by increasing the nickel content that is well known to help reducing the temperature threshold of cold brittleness and increasing toughness [5].

CONCLUSION

Increasing the tempering temperature contributes to greater homogenization of the structure. Complex doping in this combination of elements contributes to increasing hardenability, a more complete course of the hardening process. Increasing strength and hardness in all the samples of 30 CrMoV9 steel after additional treatment is also explained by a lower tempering temperature, which leads to the formation of a finer-grained structure (Figure 2b, c). On the basis of the experimental data obtained, it can be argued that after additional doping and heat treatment according to the proposed mode, an optimal structure was formed according to the Charpy principle: a strong tough matrix with a large number of uniformly distributed solid inclusions (Figure 2c).

Thus, the studies carried out have shown that additional treatment of 30 CrMoV9 steel with ferronickel and ferromanganese with the nickel content of 0,5 – 0,6 % and manganese content of 1,5 – 1,7 % followed by heat treatment according to the corrected mode: quenching at 890 °C, oil, tempering at 500 - 550 °C, water, allows increasing wear resistance and strength properties of this steel, comparable to the properties of Hardox 500 steel while maintaining good toughness.

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Note*:* The responsible for England language is Nataliya Drag, Karaganda Kazakhstan