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The Influence of Alloying Elements on Structure Formation, Phase Composition and Properties of Chromium-Manganese Iron in the Cast State

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Abstract
Structures, phase composition, hardness, microhardness of the investigated chromo-manganese cast iron alloys in the cast stay were studied at the present work. It is shown that the hardness and wear resistance of the investigated alloys are determined by the carbon content, degree of alloying matrix and austenite-carbide eutectic and also the number and form parameter eutectic carbide.
Keywords: CHROMO-MANGANESE CAST IRON, AUSTENITE, FERRITE, CEMENTITE, AUSTENITE-CARBIDE EUTECTIC, FORM PARAMETER, DEGREE OF ALLOYING, MICROHARDNESS, HARDNESS, WEAR RESISTANCE

Nowadays alloy structural materials are designed to work under the influence of the force of friction, aggressive corrosion medium, abrasive and impact-wear abrasive and are characterized by containing high levels of chromium, manganese and critical alloying elements such as molybdenum, nickel and vanadium [1-4].

It should be noted that the wear in abrasive media and under alternating and impact loading is a complex and ambiguous function of interaction conditions of metal parts with abrasive particles, medium and level of impact loading. It depends on many factors such as duration of operation, concentration of the abrasive, size, shape and hardness of the abrasive particles, their velocity at impact on the surface of the workpiece, the attack angle of the wear surface particles, the level of impact loadings which reduces the mechanical properties of the material due to the softening effects on a medium etc. [5].

Current researches indicate that economically alloying chromium-manganese cast irons are advanced materials for use in such an environment with a high level of properties set at low cost [6-8].

Nowadays chromium-manganese cast irons are widely used in cast and in heat treated condition as a highly wear tribological materials. Shotblasting blades, armor plate mills and tumbling bodies for hard materials grinding are producer from this iron as well as the mill rolls and a rolling instrument.

We can purposefully influence on the formation of desired properties of chromium-manganese iron by changing the structure heterogeneity depending on the functionality of the alloy by alloying and rational use of different heat treatment modes.

Hence an actual problem of modern materials science is the study of formation regularities of the structure, phase composition and properties of chromium-manganese iron of economically alloying iron in the cast state.

Material and Method of investigation

The samples of semiproduction experimental melts of chromium-manganese pig iron were objects of research in the present article the chemical composition of which is shown in the Tabl 1.

The microstructure of the samples was detected in 10% nitric acid solution. Investigation of the microstructure was performed using an optical microscope «Neophot-21.» Microhardness phases and structural components was determined using microhardness tester PMT-3 by standard techniques. The phase composition of the samples was studied on a DRON-3M FeK$_a$- radiation. The composition of the phases was determined by the local X-ray analysis with an electron microscope JSM-840 with microanalysis system «Link- 860/500» («Link Analytical» company, England). Hardness (HRC) of the investigated cast iron was measured by Rockwell in standard methods.

Investigation results

The structure, phase composition, hardness, microhardness of structural components of chromium-manganese samples of cast iron were studied in this article.

The microstructure of the investigated melts ща chromium-manganese iron in the original cast state shown in Fig. 13. Analysis of the microstructure of the cast iron samples (Fig. 1-3) shows that the crystallization starts with selection of primary austenite dendrites crystals and completes with the formation of eutectic colonies.

In the microstructure carbides Me_7C_3 are presented both longitudinally and in cross-section and also finely differentiated austenite eutectic based on the carbide Me_7C_3 (Fig. 1-3)

Methods of quantitative metallography and X-ray analysis determine the proportion of primary austenite (A_I) and eutectic carbide (EC). For the alloy 1 the ratio is A_I = 65 %, EC = 35 %, for the alloy 2: A_I = 48 %, EC = 62 %, for the alloy 3: A_I = 22 %, EC = 78 %. The length of the eutectic carbides plates was determined (EC) Me_7C_3 for all alloys: for the alloy 1 it equals 36.5 microns; for the alloy 2 it equals 42.5 microns, and for the alloy 3 carbide is characterized by the greatest length which is 55.65 microns. Shape parameter (SP) of the eutectic carbides plates (EC) Me_7C_3 in alloy 1 is 3.95, in alloy 2 is equal to 3.85, in alloy 3 is equal to 2.68. Shape parameter (SP) characterizes EC the differentiation of eutectic the less SP the greater the differentiation of eutectic, which contributes to the strength and plastic properties of the alloy.

The quantitative ratio of primary austenite dendrites and eutectic component is determined by the

Table 1. The chemical composition of the iron investigated

No in order	Content of alloying elements %									
	C	Cr	Ni	V	Mn	Si	Cu	S	P	Fe
1	2.2	12.63	0.83	0.25	5.7	1.0	0.10	0.009	0.013	77.3
2	2.7	15.91	0.95	0.25	10.5	0.9	0.9	0.009	0.027	67.9
3	3.1	13.1	1.15	0.25	15.75	0.9	0.15	0.003	0.025	65.57

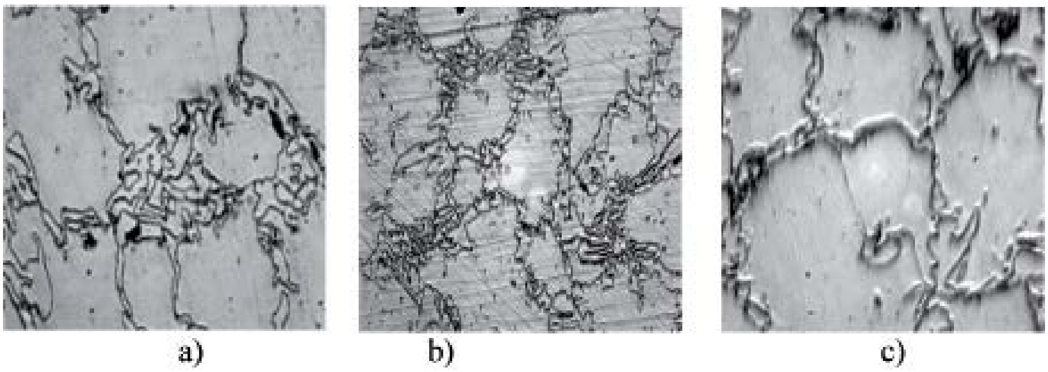

Figure 1. Microstructure of chromium-manganese cast iron (alloy 1): a, b - × 500; c - × 1000

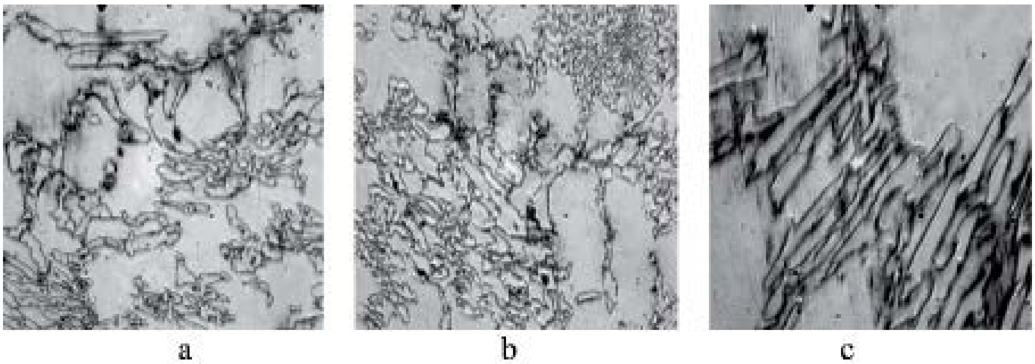

Figure 2. Microstructure of chromium-manganese cast iron (alloy 2): a, b - × 500; c - × 1000

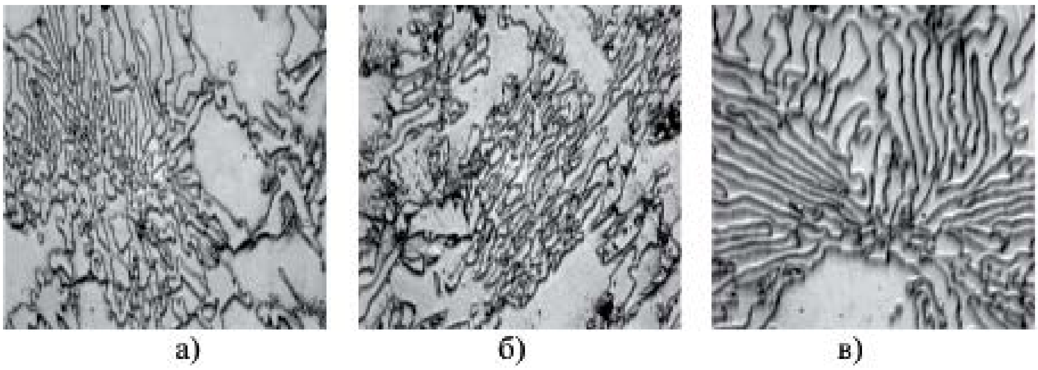

Figure 3. Microstructure of chromium-manganese cast iron (alloy 3): a, b - × 500; c - × 1000

carbon content and the ratio of the main alloying elements such as chromium and manganese. In connection with it in the alloy 3, wherein the amount of carbon and manganese is on maximum range, the number of carbides is increased in compare with the alloys 1 and 2, respectively in 2.2 and 1.7 times.

The phase composition of the investigated chromium-manganese alloys were studied by x-ray analysis. Fig. 4 shows a diffractogram scheme of the investigated chromium-manganese cast iron. X-ray analysis in the investigated alloys has revealed carbide Me_7C_3 - $(Cr, Mn, Fe)_7C_3$ [9], cementite, austenite and ferrite.

Quantitative X-ray diffraction data are shown in Table. 2. The amount of austenite in the matrix of the investigated iron increases from 76% to 91% with expensing of carbon content and alloying elements (chromium and manganese), ferrite decreases, respectively, from 24% to 9% (Table. 2). The presence of ferrite is probably associated with the lack of stability of austenite undergoes decomposition into ferrite and carbide during cooling. Analysis of the Table 2 data shows that in the structure of cast iron almost equilibrium α-phase and the degree of imperfection ($\beta_{0,5}$) are presented, wherein the lattice is in the range of from 0.57 to 0.59. The lattice parameter of α-phase (a_α) is 2.87- 2.88.

Table 2. The X-ray diffraction data of the chromium-manganese cast iron

No In order	aα at (011) α	aγ at (022) γ	Imperfection degree of α-phase ($\beta_{0,5}$)	% γ, In matrix	% α, In matrix
1	2.87	3.60	0.59	76	24
2	2.88	3.62	0.59	87	13
3	2.87	3.62	0.57	91	9

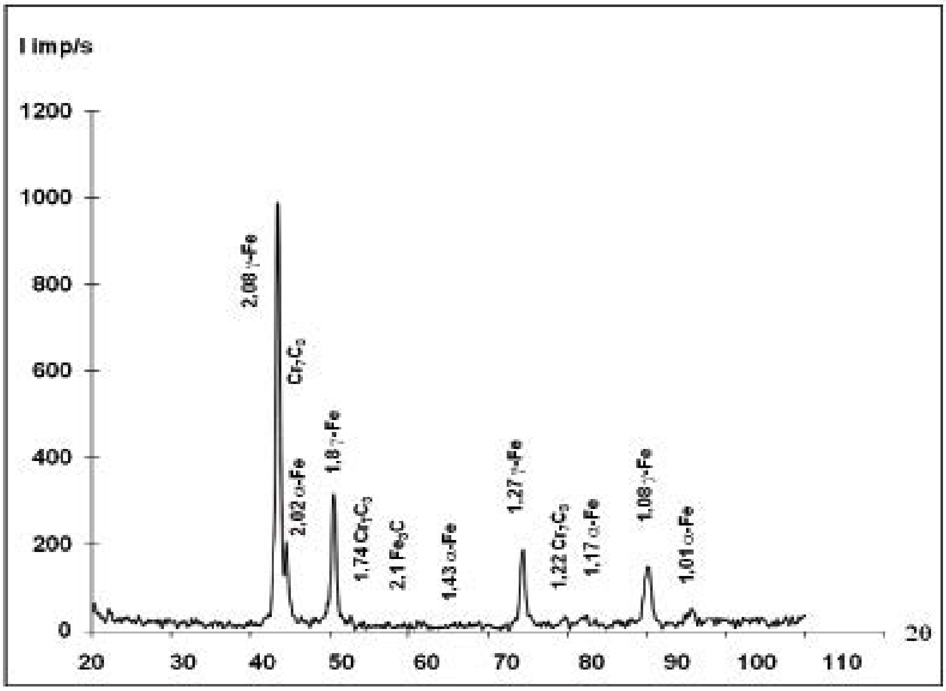

Figure 4. Scheme diffractogram of the chromium-manganese cast iron (alloy 1)

The microhardness of phases and structural components of the alloys in the cast state are given in Table. 3.

Table 3. The microhardness of the phases and structural components of chromium-manganese cast iron

No In order	Microhardness of structural components, MPa			Hardness, HRC
	A-K eutectic	Matrix	Eutectic carbide	
1	7920	4137	6577	35
2	8934	4228	8244	42
3	9195	4663	8965	42

The microhardness of the matrix and eutectic carbides all investigated alloys increases as the amount of carbon, chromium and manganese (Table. 3). The hardness of alloys 2 and 3 is identical and equals 42 HRC units, but in the alloy 1 is significantly less - 35 units (Table. 3). The hardness the investigated alloys, as well as microhardness of the matrix and austenite-carbide eutectic based on Me_7C_3 carbide is determined by the alloying degree and the SP of eutectic carbide.

Using the local X-ray analysis it was found that in the invwstigated alloys in the eutectic chromium carbides present in amounts of (~ 34,9-36,7%), manganese - 8,9-9,33%, silicon - 0,11-0,23 %. Results of local X-ray analysis of the distribution of alloying elements between phases and structural components show that with increasing content of carbon, chromium and manganese in investigated alloys the degree of alloying of a matrix and eutectic carbide are increased, which provides amplified microhardness hardness and correspondingly wear resistance.

Conclusion

The structure, phase composition, hardness, microhardness of chromium-manganese cast iron were studied. It was found that:

- The proportion of primary austenite dendrites (A_1) and eutectic component (EC) is determined by the ratio of carbon and main alloying elements content (chromium and manganese);

- Hardness of investigated iron is determined by the carbon content and amount of carbide component;

- Characterized by maximum hardness alloys 2 and 3 allow to forecast an increase in wear resistance in cast and heat treated condition.

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