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STUDYING MICROSTRUCTURE AND PHASE COMPOSITION OF A NEW COMPLEX CALCIUM CONTAINING ALLOY

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In the given article there are presented the results of studying the microstructure and phase structure of a complex alloy of alumosilicon with calcium. It is established that in the studied CAMS alloy active elements are present at a type of difficult intermetallid that positively influences quality of both ordinary, and qualitative brands of steel.

Key words: alloy Mn, Si, Al, Ca; chemical composition, phase composition, microstructure

INTRODUCTION

Effectiveness and expediency of using complex ferroalloys in steel and cast iron production are defined not only by its deoxidizing and modifying capacity, but also physicochemical characteristics: density, melting point, tendency for dispersion, moisture resistance, microstructure, phase composition, etc [1-3]. Therefore, within the framework of the research, at studied the microstructure and phase composition of a complex calcium-containing manganese alumosilicon alloy through a various analysis methods [4].

METHODOLOGY OF SOLVING THE TASKS OF THE STUDY

For the studies, we selected alloys of manganese alumosilicon with calcium (CAMS) with different content of calcium, aluminum, silicon and manganese (Table 1).

Table 1 **Chemical composition of the alloy / weight %**

Alloy No.	Chemical composition / %					
	Mn	Si	Al	Ca	Fe	P
1	11,74	24,82	25,92	6,21	31,15	0,016
2	15,02	41,9	24,54	8,06	9,65	0,024
3	16,4	48,49	18,3	10,41	5,43	0,024

Microstructure and phase composition of the new complex alloy CAMS was comprehensively studied using X-ray equipment DRON-2, optical microscope OLYMPUS BX51 and scanning electron microscope JEOL- JSM7001F (with a maximum increase of 1,5 million times).

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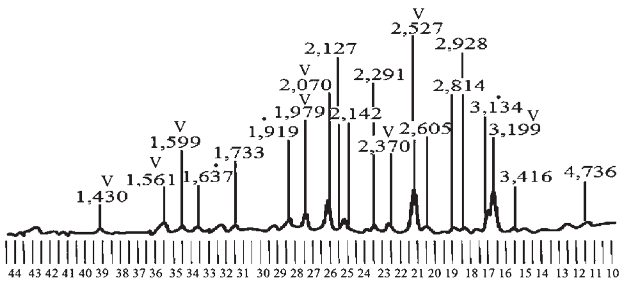
In order to determine the phase composition of a new calcium-containing manganese alumosilicon alloy, X-ray analysis had been conducted. XRD patterns of the obtained metals are shown in Figures 1-3.

EXPERIMENTAL WORK

X-ray diffraction analysis was carried using DRON-2 diffractometer. Conditions of the X-ray exposure: filtered Cu-radiation, 30 kW tube voltage, 30 mA tube current. The resulting diffraction pattern of the samples is identified according to the ASTM catalogue.

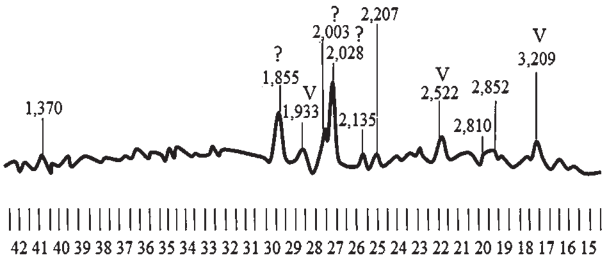
According to X-ray analysis, calcium-containing manganese alumosilicone alloy is represented by the following phases: $CaAl_2Si_{1,5}$; $CaSi_2$ and uncomplexed structurally-free silicon. According to X-ray structure, complex intermetallic compounds ($CaAl_2Si_{1,5}$, $CaSi_2$) are typical for the structure of experimental CAMS alloys, as confirmed by the subsequent metallographic studies.

Microstructure and phase composition of the new complex alloy CAMS was comprehensively studied optical microscope OLYMPUS BX51 and scanning electron microscope JEOL- JSM7001F (with a maximum increase of 1,5 million times). CAMS No. 3 alloy was subject to research since there is higher calcium content as compared to other alloys (Table 1).



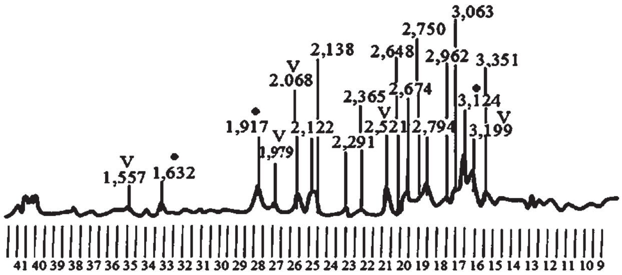
V - $CaAl_2Si_{1,5}$ (1,430; 1,561; 1,599; 1,979; 2,070; 2,370; 2,527; 3,199)
• – Si (1,637; 1,919; 3,134)

Figure 1 XRD pattern of a metal No. 1



V - $CaAl_2Si_{1,5}$ (1,933; 2,522; 3,209)

Figure 2 XRD pattern of a metal No. 2



• - Si (1,632; 1,917; 3,124);
V - $CaAl_2Si_{1,5}$ (1,557; 1,979; 2,068; 2,521; 3,199);
• - $CaSi_2$(1,917; 2,674; 3,351)

Figure 3 XRD pattern of a metal No. 3

Macroscopically, the samples of the studied CAMS alloys are identical to silicon alloys and are mainly silver-gray, light yellow or in some places gray-blue; in the place of fracture, the samples have a fine grain uniform structure. Due to calcium, large crystal grains in the form of plates appear in the alloy which is typical for calcium-containing silicon alloys.

Scanning microscopy within the secondary electrons mode was used in metallographic thin section prepared on the equipment of Struers company. The samples had been cut for thin sections with a high-speed circular saw with a diamond edge on the IsoMet Low Speed machine. For grinding, manual grinders had been used. The task of the rough grinding was to eliminate all irregularities of the sample surface, remove the resin covering the sample, reduce its thickness, and to prepare a smooth surface for subsequent processing. Grinding was carried out on sandpaper of varying dimensions of grains. It was important at each processing stage to protect the sample from heating and contamination by abrasive particles.

Soft grinding was carried out using diamond pastes with the dimensions P120, P220, P400, P600, R1200. Polishing was performed using a pulp Tegra Force-1 and polishing clothes Piano cleanliness class 12 of matrix surface. Chemical etching of the thin sections was not applied.

The microstructure of the test sample (Figure 4) in 30 % of the area is represented by a phase of a light yellow color of plate shape which corresponds to iron disilicide ($FeSi_2$). About 10 % of the area in the thin section is occupied by the phase of dark gray color in the form of grains of irregular shape with sharp edges which is identified as the structurally free silicon (Si), 30 % of

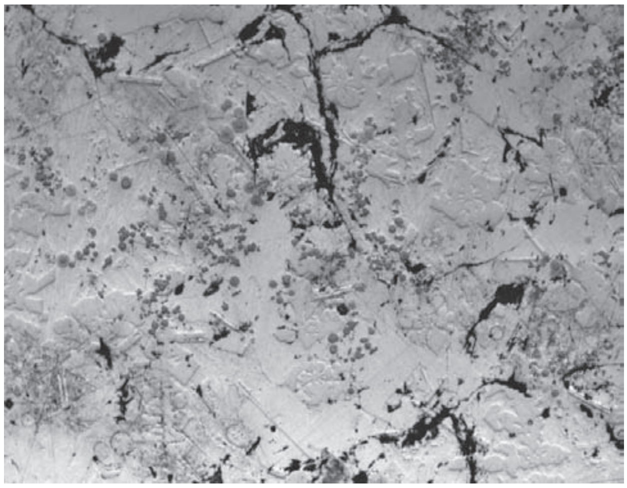


Figure 4 Microstructure of CAMS alloy

the area of the section is occupied by an eutectics with matrix of light-gray color; according to the analysis it corresponds to the phase of calcium disilicide ($CaSi_2$). In the thin section, there is seen the eutectics consisting of ($CaAl2Si_{1,5}$). Against a background of this eutectics, there are small gray roundels visible corresponding by external signs to the phase (SiMn) of manganese silicide. A small area in the thin section is occupied by the blue-gray phase with visible crystals of an excess phase of irregular shape which, according to microstructural analysis, are composed of Ba, Al and Si and by the re-

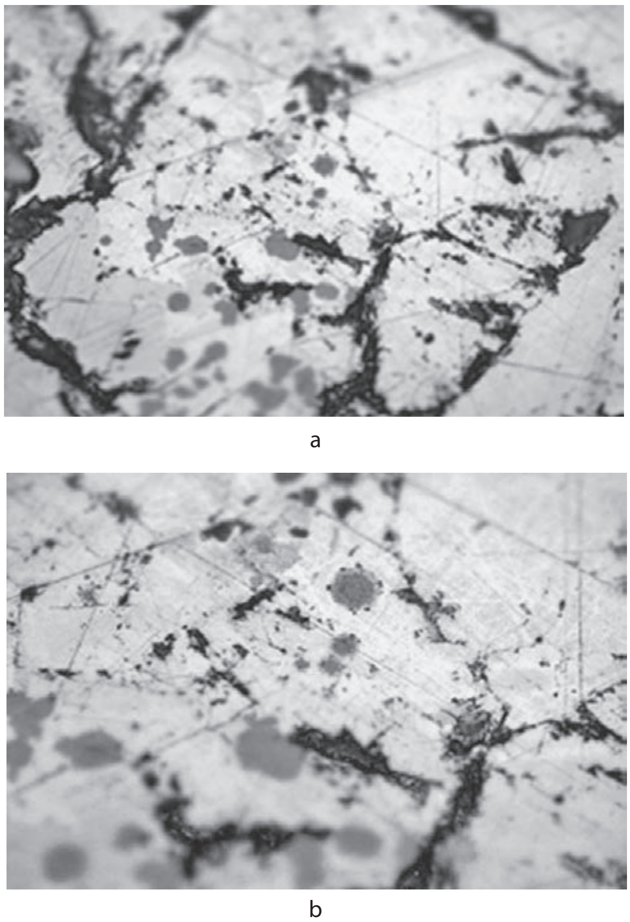


Figure 5 Microstructure of CAMS alloy

Table 2 **Content of elements by weight / %**

Spectra	Chemical composition / %					
	Al	Si	Ca	Mn	Fe	Ba
Spectrum 1	12,6	43,8	3,2	0,1	0,1	40,2
Spectrum 2	0,8	45,9	0,0	46,5	7,0	0,2
Spectrum 3	0,8	58,0	40,7	0,2	0,1	0,2
Spectrum 4	35,0	37,3	26,9	0,3	0,1	0,4
Spectrum 5	0,1	99,8	0,0	0,0	0,0	0,0
Average	9,8	57,0	14,2	9,4	1,5	8,1
Standard deviation	15,0	25,1	18,6	20,7	3,1	17,9
Max.	35,0	99,8	40,7	46,5	7,0	40,2
Min.	0,1	37,3	0,0	0,0	0,0	0,2

Table 3 **Content of elements in atomic percent / %**

Spectra	Chemical composition / %					
	Al	Si	Ca	Mn	Fe	Ba
Spectrum 1	19,4	64,9	3,3	0,1	0,1	12,2
Spectrum 2	1,1	62,1	0,0	32,1	4,8	0,1
Spectrum 3	0,9	66,3	32,5	0,1	0,0	0,1
Spectrum 4	39,2	40,2	20,3	0,1	0,1	0,1
Spectrum 5	0,1	99,8	0,0	0,0	0,0	0,0
Average	12,1	66,7	11,2	6,5	1,0	2,5
Standard deviation	17,2	21,4	14,6	14,3	2,1	5,4
Max.	39,2	99,8	32,5	32,1	4,8	12,2
Min.	0,1	40,2	0,0	0,0	0,0	0,1

sults of quantitative analysis identified as a phase $Ba(SiAl)_4$.

Microstructure of the test sample at 500× and 1000× magnification is shown in Figure 5.

The microstructure was also studied by a scanning electron microscope JEOL - JSM7001F. This microscope is unique as it automatically reads chemical composition from the spectrum and allows for determining the phase by a chemical composition of a given point.

Figure 6 shows that the spectrum 1 is represented by a bright white phase, occupies a small area, and is characterized by the presence of barium up to 40 % by weight and 12 % atomic respectively (Tables 2 and 3). This range corresponds to the phase $Ba(SiAl)_4$ in chemical composition. Spectrum 2 is light gray, occupies about 20 % of the area and by external signs and chemical data corresponds to the phase of (SiMn) manganese silicide.

In the spectrum 3, there are visible signs of eutectics with light-gray matrix; according to electronic indicators and chemical analysis, the composition is as follows: by weight 58 % Si and 40,7 % Ca, by atomic 66,3 % and 32,5 % respectively (Table 2 and 3), which corresponds to a phase of calcium disilicide ($CaSi_2$). Spectrum 4 occupies about 40 – 50 % of the area; microstructure of this phase in addition to free silica and iron

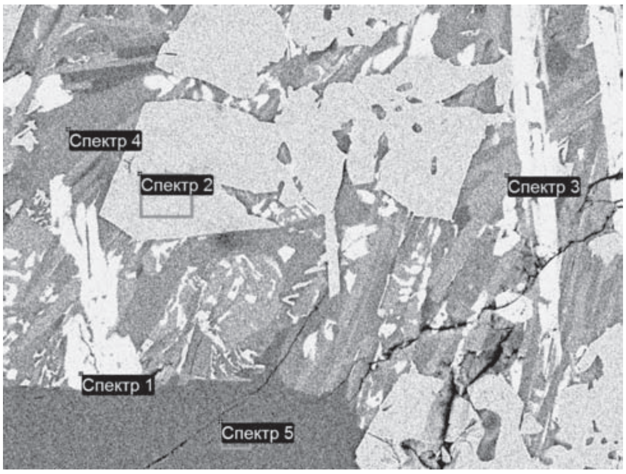


Figure 6 Microstructure of CAMS alloy through electron microscope JEOL-JSM7001F with an increase of 400 mkm

disilicide shows subtly differentiated eutectics. By complex method of X-ray diffraction, microstructural and electronic analysis, it is defined as the phase ($CaAl_2Si_{1,5}$). Spectrum 5 is dark gray, and specifics of this phase is the presence of pure silicon up to 99,8 % by weight and 99,8 % by atomic respectively (Table 2 and 3), which is identified as a structurally free silicon (Si).

CONCLUSION

In this regard, according to the studies, in alloy CAMS, active elements (Mn, Si, Al, Ca) present in the form of such complex intermetallic compounds as ($CaAl_2Si_{1,5}$), ($CaSi_2$) and Ba $(SiAl)_4$ which prevents the formation of aggregates of corundum which adversely affect mechanical properties of the metal and contribute to globularization of oxide inclusions during deoxidation and modification of both ordinary and high-quality steel grades.

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