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ISSN 0543-5846
METABK 61(3-4) 804-806 (2022)
UDC – UDK 669.715.782.74:336.31:66.014:531.75:620.18=111

RESEARCH OF MICROSTRUCTURE AND PHASE COMPOSITION OF A NEW COMPLEX ALLOY – ALUMOSILICOMANGANESE (Al-Si-Mn)

Received – Primljeno: 2021-12-24
Accepted – Prihvaćeno: 2022-03-10
Preliminary Note – Prethodno priopćenje

The paper presents the results of a physicochemical study of a new complex alloy of alumosilicomanganese. The phase composition of the alloy was studied by X-ray diffraction (XRD) phase analysis on an Empyrean Malvern Panalytical X-ray diffractometer. Radiographs were processed and decoded using the Match! 3 software and the FullProf-2021 database. The HighScorePlus, Match! 3 and FullProf-2021 programs are based on the Rietveld method. The study of the microstructure of the alloy was carried out on a scanning electron microscope (SEM) of the JEOL - JSM7001F type. The chemical composition of the phases was determined using an Oxford INCA X-max 80 energy dispersive spectrometer (EDS) installed on a JEOL JSM-7001F scanning electron microscope.

Keywords: Al-Si-Mn alloy, X-ray research (XRD, EDS, SEM) phase, chemical composition, density, microstructure.

INTRODUCTION

The practice of steelmaking and iron foundries shows that the efficiency and feasibility of using certain grades of ferroalloys is predetermined not only by their chemical composition (concentration of leading elements and associated impurities), but also by physicochemical properties (particle size distribution, density, surface condition of pieces, melting temperature, the content of non-metallic inclusions, oxygen, hydrogen, etc.) [1].

From the point of view of the efficiency of using ferroalloys by real industries, the following basic requirements can be distinguished [2-4]:

- The composition of the ferroalloy must be in accordance with the economic efficiency and technological features of its production and use.
- The thermal effect of the interaction of the ferroalloy with the liquid metal should lead to minimal cooling of thelatter. Consequently, the optimum temperature (onset of crystallization) of melting of ferroalloys should be lower than the metal being processed.
- Optimum density of ferroalloys. Currently, more than 95 % of all ferroalloys are introduced into liquid steel in lumps. Ferroalloys with optimal density are most fully involved in hydrodynamic motion by steel flows in a ladle and, as a result, have time to melt most quickly and completely, and completely assimilate in steel.
- Complex deoxidizers should contain elements with different affinity for oxygen and ensuring maximum removal, grinding and globularization of non-metallic inclusions.

In connection with all of the above, it is obvious that for new grades of ferroalloys it is necessary to carry out a complex of comprehensive studies of their physical and chemical properties and features.

RESEARCH METHODOLOGY

Earlier, studies were carried out to study and develop the technological process of smelting a complex ferroalloy - alumosilicomanganese from poor manganese ores using high-ash coal (with an ash content of more than 45 %) from the Saryadyr, Borly and Ekibastuz deposits. Smelting experiments were carried out at the experimental site of the chemical-metallurgical institution named after Zh. Abishev on a thermal ore furnace with a transformer capacity of 200 kVA, which simulates industrial conditions. As a result, a pilot batch of alloy was developed, the chemical composition was within / %: Si - 30 - 35, Al - 12 - 20, Mn - 25 - 47 and rest. Iron [5,6].

For each new ferroalloy, the effectiveness of its use for deoxidation, microalloying and modification of steel is determined primarily due to one or another of its characteristics (chemical and phase composition, mineralogy, thermal properties, etc.). Accordingly, for the obtained ferroalloy, a number of studies were carried out in this work, including the study of the phase composition by

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the method of X-ray phase analysis (XRD) and microstructural analysis on an electron microscope (SEM).

RESULTS RESEARCH

To identify the phase composition of the alloy samples, the method of X-ray phase analysis was used. The phase composition of the materials was studied by X-ray phase analysis on an Empyrean Malvern Panalytical X-ray diffractometer. The diffractometer is equipped with a Cu tube (Kα1= 1,541874 Å). The measurements were carried out at room temperature in the range of angles 2θ, in the range from 0 ° to 90 ° in the step-by-step scanning mode with a step of 0,013 degrees. Radiographs were processed and interpreted using the Match! 3 program and the program database

FullProf - The HighScorePlus, Match!3 and FullProf - 2021 programs are based on the Rietveld method. The Rietveld method consists in the refinement, calculation of the diffraction spectrum according to a given model of the structure according to a given shape of the profiles of diffraction lines. The results of X-ray phase analysis of alumosilicomanganese alloys are shown in Figures 1 and 2.

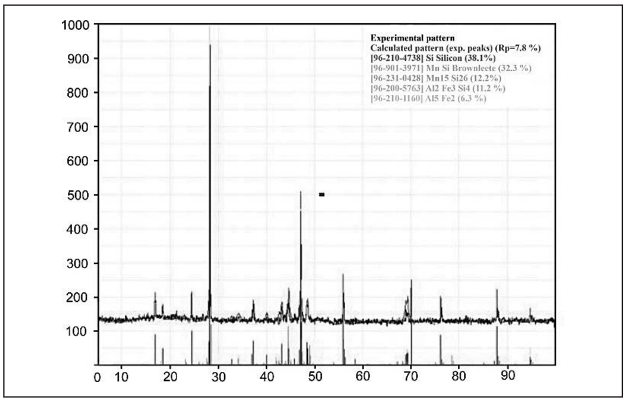

Figure 1 XRD of the aluminosilicomanganese alloy No. 1

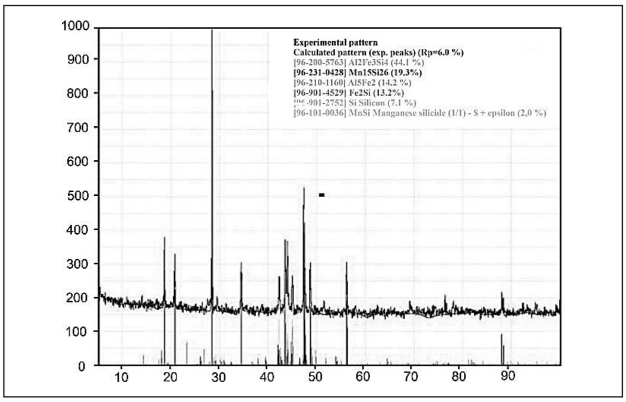

Figure 2 XRD of the aluminosilicomanganese alloy No. 2

As a result of the analysis, it was established that the phase composition of the complex alloy of alumosilicomanganese is presented in the form of an intermetallic compound - MnSi, $Mn_{15}Si_{26}$, $Al_2Fe_3Si_4$, Al_5Fe_2, FeSi and structurally free silicon. No ternary compounds of manganese intermetallide were found, however, according to the Scientific Group Thermodata Europe database (SGTE 2 017), 3 ternary compounds are indicated in the Al - Si - Mn system: $Mn_4Al_3Si_2$, Mn_2Al_9Si and Mn_3Al_9Si in liquid state at temperature 1 500 K [8, 9].

Also, authors of [10] studied the Al - Si - Fe system from the point of view of crystallization of a ferrosilicoaluminum alloy and gave the following 10 ternary phases: $Al_2Fe_3Si_3$, $Al_5Fe_2Si_2$, $Al_9Fe_5Si_5$, Al_2FeSi, Al_3FeSi_2, Al_8Fe_2Si, $Al_9Fe_2Si_2$, $Al_3Fe_2Si_3$, $Al_2Fe_3Si_4$, $Al_{12}Fe_5Si_3$. В работе The [6, 8] following connections have been established for the Al - Si - Fe system: Al_8Fe_2Si, Al_5FeSi, Al_4FeSi_2, Al_3FeSi, Al_2FeSi and Al_2Fe_2Si.

Among the most important physicochemical characteristics of alloys, a special place is occupied by the density of a ferroalloy, which has a significant effect not only on the process of its preparation, but also on the degree and stability of assimilation of the leading elements, the rate of its dissolution and the uniformity of distribution in the volume of the metal. The optimum density of ferroalloys has specific limits associated with the movement of its pieces in the ladle.

The density of the investigated ferroalloys was determined by the pycnometric method, which is based on measuring the mass of a liquid with a metal powder. As a result, it was found that the density of the obtained ferroalloy is 4,5 - 5,5 g / cm^3. Consequently, the use of the obtained alloy containing silicon, manganese, aluminum and other metals as a steel deoxidizer is much more effective; moreover, it can completely or partially replace the mechanical mixture of aluminum and ferrosilicon - aluminum.

The metallographic study of the structure of alumosilicomanganese obtained from poor manganese ores by the carbothermal method was carried out on a JEOL-JSM7001F scanning electron microscope. This microscope is unique in that it automatically subtracts the chemical composition from the spectrum and makes it possible to determine the phase using the chemical composition of a given point. The chemical composi-

Table 1 **Composition of the spectra of the alumosilicomanganese alloy No. 1**

№ of spectra	Element contents in atomic weights / %			
	Al	Si	Mn	Fe
26	-	99,9	-	0,1
27	39,0	44,7	6,2	10,0
28	18,5	49,1	16,2	16,3
29	17,4	51,7	15,2	15,7
30	39,8	42,5	2,9	3,8
31	20,1	77,9	-	0,5
32	20,4	75,9	-	1,6
33	16,4	50,9	15,8	16,8
34	39.1	50,6	-	10,4
35	-	100,0	-	-
36	40,8	48,8	-	10,5
37	22,9	72,8	1,0	1,3
38	4.7	94,2	0,1	0,2
39	8,2	89,4	0,2	0,3
40	5,7	93,0	0,3	0,5
max.	40,8	100,0	16,2	16,8
min.	4,7	42,5	0,1	0,1

Table 2 **Composition of the spectra of the alumosilicomanganese alloy No. 2**

№ of spectra	Element contents in atomic weights / %			
	Al	Si	Mn	Fe
58	4,7	52,5	20,9	7,2
59	36,5	47,1	10,8	5,6
60	-	99,7	0,1	0,1
61	3,2	61,5	29,9	5,4
62	36,4	47,2	10,4	6,0
63	-	99,7	0,2	0,1
64	52,3	44,5	-	1,7
65	20,9	74,8	1,2	1,3
66	3,2	61,6	30,0	5,2
67	21,9	46,0	29,0	1,1
68	5,5	48,3	16,1	8,2
69	23,2	44,8	28,4	1,1
70	39,5	40,8	0,1	-
71	40,2	42,9	11,9	5,0
72	27,5	53,8	11,7	5,3
73	18,8	80,6	0,2	0,4
74	-	99,8	0,2	-
max.	52,3	99,8	30,0	8,2
min.	3,2	40,8	0,1	0,1

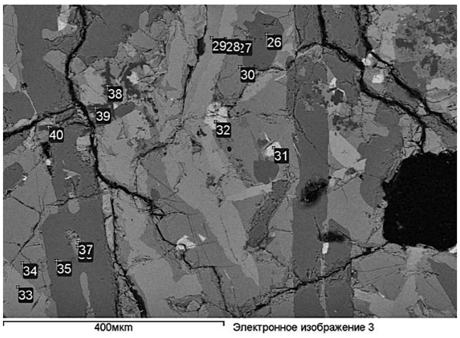

Figure 3 The structure of the alumosilicomanganese alloy No. 1, with an increase of x 400

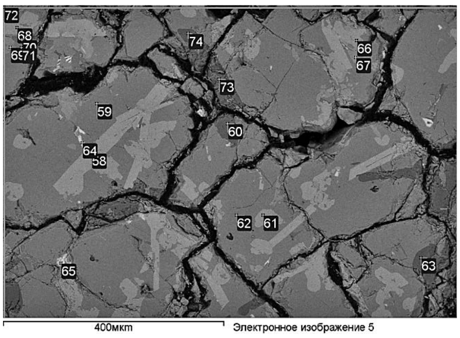

Figure 4 The structure of the alumosilicomanganese alloy No. 2, with an increase of x 400

tion of the phases was determined using an Oxford INCA X-max 80 energy dispersive spectrometer installed on a JEOL JSM-7001F scanning electron microscope. The composition of the spectra is shown in Tables 1 and 2. A snapshot of the microstructure is shown in Figures 3 and 4.

Metallographic analysis shows that alumosilicomanganese is represented by three main structural components, which are distinguished by different shades: white - in the form of interspersed dots, gray - occupies the main area of the form, dark gray - matrix.

CONCLUSION

Thus, according to the results of the above studies, it was found that in the experimentally obtained alumosilico-manganese elements (Mn, Si, Al and Fe) are present in the form of complex intermetallic compounds, such as MnSi, $Mn_{15}Si_{26}$, $Al_2Fe_3Si_4$, Al_5Fe_2, FeSi and structurally free silicon. As a result of differential-thermal analysis, the melting point (crystallization) of the alloy was established - 910 - 1 000 ºC. The density of the alloy under study was also determined, which is 4,5 - 5,5 g / cm^3, which is within the limits of the maximum permissible standards. Consequently, the use of the obtained alloy containing silicon, aluminum, manganese and other metals as a steel deoxidizer is much more effective; moreover, it can completely or partially replace the mechanical mixture of aluminum and ferrosilicoaluminum.

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Note: The responsible translator for English language is Tushiyev Tair, Temirtau, Kazakhstan