INTERACTION BETWEEN MATRIX ALLOY AND REINFORCING GRANULES DURING THE PROCESS OF CASTED COMPOSITE MATERIAL SYNTHESIS

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Nowadays casted composite materials (CCM) have been rather widely used for products of various purposes due to the lower cost and the possibility of manufacturing parts of various geometries, almost without size restrictions [1, 2]. Large share in the production of casted composite

When choosing the composition of composite materials, as well as concerning metal and non-metallic materials, nextcommon provisions should be taken into account, which can be formulated as follows: a material can be considered correctly selected if it best meets three main requirements as operational reliability, manufacturability and economy [4]. However, due to non-uniform heterogeneous nature of such materials, certain problems arise in their synthesis and processing, leading to specific to these materials defects. The properties of composite materials are determined both by the properties of the components and their interaction. The fundamental issue of creating casted composite materials is the possibility of controlling the processes of physical and chemical interaction at the "matrix – reinforcing phase" boundary.Without solving this problem, you cannot expect to achieve the desired level of physical, mechanical and operational properties. It should be noted that the processes at the interphase boundaries are determined by the structure of the substance, which requires a detailed study of these processes aiming to determine the ways that prevent the development of undesirable interaction of the composite components.

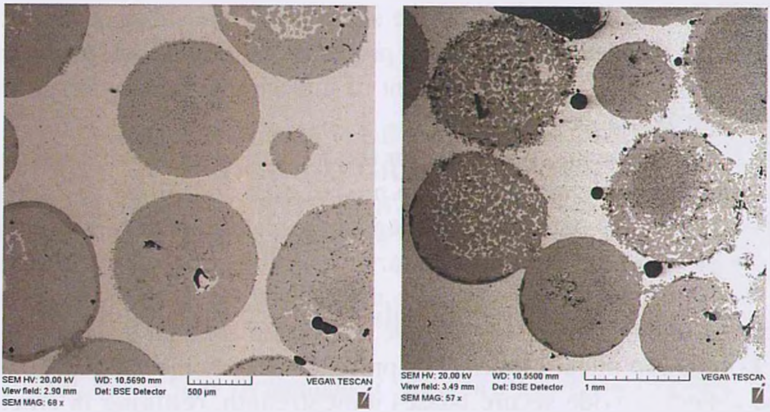
One of the main conditions for the formation of CCM is wetting the reinforcing elements with the matrix melt and filling the pores, capillaries and voids with it. Wetting by the melt leads to good contact of the phases, which is a necessary condition for the development of chemical interaction processes at the interface. Some researchers consider that it is necessary to have a diffusion zone for a strong connection of two metal phases. The presence of only mechanical adhesion cannot provide secure phases joint strength, resulting in cracks at high loads.

CCM obtained by infiltration of $BrSi_3Mn$ bronze into the frame formed by cast-iron granules are of scientific and practical interests which were successfully used in heavy-loaded friction units of steam turbines [5]. Previously, the possibility of destruction of granules during holding out due to the diffusion of atoms into them from the matrix layer was established. As a result, internal stresses appeared which led to the destruction of the granules of the reinforcing phase and reduction in the physical and mechanical properties of the composite [6]. Therefore, the study of the interaction between the matrix melt and the reinforcing phase is an important task for obtaining composites with the desired properties.

The aim of present work was to study the effect of synthesis time on the formation of the transition zone at the matrix alloy – cast iron granules boundary.

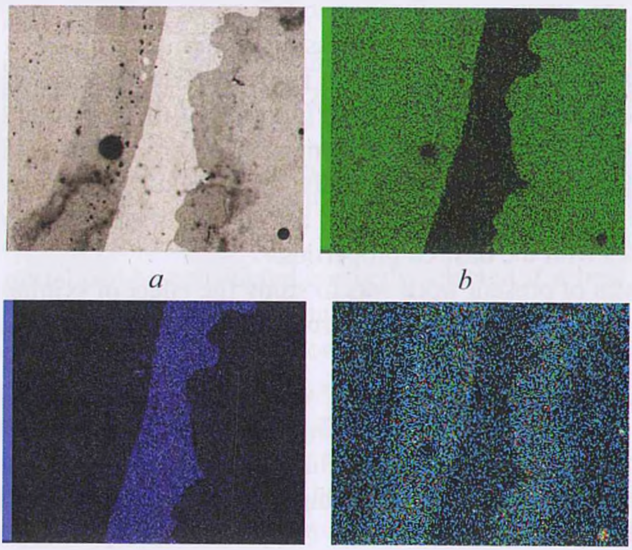
The process of CCM synthesis was carried out at the temperature of 1080 °C. Immediately after the infiltration was completed, the first samples were removed from the furnace and cooled in water to fix the microstructure. Subsequent samples were extracted at 20-minute intervals and also cooled in water. The maximum exposure time was 100 minutes.

The studies were carried out using electron microscopy. Fig. 1 shows the structure of the composite material samples extracted immediately after the completion of the infiltration process.



a *b*

Fig. 1. Microstructure of samples immediately after completion of the infiltration process (*a*) and afterholding for 100 minutes (*b*)



a *b* *c* *d*

Fig. 2. Distribution of the main alloying elements in the contact zone "granules-matrix" for the initial sample (Fig. 1, *a*): *a* – SEM-image, *b* – distribution of iron atoms, *c* – distribution of copper atoms, *d* – distribution of silicon atoms

As can be seen from Fig. 1, the structure of the samples differs significantly. For a more detailed analysis, maps of the distribution of elements in the contact zone were obtained, as well as the chemical composition at various points of the matrix alloy and granules. Fig. 2 shows the maps of the distribution of elements in the contact zone for the sample shown in Fig. 1, *a*, and Fig. 3-for the sample shown in Fig. 1, *b*.

As can be seen from Fig. 2, the main alloying elements are in the initial components of the composite and the development of diffusion processes is not observed. However, it is interesting to note that there is an increased content of silicon in the transition zone, which may indicate the formation of iron silicides with silicon from the matrix melt.

When the exposure time is increased to 100 minutes, the maps show the results of diffusion of copper and silicon into granules. Matrix melt destroys the continuity of the transition zone, dividing it into Islands (Fig. 3).

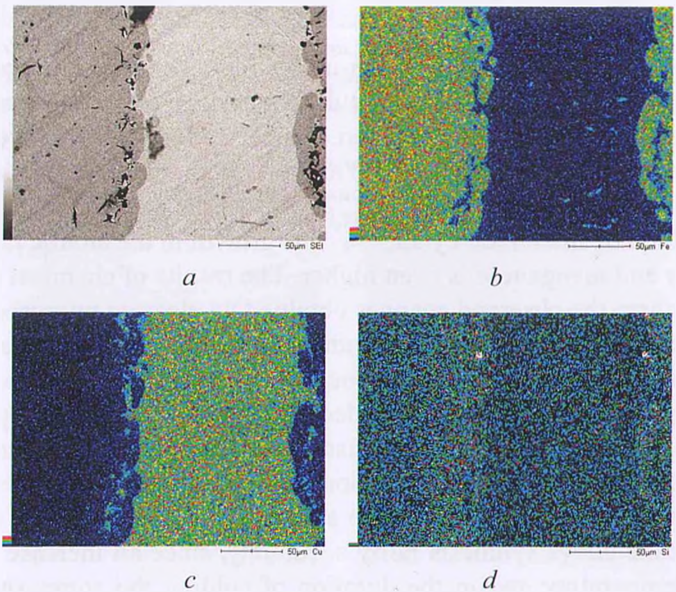


Fig. 3. Distribution of the main alloying elements in the contact zone "granules-matrix" for the initial sample (Fig. 1, *b*): *a* – SEM-image; *b* – distribution of iron atoms; *c* – distribution of copper atoms; *d* – distribution of silicon atoms

The increased content of silicon in the transition zone is still present, but it can be seen that it diffuses into the depth of the granules. The presence of copper atoms in the depth of the granules is also noticeable. The chemical analysis of the main elements in the granule for a point located at a distance of 100 microns from the interface for both samples is shown in the Table.

Chemical composition of CCMfor the point at a distance of 100 microns from the surface

Specimen from Fig. 1, *a*					Specimen from Fig. 1, *b*				
Element	(keV)	mas.%	Error %	At %	Element	(keV)	mas.%	Error %	At %
O K	0.525	0.60	0.02	2.05	O K	0.525	0.61	0.03	2.09
Si K	1.739	1.55	0.01	3.01	Si K	1.739	0.41	0.02	0.80
Mn K	5.894	1.27	0.02	1.25	Mn K	5.894	1.56	0.03	1.56
Fe K	6.398	93.28	0.02	90.86	Fe K	6.398	93.32	0.03	91.99
Cu K	8.040	3.30	0.04	2.83	Cu K	8.040	4.11	0.06	3.56
Total	100.00		100.00		Total	100.00		100.00	

Analysis of the results shown in the Table confirms the presence of copper and manganese atoms diffusion deep into the granule as well as the redistribution of silicon. Concentration (by weight) copper in the granule at a distance of 100 microns from the surface increased by 24.5 %, and manganese – by 22.8 %. At the same time, the concentration of silicon fell by 73.5 %. The growth in the atomic ratio for copper and manganese is even higher. The results of chemical analysis confirm the observed changes obtained by electron microscopy.

Conclusion. The studies conducted allowed us to estimate the diffusion of matrix alloy components into the granules of the reinforcing phase, which led to a decrease in the strength properties of the composite due to an increase in the thickness of the transition zone and its subsequent destruction. It is established that it is necessary to maintain the temperature and time parameters of the casted composite alloys synthesis fairly accurately, since an increase in the melt temperature and in the duration of holding the composite into the furnace can be expected to increase the diffusion rate. As a result, the physical, mechanical and operational characteristics will be significantly lower than the predicted values.

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