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Influence of microstructure parameters of [Al – FeCr] cast composite material, obtained in the “volume” of foundry mold using lost-foam casting process, on its mechanical characteristics

The authors conducted an in-depth analysis of domestic and foreign literary data, as well as formulated and set the goal of this scientific work. The inoculation of cast Al-based alloy of the AK12 DSTU 2839:1994 with dispersed intermetallic FeCr in the “volume” of the casting mold (CM) during casting by using of Lost-foam casting (LFC-process) allowed to get samples of zero-dimensional cast composite material (CCM) of the system [Al – FeCr]. Metallographic analysis (MGA) showed that the parameters of the microstructure, such as the specific number of σ -phase inclusions and its dispersion, can vary not only along the height of the cast samples, but are also dependent on each other. Mechanical tests of the obtained material showed that not only the height of the composite casting, but also the parameters of its microstructure affect the temporary resistance to rupture, relative elongation and hardness on the Brinell scale. The application of MGA and mechanical tests for the zero-dimensional CCM of the system [Al – FeCr] and, accordingly, for the control casting showed experimentally what a decrease in the average dispersion of σ -phase inclusions from 26.6 μm to 57.1 μm leads to the fact that the temporary resistance to rupture and the relative elongation of the investigated composite decrease from 135 MPa and 2.5 % to 60 MPa and 0.5 %, respectively. At the same time, the increase in the hardness of samples of the zero-dimensional CCM system [Al – FeCr] from 6.923×10^{-1} GPa to 7.885×10^{-1} GPa on the Brinell scale is a consequence of the fact that the average dispersion of σ -phase inclusions in the structure of the studied composite decreases from 26.6 μm to 57.1 μm . The results of the conducted research also made it possible to find out that the increase in the specific number of σ -phase inclusions from 63 mm^{-2} to 263 mm^{-2} is the reason for the increase in the temporary resistance to rupture and the relative elongation of the zero-dimensional CCM of the system [Al – FeCr] from 60 MPa and 0.5 % up to 135 MPa and 2.5 %, respectively. However, the hardness of the composite casting, which was determined according to the Brinell scale, and under the condition that the specific number of σ -phase inclusions in the structure of the zero-dimensional CCM of the system [Al – FeCr] is in the range given above, as a result decreases from 7.885×10^{-1} GPa to 6.923×10^{-1} GPa.

Keywords: Al-matrix, FeCr, σ -phase, reinforcement, dispersed-filled gasmodel, intermetallic reinforcing phase, composite casting, composite strengthening, lost-foam casting (LFC-process), cast composite material of [Al – FeCr] system, metallographic analysis, mechanical trials, mechanical properties, microstructure.

Introduction. The needs of modern industrial production and the rapid dynamics of scientific and technical progress present the main prospects for the use of composite materials (CM). Information on the use of dispersion-reinforced aluminomatrix CM in domestic and foreign developments, analysis of scientific and technical and patent literature show that to date, certain experience has been accumulated in the use of the CM system "Al-alloys – refractory, heat-resistant, hard parts" in tribotechnics. The development of aluminomatrix CM is the very important for aviation and rocket engineering (skinning, spars, panels, etc.). In space technology, these materials are used for components of power structures that heat up during operation. In the automotive industry, it is used to lighten bodies, frames, bumpers, etc. In civil construction, these are spans of bridges, elements of prefabricated structures of high-rise buildings, etc. The filler in the form of reinforcing elements in the bars of CM volume is distributed uniformly or uniformly with a given gradient in the entire cross-section of the Me-matrix. A wide variety of components are chosen as the reinforcing phase (RP): molybdenum, vanadium, aluminum oxide, graphite, borides, carbides, nitrides, carbonitrides, and the like. Wide prospects open up for non-metallic oxygen-free refractory compounds such as carbides and nitrides of boron and silicon, as well as solid refractory oxides of aluminum, zirconium and other metals; silates, intermetallics, various chemical compounds and ceramics [1]. The RP can be presented in the form of sheets or fibers, in which case the CM is anisotropic (two- or one-dimensional, respectively), or in the form of dispersed particles, in which case it is isotropic (zero-dimensional). Highly dispersed particles of the other component are uniformly distributed in the Al-matrix, as a result of which an isotropic structure is formed, which effectively resists plastic deformation.

The cast aluminum alloys (Al-alloys) have become widespread in almost all branches of the national economy, and in aviation and rocketry these alloys play an extremely important role [2]. This was already mentioned earlier. This became possible at a successful combination of high specific strength with good technological and casting properties [3]. However, the low hardness and wear resistance of Al-alloys limit their use in engineering for the production of parts that work in friction nodes and abrasive wear conditions [2-4].

Analysis of literary data and the purpose of the work. To date, a number of technological methods and techniques for improving Al-alloys are known [2-26], in particular foundry ones [2-4, 6, 8-22, 24, 26], among which their reinforcement (composite strengthening) occupies a central place [2, 4, 6, 8, 10, 12, 14-22, 24, 26]. The CCM, obtained on the basis of these alloys, have an optimal microstructure, as well as high hardness and wear resistance [2, 4, 6, 8, 10, 12, 14-22, 24]. However, the dependence of the mechanical characteristics of CCM, in particular zero-dimensional, which were obtained in the "volume" of the CM according to the LFC-process, on the parameters of its microstructure, has not been studied to a sufficient extent. The service and operational properties of zero-dimensional CCM system

[Al – RP] (reinforcing phase – RP) directly depend on this, which will be discussed further.

However, traditional casting methods do not provide composite castings with high dimensional accuracy and minimal allowances for mechanical processing [4, 15, 17]. The most promising method for the production of Al-matrix zero-dimensional CCM's is the LFC-process [6], since its main feature is the use of a gasifiable model (GM), that is, a model that is not removed before filling the CM with liquid metal, defines the main advantages of this technological process in comparison with other methods of casting. In addition, GM can be obtained in the volume of the press-form (i. e. mold) (PF) from prefoamed granular modeling material. These circumstances made it possible to introduce dispersed additives into the composition of GM, and thus to solve a two-fold task – to carry out reinforcing inoculation of the matrix melt [8, 10, 12] in the "volume" of the CM and to carry out the disposal of dust-like waste from the ferroalloy industry. Implantation of the RP in the "body" of the GM in practice is reduced to cold plating of the surface of the foamed granules of the model material with dispersed ferroalloys before they are blown or filled into the volume of the PF [27].

In most cases, expanded polystyrene is used for the manufacture of GM by the autoclave method. It is obtained by two-stage foaming of polystyrene. The physico-chemistry and technology of the process of industrial production of polystyrene is described in detail by the author in the paper [28].

The distribution of dispersed inclusions in the Me-matrix does not change even with a significant increase in temperature, since these inclusions, being separated by the matrix itself, almost do not agglomerate due to diffusion processes. In CM with a Me-matrix, the advantages of structural materials on a metallic basis are combined with the advantages of filler, most often a high-modulus ceramic or intermetallic one. At the moment, dispersion-strengthened CM are used in industry based on almost all alloys of ferrous and non-ferrous metals widely used in technology. An optimal Me-matrix makes it possible to implement high characteristics of the original components and to form a CM that corresponds to the specific conditions of its operation. When choosing a Me-matrix, it is necessary to take into account both the mechanical and operational properties of CM, as well as the manufacturability of the production process of such a material. In practice, the requirements for CM are reduced not only to ensuring the necessary mechanical properties, but also its operational characteristics and reliability, which is associated with high fracture toughness, should also be remembered.

Based on these considerations, the goal of this scientific-research work was formulated and set. It consisted of obtaining samples of the zero-dimensional CCM of the [Al – RP] system, investigating its microstructure and mechanical properties, and also finding out how and to what extent do the mechanical characteristics of the studied CCM depend on the average dispersion and the specific amount of RP inclusions in the structure of the composite casting.

Table 1

Chemical composition [% (mass fraction)] of the control alloy

Alloy type	Alloying elements (Al – base)							
	Si	Mg	Cu	Mn	Ni	Ti	Fe	Cr
AK12 DSTU 2839:1994	11.002	0.028	1.105	0.370	0.025	0.055	0.500	0.015
DSTU 2839:1994 is the State Standard of Ukraine 2839:1994								

Since silumin of the eutectic composition of the AK12 type has high casting and technological characteristics [3], samples of the zero-dimensional CCM system [Al – RP] were obtained on the basis of this commercially available alloy with dimensionals, mm: length – 100, width – 10, height – 300. As the RP of the experimental composite, in this scientific work, a dispersed intermetallic FeCr, better known in the alloys of the binary system “Iron – Chromium” as the σ -phase, was used in the amount of 10 % of the mass of the control casting. Thus, in this scientific work, according to the classification [15], we are talking about the zero-dimensional CCM of the [Al – FeCr] system, hereinafter referred to as the CCM of the [Al – FeCr] system.

Research methodology. In order to obtain samples of the CCM of the [Al – FeCr] system, which were mentioned earlier, a cast Al-alloy of the AK12 type was prepared. The test material, the chemical composition of which (Table 1) is given below, was melted in a crucible furnace of the “CAT-025-И2” model. The temperature of the matrix melt is, K: at the outlet from the melting unit – 1053; during mold filling – 1023. Supply of liquid metal into the “volume” of the CM was carried out from above into the side wall of the CM to obtain casting. The supply of liquid metal into the “volume” of the CM was carried out from top side.

Dispersed intermetallic FeCr was obtained from cast samples of a high-chromium Fe-based alloy. For this, the bar material was pre-annealed in a laboratory muffle furnace of model “CHO-2,5.5.2,5/13,6 И1” for the formation and separation of the σ -phase from a solid solution of Cr in Fe and crushed by laboratory crusher of model “Вібротехнік ШД-10 6411-00013” and sieved through sieves. Characteristics of RP: annealing temperature – 1073 K, isothermal exposure time – 3600 s, dispersion – 20 ... 100 μm , the shape of the particles is scaly, the unevenness factor is 2 ... 5. The chemical composition of RP (Table 2) of the composite casting is presented below.

It was possible to obtain a powder of the specified dispersion by to sieve analysis. For this, a set of laboratory sieves made of braided wire fabric, regulated by DSTU EN 233-2:201_ (EN 233-2:1995, IDT), was used. The average dispersion of σ -phase particles was determined by the formula [29]:

$$\langle d \rangle = \frac{\sum_{i=1}^n m_i d_i}{\sum_{i=1}^n m_i}, \quad (1)$$

where m_i – the mass of the i -th fraction of the powdered σ -phase, kg; d_i – the arithmetic average of the dispersion of the σ -phase particles in the i -th fraction, $\times 10^{-6}$ m.

Depending on the size of the particles (dispersity), the FeCr intermetallic powder, in our case, is, conditionally, a mixture of powders of 2 incomplete groups [29]. Such groups are fine powder (10 ... 40 μm) and medium-sized powder (40 ... 250 μm).

The study of the influence of the height of composite castings on mechanical characteristics was carried out according to the original method developed by specialists of the Physico-technological Institute of Metals and Alloys of the NAS of Ukraine [10, 22]. For this, the cast bars (Table 3) were pre-marked and cut into templates. From the templates, grindstones for MGA at dimensionals – 25×10×50 mm and samples for mechanical tests at dimensionals – 75×10×50 mm were made. The MGA of the [Al – FeCr] CCM samples and their mechanical tests were carried out according to standard methods corresponding to [30, 31]. The method of determining the microstructure parameters of composite castings is also regulated by GOST 1778-70. Methodology for determining temporary resistance to rupture and relative elongation and hardness is corresponds of GOST 1497-84, 9012-59, 25.503-97. The microstructure of the metallographic sections was etched using a water solution of a mixture of mineral (inorganic) acids with the following chemical composition according to [29], % (mass fraction): HF (hydrofluoric acid) – 1.0; HCl (hydrochloric acid) – 1.5; HNO₃ (nitric acid) – 2.5; H₂O (distilled water) – 95.0.

Discussion of the results of the experiment. It has been experimentally determined that the effectiveness of the composite strengthening of cast Al-alloys with dispersed intermetallic FeCr (in particular for the AK12 type) is primarily determined by the microstructure of the CCM system [Al – FeCr], which can be obtained on the basis of these alloys (this alloy). The criteria for evaluation or main parameters of the microstructure of a composite casting are, first of all, the average dispersion and the specific number of inclusions of intermetallic RP. First of

Table 2

Chemical composition [% (mass fraction)] of the reinforcing phase before reinforcement

Material	Alloying elements and impurities (Fe – base)							
	Al	Cu	Mn	Ni	Ti	Cr	Mo	W
Intermetallic FeCr	0.363	0.147	1.105	0.359	0.297	39.951	0.447	0.930

Table 3

Microstructure of the CCM system [Al – FeCr] and its mechanical properties

Index template	Microstructure parameters		Index template	Mechanical characteristics		
	$\bar{D}$, μm	n , mm^{-2}		σ_B , MPa	δ_5 , %	HB, $\times 10^{-1}$ GPa
1-B	27.5	195	1-A	120	2.0	7.110
2-B	26.6	263	2-A	135	2.5	6.923
3-B	35.5	184	3-A	110	1.7	7.277
4-B	50.9	074	4-A	075	1.0	7.679
5-B	57.1	063	5-A	060	0.5	7.885
6-B	45.4	068	6-A	090	1.3	7.522

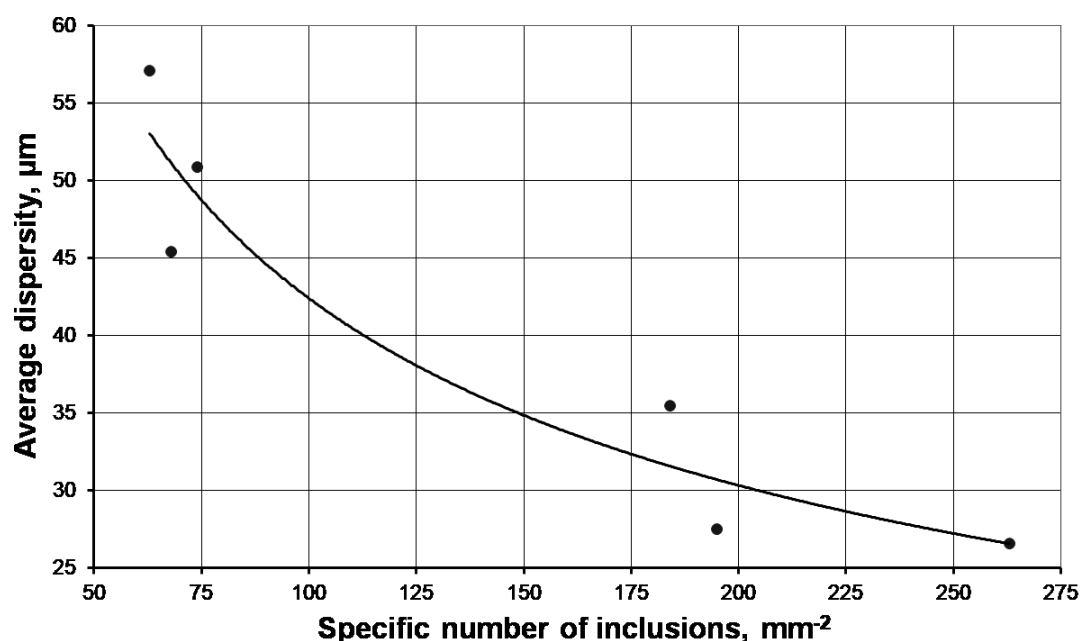
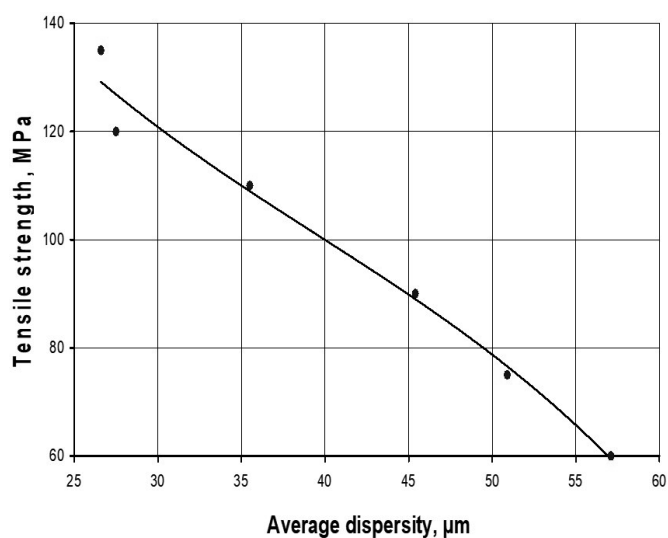


Fig. 1. Specific number of the FeCr intermetallic reinforcing phase inclusions influence on its average dispersion

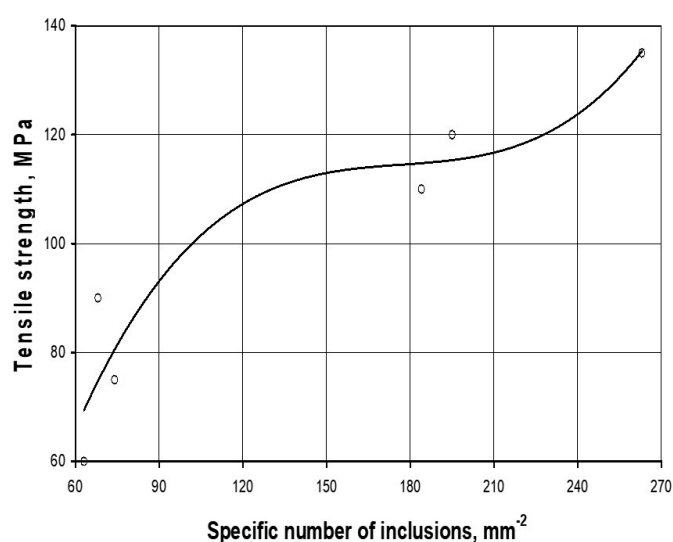
all, the physico-mechanical [10, 14, 22] and special, in particular, tribotechnical [12, 14, 18] properties of the obtained composite depend on these indicators. This was already mentioned earlier.

The above conclusions were reached on the basis of analysis after determining the mechanical characteristics [10, 14, 22] and parameters of the microstructure [2, 8, 16, 18, 20, 22, 24] of the CCM samples of the [Al – FeCr] system, which were carried out in height for composite castings. In order to refute or confirm the hypothesis put forward for discussion, it is necessary to conduct a series of additional studies. This will make it possible to find out how and to what extent the average dispersion, the specific number of inclusions of intermetallic RP affect the temporary resistance to rupture of the material and the relative elongation and hardness of the CCM of the [Al – FeCr] system. In the future, in order to predict the dependence of the mechanical characteristics of the obtained material on the parameters of its microstructure, it is advisable to derive empirical equations through mathematical processing of experimental data, which will allow to analytically describing the functional relationship of independent factors with certain qualitative and quantitative indicators.

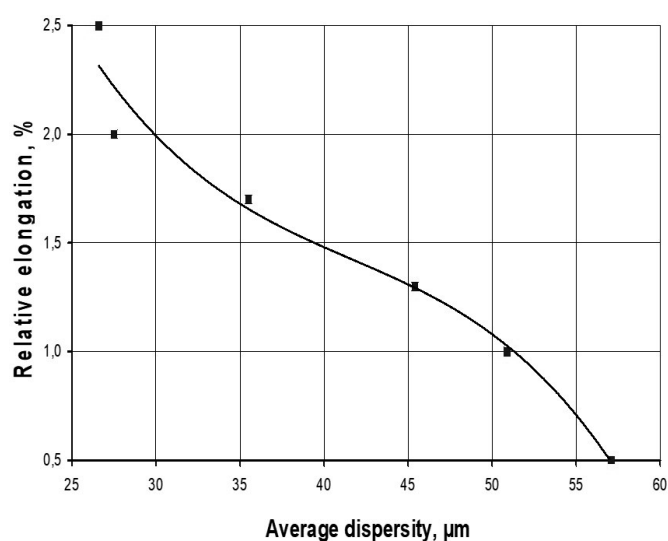
The results of the experimental data (Table 3) showed that the average dispersion and the specific number of inclusions of intermetallic RP not only change along the height of the composite casting, but are also directly functionally dependent. To reveal its nature, we resorted to a graphical interpretation of the results of the conducted experiment (Fig. 1). The analysis showed that the graphic dependence has a power-law character. For example, an increase in the specific number of FeCr intermetallic inclusions from 63 mm^{-2} to 263 mm^{-2} is the reason for an increase in the average dispersion from 53.1 μm to 26.6 μm . Such a phenomenon is a consequence of thermo-physical processes occurring in the process of crystallization during and, accordingly, after filling the volume of the mold. The processes that take place in the system “Al-melt – GM – DI – CM” (that is, which we are talking about) are described in detail by the authors of the research paper [2]. Mathematical processing of the results of the conducted research made it possible to derive an empirical equation ($R^2 = 0.9096$), which analytically describes the influence of the specific number of inclusions of intermetallic RP on its average dispersion in the structure of the CCM system [Al – FeCr]:



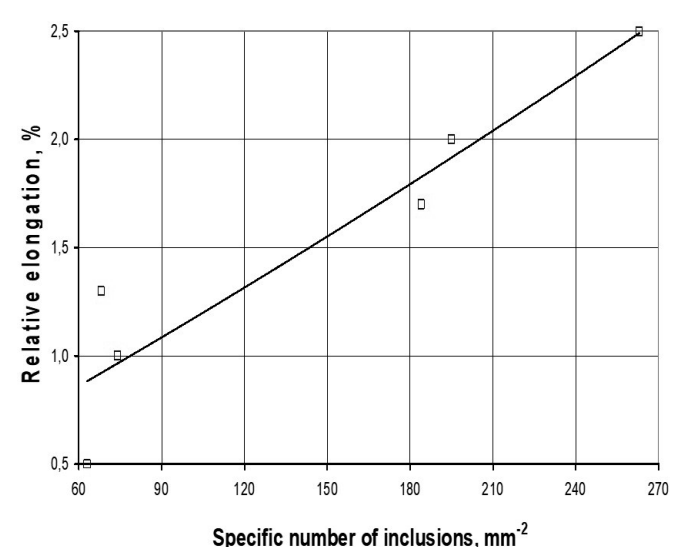
a



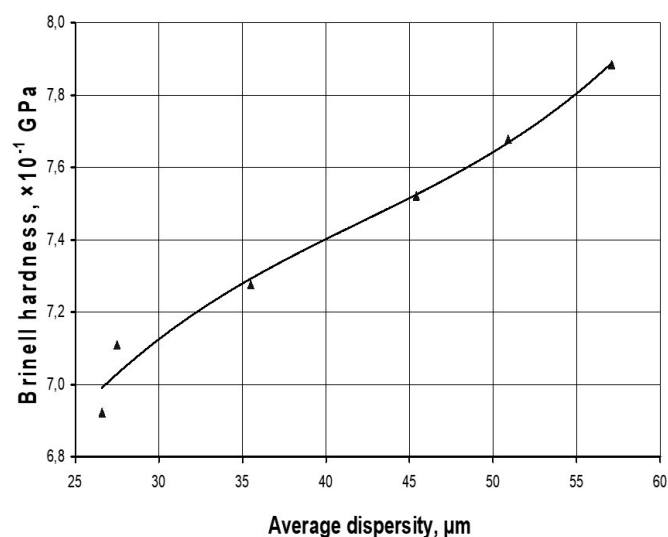
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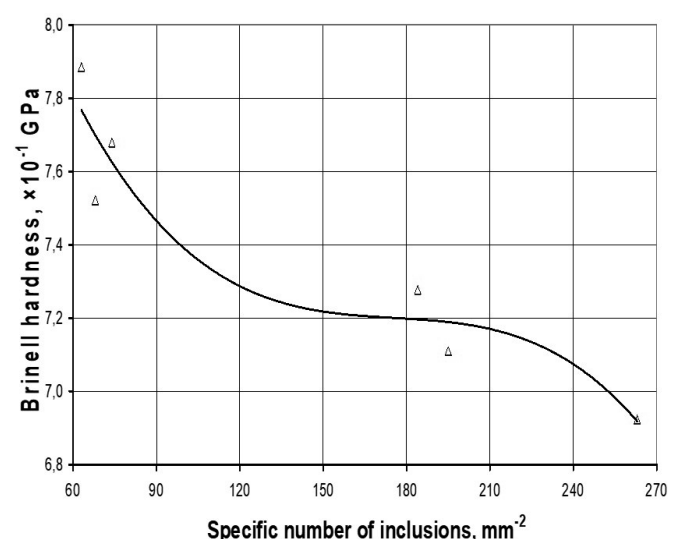
b



b



c



c

Fig. 2. Influence of average dispersion intermetallic reinforcing phase to mechanical characteristics of the CCM system [Al – FeCr]: a – temporary rupture resistance; b – relative elongation; c – Brinell hardness

Fig. 3. Dependence of the mechanical properties of the CCM system [Al – FeCr] on the specific amount of those inclusions of the intermetallic reinforcing phase: a – temporary gap resistance; b – relative elongation; c – Brinell hardness

$$\bar{D} = 394.7 n^{-0.484}, \quad (2)$$

where R^2 – approximation reliability value; $\bar{D}$ – average dispersity of intermetallic RP, μm ; n – specific number of FeCr intermetallic inclusions, mm^{-2} .

The analysis of the results of the experiment (see Table 3) made it possible to find out that there is a functional relationship between the parameters of the microstructure for composite castings and their mechanical properties. Graphical interpretation of the array of experimental data (Fig. 2, 3) showed that this relationship is of polygonal character. In particular [Fig. 2 (a, b)], a decrease in the average dispersion of the σ -phase inclusions from 26.6 μm to 57.1 μm leads to the fact that the temporary breaking strength and relative elongation of the investigated composite decrease from 135 MPa and 2.5 % to 60 MPa and 0.5 %, respectively. Along with this [see Fig. 2 (c)], the increase in the hardness of the samples of the zero-dimensional CCM system [Al – FeCr] from $6,923 \times 10^{-1}$ GPa to $7,885 \times 10^{-1}$ GPa on the Brinell scale is a consequence of the fact that the average dispersion of σ -phase inclusions in the structure of the investigated composite decreases from 26.6 μm to 57.1 μm . The results of the conducted research [see Fig. 3 (a, b)] also made it possible to find out that the increase in the specific number of σ -phase inclusions from 63 mm^{-2} to 263 mm^{-2} is the reason for the increase in the temporary resistance to rupture and the relative elongation of the zero-dimensional CCM of the system [Al – FeCr] from 60 MPa and 0.5 % to 135 MPa and 2.5 %, respectively. However [see Fig. 3 (c)], the hardness of the composite casting, which was determined according to the Brinell scale, and provided that the specific number of σ -phase inclusions in the structure of the zero-dimensional CCM of the system [Al – FeCr] is in the range given above, as a result, it decreases from $7,885 \times 10^{-1}$ GPa to $6,923 \times 10^{-1}$ GPa.

At the same time, the examination of fracture of samples of the studied material after rupture showed that macrograins of CCM system [Al – FeCr] and control Al-alloy AK12 type (DSTU 2839:1994) differ from each other in size and color. In the 1-st case, the studied material has a silvery-white coarse-grained macrostructure, and in the 2-nd – ash-gray fine-grained. Therefore, a preliminary conclusion is suggested that the color and granularity of the fracture of the examined casting from the CCM system [Al – FeCr] is determined by the intermetallic RP, which also has a silver-white color, and in this case, most likely, the fracture of the studied material has a brittle intercrystalline nature [32], which cannot be said about the control cast sample. In addition, this assumption is also confirmed by the fact that the temporary resistance to rupture and the relative elongation of the CCM system [Al – FeCr] are lower, and the hardness is higher than that of the basic Al-alloy of AK12 type (DSTU 2839:1994). However, for the final confirmation of this assumption, it is necessary that the condition of brittle fracture be fulfilled, under which the destructive stress would be no less than that proposed by the authors [32]:

$$\sigma_f = \frac{4 \mu \gamma}{\alpha k \sqrt{l}}, \quad (3)$$

where σ_f – crack initiation stress, MPa; μ – shear modulus, MJ/m²; γ – effective crack surface energy, MJ/m²; α – fraction of dislocation energy, MJ/m; k – proportionality factor ($k = \text{const}$), $m^{-0.5}$; l – length of the sliding strip, m.

Mathematical processing of the research results was reduced to polynomial approximation of the ratios of physical quantities given in tabular form (see Table 3) and made it possible to obtain empirical dependences ($R^2 = 0.9787, 0.967, 0.9824$, respectively) of the mechanical characteristics of the studied material on the average dispersion of intermetallic FeCr particles, distributed in the volume of the composite casting:

$$\sigma_{\sigma}^{[\text{Al} - \text{FeCr}]} = -1.2 \cdot 10^{-3} \cdot \bar{D}^3 + 1.437 \cdot 10^{-1} \cdot \bar{D}^2 - 7.6636 \cdot \bar{D} + 254.11, \quad (4)$$

$$\delta_5^{[\text{Al} - \text{FeCr}]} = -10^{-4} \cdot \bar{D}^3 + 1.42 \cdot 10^{-2} \cdot \bar{D}^2 - 6.262 \cdot 10^{-1} \cdot \bar{D} + 11.044, \quad (5)$$

$$HB_{[\text{Al} - \text{FeCr}]} = 3.0 \cdot 10^{-5} \cdot \bar{D}^3 - 3.7 \cdot 10^{-3} \cdot \bar{D}^2 + 1.801 \cdot 10^{-1} \cdot \bar{D} + 4.2925, \quad (6)$$

as well as the specific number of intermetallic RP inclusions σ -phases in its structure ($R^2 = 0.9016, R^2 = 0.8778, R^2 = 0.907$, respectively):

$$\sigma_{\sigma}^{[\text{Al} - \text{FeCr}]} = 3.0 \cdot 10^{-5} \cdot n^3 - 1.47 \cdot 10^{-2} \cdot n^2 + 2.6356 \cdot n - 45.278, \quad (7)$$

$$\delta_5^{[\text{Al} - \text{FeCr}]} = 3.0 \cdot 10^{-6} \cdot n^2 + 7.0 \cdot 10^{-3} \cdot n + 4.289 \cdot 10^{-1}, \quad (8)$$

$$HB_{[\text{Al} - \text{FeCr}]} = -4.0 \cdot 10^{-7} \cdot n^3 + 2.0 \cdot 10^{-4} \cdot n^2 - 3.4 \cdot 10^{-2} \cdot n + 9.2426, \quad (9)$$

where $\sigma_{\sigma}^{[\text{Al} - \text{FeCr}]}$ – temporary resistance to rupture for the CCM system [Al – FeCr], MPa; $\delta_5^{[\text{Al} - \text{FeCr}]}$ – relative elongation of the CCM system [Al – FeCr], %; $HB_{[\text{Al} - \text{FeCr}]}$ – the hardness of the CCM system [Al – FeCr] according to the Brinell scale, kgf/mm².

This is the influence of the main parameters of microstructure on the mechanical properties of the composite casting can be explained as follows. As the average dispersion of intermetallic RP particles decreases, their total area in the field of the metallographic slide increases, and the total area of the Al-matrix, accordingly, decreases. This, of course, leads to the fact that the hardness of the samples from the CCM system [Al – FeCr], determined according to the Brinell scale, increases somewhat as a result. In particularly, the particles of intermetallic FeCr is the as stress concentrators. In other words, they “cut” and separate the Al-matrix. The lower their average dispersion, the stronger the effect will be. Therefore, the relative elongation, and especially the temporary resistance to rupture of composite castings, will be significantly reduced. An increase in the specific number of inclusions of intermetallic RP is possible under the

condition of a constant concentration of them in the volume of the studied cast sample. There is a relationship between the average dispersion and the specific number of FeCr intermetallic particles, which is clearly shown in fig. 1. It is described using the empirical equation (2). The slope of the line of functional dependence indicates favorable conditions for the appearance of areas with an increased area of the Al-matrix in the field of the metallographic slide. An increase in the area of the areas, as a final result, leads to a certain decrease in the hardness of the CCM system [Al – FeCr] according to the Brinell scale. At the same time, as the specific number of inclusions of intermetallic RP (which has increased dispersion) increases, the Al-matrix of the composite casting is strengthened due to the inhibition of the movement of dislocations of highly dispersed FeCr-based inclusions. These circumstances are the root cause that contributes to the increase in relative elongation, and first of all, the temporary resistance to rupture of the samples for CCM system [Al – FeCr].

Conclusions

With the use of MGA and as a result of mechanical testing of castings from cast Al-alloy AK12 type (DSTU 2839:1994), reinforced with the help of dispersed-filled GM with FeCr intermetalide, it was experimentally proven that:

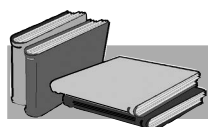
a) there is a functional relationship between the specific number of inclusions of intermetallic RP in the CCM

structure of the [Al – FeCr] system and its average dispersion, and this relationship is of a power-law nature; for example, an increase in the specific number of σ -phase inclusions from 63 mm⁻² to 263 mm⁻² leads to an increase in its average dispersion from 53.1 μ m to 26.6 μ m;

b) as the average dispersion of FeCr intermetallic particles in the volume of composite castings decreases from 26.6 μ m to 57.1 μ m, their Brinell hardness increases from 6.923×10^{-1} GPa to 7.885×10^{-1} GPa, and the relative elongation and temporary rupture resistance, on the other hand, decrease from 2.5 % and 135 MPa to 0.5 % and 60 MPa, respectively;

c) an increase in the specific number of inclusions of intermetallic RP in the structure of cast blanks from 63 mm⁻² to 263 mm⁻² leads to a decrease in the hardness of the CCM [Al – FeCr], determined according to the Brinell scale, from 7.885×10^{-1} GPa to 6.923×10^{-1} GPa, as well as an increase in its relative elongation and an increase in temporary rupture resistance from 0.5 % and 60 MPa to 2.5 % and 135 MPa, respectively;

d) the temporary breaking strength and relative elongation of the composite casting, on average [10], are 16.7 MPa and 1.7 % less than the similar properties of the cast Al-alloy AK12 type (DSTU 2839:1994), respectively, while the hardness according to the Brinell scale of the CCM system [Al – FeCr] exceeds the same characteristic of the cast sample from the control alloy by 1.329×10^{-1} GPa.

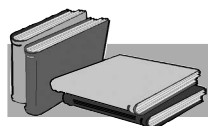


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Вплив параметрів мікроструктури литого композиційного матеріалу системи [Al – FeCr], отриманого у «порожнині» ливарної форми за ЛГМ-процесом, на його механічні характеристики

Авторами проведено глибокий аналіз вітчизняних та зарубіжних літературних даних, а також сформульовано й поставлено ними мету цієї науково-дослідної роботи (НДР). Шляхом інокулювання ливарного Al-сплаву марки АК12 ДСТУ 2839:1994 дисперсним інтерметалідом FeCr у «порожнині» ливарної форми (ЛФ) при литті за моделями, що газифікуються, (за ЛГМ-процесом) одержали зразки нульмірного литого композиційного матеріалу (ЛКМ) системи [Al – FeCr]. За допомогою металографічного аналізу (МГА) було доведено, що параметри мікроструктури (питома кількість включень σ-фази та її дисперсність) залежать один від одного. Результати механічних випробувань досліджуваного матеріалу показали, що на механічні характеристики (тимчасовий опір розриву, відносне видовження і твердість за

шкалою Брінелля) впливають не лише висота композитного виливка, що було доведено раніше, а й параметри його мікроструктури. Із застосуванням МГА та в результаті механічних випробувань зразків нульмірного ЛКМ системи [Al – FeCr] було експериментально доведено, що зниження середньої дисперсності включень σ -фази від 26,6 мкм до 57,1 мкм призводить до того, що тимчасовий опір розриву й відносне видовження досліджуваного композиту зменшуються від 135 МПа й 2,5 % до 60 МПа й 0,5 %, відповідно. Разом із цим, підвищення твердості зразків нульмірного ЛКМ системи [Al – FeCr] від $6,923 \times 10^{-1}$ ГПа до $7,885 \times 10^{-1}$ ГПа за шкалою Брінелля є наслідком того, що середня дисперсність включень σ -фази в структурі досліджуваного композиту знижується від 26,6 мкм до 57,1 мкм. Результати проведених досліджень дозволили також з'ясувати, що збільшення питомої кількості включень σ -фази від 63 мм^2 до 263 мм^2 є причиною зростання тимчасового опору розриву та відносного видовження нульмірного ЛКМ системи [Al – FeCr] від 60 МПа та 0,5 % до 135 МПа та 2,5 %, відповідно. Проте, твердість композитного виливка, яка була визначена за шкалою Брінелля, і за умови, що питома кількість включень σ -фази в структурі нульмірного ЛКМ системи [Al – FeCr] знаходиться у діапазоні, наведеному вище, в результаті знижується від $7,885 \times 10^{-1}$ ГПа до $6,923 \times 10^{-1}$ ГПа.

Ключові слова

Al-матриця, FeCr, σ -фаза, армування, дисперсно-наповнена газомодель, інтерметалідна армуюча фаза, композитний виливок, композиційне зміцнення, ЛГМ-процес, ЛКМ системи [Al – FeCr], металографічний аналіз, механічні випробування, механічні властивості, мікроструктура.