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CHANGES IN THE STRUCTURE AND PROPERTIES OF CAST ALUMINUM ALLOYS DISPERSED MODIFICATION

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Introduction. In modern engineering requires a combination of high mechanical properties, corrosion resistance, low density. These requirements meet aluminum alloys of the system, which strengthened 700−800 MPa in deformation and heat treatment, which leads to their prospects for modern engineering.

In domestic machine building used for casting aluminium alloys system aluminium-silicon, in particular, marks AL4(AK9c), ALS, AK8 and AK7. These alloys have high mechanical properties in heat-treated condition, high corrosion resistance, making them promising for production.

However, the lack of adaptability in casting and machining constraining wide application of aluminium alloys as structural materials. Low adaptability explained by the presence in the alloy fragile and difficult soluble phases $FeAl_3$, Mg_2Si, $MgZn_2$, released in the form large clusters and forming a continuous grid [1]. These fragile components are the cause of cracking in casting of ingots and shaped castings. In addition, slow diffusion processes of dissolution Mg_2Si when homogenizing castings [2]. Another important reason for low adaptability is high gassy in alloys.

Theoretical substantiation of the problem. The development of modern technology requires the creation of new materials and improvement of already existing alloys. One of the effective ways of improving the quality of castings, address bar and fan patterns, grind grain and homogeneous structure is the modification [3]. Industrial enterprises of Ukraine apply the modification of cast aluminium alloys sodium salts, which promotes differentiation eutectic Al-Si. However, low-melting salt of sodium ethnologica for processing of large masses of melts, because there is less time-modifier and environmental problems of application of modifiers.

To enhance the technological and mechanical properties of castings of aluminum-silicon alloys carry out the modification. Currently a promising direction is the use of dispersed refractory properties: carbides, nitrides, borides, pure metals size of 0,1…1 mkm [3]. When modifying foundry of aluminium alloys of AK12 and AK9c the dispersed particles of silicon carbide sizes up to 1 mkm was an increase of technological and mechanical properties of alloys and corrosion resistance.

Theoretical bases of the modification set out in the fundamental works of C. I. Danilov, V. E. of Neimark, M. C. Maltsev. Currently, there are a few theories as to certain parties of the process of modifying the aluminum alloys, but none of them describe it fully. This is due, firstly, the complexity of the process and its dependence on conditions of melting and casting, and, secondly, the influence of uncontrolled impurities and interaction introduced components that can both enhance, and to weaken the grinding of grain.

All substances with a lower electronegativity or effective ionized potential U_{ef}, than the metallic basis of this alloy, will have a modifying effect of crystallization, i.e. will reduce the size of the crystals.

All the substances having a greater value than U_{ef} metal base alloy crystallization will have gemodificeerde impact, i.e. will be the ability of the consolidation of a primary crystal structure. This is because the lower the value of the ionizing potential, the easier substance gives up its valence electrons, and vice versa.

The degree modifying influence of one or another element to estimate the sign of the difference between effective ionized potentials matrix modifier and $U_{Me} – U_{mod}$. If this difference is greater than zero, then the element can be a modifier. If the difference is less than zero, then this element will be remodification of the first kind.

Factor that characterizes the ability of a substance to influence the growth of crystals, should be considered as a factor of solubility of impurities in the matrix. The modifier must be located on the borders of crystals and clusters, but does not enter into its composition, i.e. the modifier must form clad clusters of atoms modifier located between clusters.

The modifier must not form their own clusters. The element having the properties of the modifier must have a low solubility in solid metal and limited in liquid. On the basis of coefficients of modifying the activity of the various elements, the most powerful modifiers of aluminium and its alloys are Ce, La, Sr, Ti, Sc.

In the influence of transition elements Hf, Ta, Ti, V, Nb, Zr, Mo on properties of aluminium alloys. It is established that the item is an effective modifier, if he's on the chart with aluminium has the largest value of interval solidification.

One of the directions of impacts on melts is the modification of the dispersed particles of transition metals. In disperse systems reflects peculiarities of the surface condition, because the share of surface atoms in such particles is predominant.

As shown in [5], the most effective modifier of aluminium alloys are powders of refractory compounds of titanium and silicon measuring less than 1 mkm.

With the purpose of improvement of quality and adaptability of multicomponent alloys of Al-Si system, improving the mechanical properties held modifying their melts finely dispersed powders on the basis of silicon the size up to 100 nm.

In industrial conditions have been tried dispersion properties: titanium, titanium nitride, SiC on alloys AL4 и AL4S, intended for the manufacture of castings of parts operating at high gidroliticheskogo.

The investigated alloys belong to the multi-component, which leads to the possibility of hardening of a solid solution of aluminium dissolved alloying elements, and also the allocation of supersaturated solid solution intermetallic phases, which creates a hardening effect during aging.

As the insertion of the composition of modifiers consist of refractory compounds, they are not dissolved in the molten aluminium, and are further solidification centers. The optimal number of input modifier defined experimentally in laboratory swimming trunks, ranged from 0.07 to 0.1 % by weight of the melt.

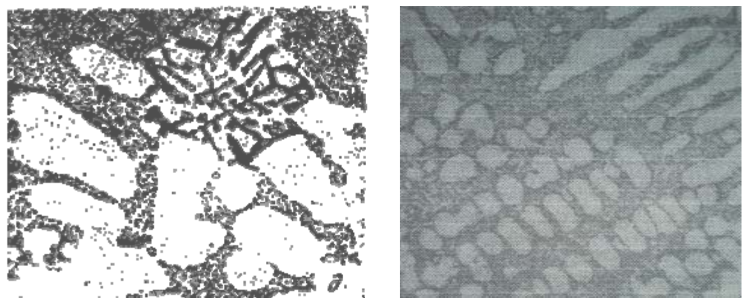
Research of a microstructure of casting alloys AL4S showed significant grinding grain patterns in a modified state. Overall, the grain size has decreased – 1.5 times from 140…150mkm from 78...90 mkm in a modified state. This effect is illustrated in table 1.

Table 1

The influence of dispersion of the additives (SiC) on macro- and microstructure of alloy AL4S

The number of additives in % mass.	Grain size, mkm		Porosity on the scale of DSTU 2839-94, score	
	To modific.	After Modific.		
0,03	140	98	3	0
0,07	140	78	2	0
0,1	150	90	2	1

The microstructure of alloy AL4S presents grains α-solid rastrowa, a small number of eutectic and various intermetallic phases. Set the fragmentation of these phases in the modified alloys and uniform their distribution. The dispersed phase SbAl, $MgZn_2$, AlFeSi, $CuAl_2$ allocated from the supersaturated solid solution in subsequent aging and strengthen the alloy.



a *b*

Fig. The microstructure of alloy Al4S before and after modification: a − before modifying × 400; b − after modification × 400

The experimental part. In a modified alloy almost no porosity. Because the solubility of hydrogen in liquid aluminium melt is higher than in the solid state. This is the main reason of gas porosity during solidification of a casting. To reduce primary porosity melts were subjected to refining hexachlorethane and advanced titanium chips. To eliminate secondary porosity by heat treatment of castings were treated with protection titanium chips. As a result, the porosity decreased from 3rd grade to the minimum acceptable score.

In this paper, developed the technological process of modifying aluminium alloys AL4(AK9c) and AK12 dispersed powder of silicon carbide. Dispersible powder SiC was selected on the basis of compliance of the crystal lattices of aluminium and SiC (g.c.c. lattice) and differences atomic radii of aluminium and SiC. The new powder SiC modification β obtained by the method of plasma-chemical synthesis. Average granulometrical composition of the modifier up to 100 nm. For facilities of infeeding in the melt method used tabletirovanija of poroshkovanija silicon [6]. The chemical composition of cast alloys are given in table 2.

Table 2

The chemical composition of cast aluminium alloys

Alloy	The content of elements, % mass.						
	Al	Si	Zn	Mg	Mn	Cu	Fe
AL4(AK9c)	baze	9−10,2	0,01	0,3	−	0,1	0,4
AL4S		9,2	0,5	0,25	0,35	1,0	0,8
AK8		7,5	0,3	0,45	−	0,3	1,0
AK7		7,0	0,4	0,35	−	1,5	3,2

It was determined that technological properties of castings of aluminium alloys: the fluidity and gas content. Fluidity is important property of the alloy, which characterizes the degree of mobility in the process of filling the forms. The higher the fluidity, the easier it is to get complicated shaped castings with a thin section. The fluidity of aluminium alloys before and after the modification is determined by the casting method samples in the form of bars. The modification of silicon carbide increases fluidity alloys AK8 and AL4(AK9c) for 5 %...11 % [8].

The gas content in the alloys were determined using technological samples. At downturn of temperature of liquid metal in the form decreases the solubility of gases and thus increases the amount of gas bubbles. Alloys AK8 and AL4(AK9c) Devechinskogo and eutectic compositions have high fluidity, and less likely to education in castings gas shells. In this work the gas content in the alloys before and after the modification was determined using the vacuum samples. Alloys AL4, ALS was smelted in electric resistance furnaces CAT−0,15A with a capacity of 150 kg. After melting and politowski ligatures, Al−Mg, Al−Si, Al−Mn alloys to overheat temperature 720−760 °C and subjected to modification. Fine modifiers were introduced to the bottom of the crucible mechanical agitation. Casting made in steel mold, while creating moderate vacuum to the solidification of alloys took place under reduced pressure.

The results of the evaluation of the samples (table 3) show that the modification of silicon carbide alloys AK8 и AL4(AK9c) provides low gas content, corresponding to 1 point porosity castings of aluminium alloys according to DSTU 2839-94.

Work carried out in the industrial conditions, showed an increase of technological and mechanical properties of modified casting aluminium alloys of marks AK8M и AK9cM, and shredding of macro- and microstructure of aluminium alloys.

Table 3

The results of determining the gas content

Alloy	The amount of gas bubbles until crystallization	Quantity of holes per 100 mm ^{2}	Fluidity, mm
AK8	10	4	358
AK8M	9	3	377
AK9	6	4	225
AK9чM	4	3	250

*M – modified

Conclusions: the use of powders of modifiers on the basis of titanium alloys ALS achieved grinding grain patterns in melted state in 1,5 times, the almost complete absence of porosity. In combination with termouprochnenuju processing modified alloy AL4S had the following level of strength properties: $\sigma_в$ = 260 MPa, which is 25 % higher than the unmodified alloy.

References

1. Fridljander I. N. Aljuminievye deformiruemye konstrukcionnye splavy / I. N. Fridljander. –M. : Metallurgija, 1979. − 365 p.
2. Mal'cev M. V. Modificirovanie struktury metallov i splavov / M. V. Mal'cev. − M. : Metallurgija, 1964. − 236 p.
3. Mal'cev M. V. Metallografija promyshlennyh cvetnyh metallov i splavov / M. V. Mal'cev. – M. : Metallurgija, 1970. − 312 p.
4. Yelagin V. I. Ligirovanie deformiruemyh aljuminievyh splavov perehodnymi metallami / V. I. Yelagin. – M. : Metallurgija, 1975. – 125 p.
5. Kalinina N. E. Modificirovanie vysokoprochnosnyh aljuminievyh splavov / N. E. Kalinina. – Dn-sk, Visnik DNU. – RKT. – № 4. – 2000. – Pp. 63–67.
6. Patent Ukrainy na korisnu model' № 71677. Tabletovanij kompleksnij modifikator dlja obrobki aljuminievih splaviv, bjuleten' №14 25.07.2012. Zajavka № U2011 15055, 19.12.2011
7. Patent № 2069702 Rossijskoj Federacii, MKI6 S21 S1/00. Modifikator dlja obrabotki chuguna / Shatov V. V., Kalinin V. T., Komljakov V. I., № 93030977; zajav. 01.03.93, opublik. 27.11.96. Bjul. № 33.
8. Vilishhuk Z. V. Vlijanie modificirovanija na fazovyj sostav vysokoprochnyh aljuminievyh splavov / Z. V. Vilishhuk, N. E. Kalinina // Starodubovskiye chteniya-2010 : Stroitel'stvo, materialovedeniye, mashinostroyeniye. − D. : PSABA, 2010. − Pp. 39–44.

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It was developed the technological process of modifying aluminium alloys AL4(AK9c) and AK12 dispersed powder of silicon carbide. It was determined technological properties of castings of aluminium alloys. Work carried out in the industrial conditions, showed an increase of technological and mechanical properties of modified casting aluminium alloys of marks AK8M и AK9cM, and shredding of macro- and microstructure of aluminium alloys.

Разработан технологический процесс модификации алюминиевых сплавов AL4(AK9c) и AK12, диспергированных карбидом кремния. Установлены технологические свойства отливок из алюминиевых сплавов. Разработки осуществлялись в промышленных условиях и показали увеличение технологических и механических свойств модифицированных литых алюминиевых сплавов марок АК8М и АК9сМ и измельчение макро- и микроструктуры алюминиевых сплавов. Разработана технология модификации алюминиевых сплавов AL4(AK9c) и AK12.

Розроблено технологічний процес модифікації алюмінієвих сплавів AL4(AK9c) та AK12, диспергованих карбідом кремнію. Встановлені технологічні властивості виливків з алюмінієвих сплавів. Розробки здійснювалися в промислових умовах та показали збільшення технологічних і механічних властивостей модифікованих литих алюмінієвих сплавів марок АК8М та К9сМ та подрібнення макро- й мікроструктури алюмінієвих сплавів. Розроблено технологію модифікації алюмінієвих сплавів AL4 (AK9c) та AK12.