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PROCESSING ALUMINUM ALLOYS BY DISPERSION MODIFIERS

Вивчення особливостей структури та властивостей алюмінієвих сплавів, оброблених дисперсними та нанодисперсними модифікаторами є актуальною проблемою матеріалознавства. В роботі проведено аналіз існуючих модифікаторів алюмінієвих сплавів системи Al-Si, Al-Mg. На основі класичної теорії модифікування обрано тип тугоплавкого модифікатора - порошок карбіду кремнію SiC розміром частинок до 100 нм. Розроблено технологію введення модифікатора в розплав. Проведено дослідні плавки алюмінієвих сплавів АЛ4, 1570, 2219.

Встановлено критерії вибору нанодисперсного модифікатора β SiC. Наведено термічні параметри модифікування. Отримано ефект подрібнення дендритних структури модифікованих сплавів. Досягнуто дрібнозернисту структуру виливків та деформованих модифікованих сплавів АЛ4, 2219. Підвищено технологічні і механічні властивості промислових алюмінієвих сплавів, знижена газонасиченість.

Ключові слова: *алюмінієві сплави, нанодисперсний модифікатор, деформовані сплави, механічні властивості, структура.*

The purpose of this work is studying of features of structure and properties of the foundry aluminum alloys processed by nanodisperse modifiers. The analysi of the existing modifiers of aluminum alloys of Al-Si system is carried out. On the basis of the classical theory of modifying the type of the refractory modifier – carbide silicon as SiC of particles in size 50…100 nanometers it was offered. The technology of input of the modifier in fusion is developed. It is carried out industrial experiences of melting of an aluminum alloy AL4, AL4S.

Criteria of a choice of the nanodispersive SiC modifier are established. Thermotemporary parameters of modifying are laid. The effect of crushing of dendrit's structure of the modified alloys is received. The uniform fine-grained structure o

f castings from the modified AL4 alloy is reached. Technological properties the industrial aluminum alloys are increased, mechanical properties is reduced.

Keywords*:* *aluminum alloys, nanodispersion modifier, casting, properties, structure.*

Formulation of the problem. Improving the quality and properties of products of responsible designation can not be solved without the development of new and improved existing processes for the production of alloys based on aluminum. For castings made of aluminum alloys that are part of turbopump units, fuel pumps make demands that combine tightness, low porosity, high complex of mechanical properties [1-3].

When obtaining cast aluminum alloys an important step is the process of melting and processing of melts. It is at these stages that the melting and refining operations are effectively used [2, 5, 6].

However, the lack of adaptation of castings to mechanical processing is hampered by the widespread use of aluminum alloys as structural materials. Low productivity is explained by the presence of fragile and difficult-soluble phases in alloys: FeAl3, Mg2Si, MgZn2, occurring in the form of large clusters and forming a continuous grid [1]. These fragile phases cause cracks in the casting of ingots and shaped castings. In addition, they contribute to the deceleration of the diffusion processes of dissolution of intermetallics in the homogenization of castings [3]. The big disadvantage is the high gas saturation of foundry alloys.

The development of modern technologies requires the creation of new materials and the improvement of existing alloys. One of the effective ways to improve the quality of casting, grinding grain and obtaining a homogeneous structure is modification [5].

Industrial enterprises apply the modification of foundry aluminum alloys with sodium salts, which contributes to the differentiation of the eutectic Al-Si. However, low-melting sodium salts are not environmentally friendly and are not applicable to the processing of large masses of melts.

A promising direction for modification is the use of disperse refractory modifiers: carbides, nitrides, borides, pure metals with a particle size of 0.1 ... 1 μm [9-11]. When modifying cast aluminum alloys with dispersed particles of silicon carbide up to 1 μm, an increase in technological and mechanical properties of alloys and corrosion resistance was noted [3, 7].

Theoretical foundations of modification are set forth in the fundamental works of MV Maltseva [2]. Currently, there are several theories of modification, they explain certain aspects of the process of modification of aluminum alloys, but do not characterize it completely. This is due to the complexity of the process and its dependence on the conditions of melting and casting, as well as the influence of uncontrolled impurities and the interaction of components that are introduced and which can both amplify and weaken the effect of modifiers.

All substances with less electronegativity and less effective ionization potential (Ume) than the metal base of the alloy will have a modifying effect on the crystallization process [7, 9, 11].

Materials that have a higher value Ume - the metal alloy base will have a negative impact. This is because the lower the value of the ionization potential, the easier the element gives its valence electrons to the matrix and vice versa. A factor characterizing the ability of a substance to influence the crystallization process should be considered as a solubility factor of impurities in the matrix. The modifier should be located on the edge of crystals and clusters, but not part of the matrix alloy.

The modifier should not create its own clusters. The element having the properties of the modifier must have low solubility in solid state and limited in liquid. On the basis of the coefficients of activity change of various elements, the most powerful modifiers of aluminum and its alloys are: Ge, La, Sr, Ti, Sc and their compounds. The influence of transition metals: Hf, Ta, Ti, V, Nb, Zr on the properties of aluminum alloys [4] was studied. Installed that an element is an effective modifier if it has the greatest value in the state diagram of the crystallization interval.

At present, a sufficient number of qualitative works devoted to the modification of refractory particles of refractory compounds have been published. In disperse systems, the features of the surface state are shown, since the particle of surface atoms in dispersed particles is predominant. In connection with the above, the subject of the submitted work is relevant for obtaining high-quality castings in mechanical engineering.

Results of the research and their discussion. In order to improve the quality of Al-Si aluminum alloy castings, experimental-industrial melting of alloys AL4 (AK9ch), AL4C, AL4D was conducted in this work. The chemical composition of the investigated aluminum alloys is shown in Table 1.

As shown in works [10-11, 13], the most effective modifier of aluminum alloys are powder refractory compositions based on SiC carbide size smaller than 1 μm.

Table 1

The chemical composition of foundry aluminum alloys

Alloys	Element content,% wt							
	Al	Si	Zn	Mg	Sb	Mn	Cu	Fe
АЛ4	basis	10,5	0,3	0,35	-	0,50	0,3	0,4
2219	basis				-			
АМг6	basis				-			

In industrial conditions pitons of titanium, nitride, titanium, silicon carbide were tested for the modification of alloys AL4 (AK9ch), 2219, AMg6. In order to improve the quality and manufacturability of multicomponent alloys of the Al-Si, Al-Mg system, the mechanical properties improved, the modification of melts by finely dispersed powders of silicon carbide of β-SiC modification up to 100 nm was performed.

The investigated alloys are multicomponent, which leads to the possibility of strengthening the solid solution of aluminum dissolved alloying elements, as well as the separation from the supersaturated solid intermetallic phase solution, which creates a strengthening effect with subsequent aging. The resulting modifier is a refractory silicon carbide that is not soluble in the melt, but serves as an additional crystallization center. The optimal amount of the introduced modifier is determined experimentally on laboratory smelter and varies from 0.07 to 0.1% of the mass of the melt.

Table 2 shows the effects of modifier quality on the grain size and porosity of the castings.

Table 2

Influence of disperse additives of β SiC modifier on grain structure of AL4 alloy

Number of additives in% of the mass of the melt	The grain size of the alloy, μm	
	Before modification	After modification
0,03	160	95
0,07	130	72
0,10	150	90

The alloy microstructure in the cast state is an α-solid solution, a small amount of eutectics, and different intermetallic phases: AlSb, MgZn2, AlFeSi, $CuAl_2$, which are isolated from the supersaturated solid solution with subsequent aging.

Since the solubility of hydrogen in the liquid melt of aluminum is higher than in solid state. This is the main reason for gas porosity when hardening castings. To reduce porosity, the refining of the melt with hexachloroethane was carried out. To eliminate the secondary porosity during thermal treatment, casting was protected by titanium chips.

In work the technological process of modification of aluminum alloys AL4, 2219 by nanodispersed silicon carbide powder is proposed. The β-SiC disperse powder was selected based on the correspondence between Al and SiC crystal lattices and a small difference between the atomic radii Al and SiC. Powder of β-SiC modification was obtained by the method of plasma-chemical synthesis. The average granulometric composition of the modifier was 100 nm. For the convenience of feeding into the melt used pill modifier.

The technological properties of the casting before and after the modification were determined. Liquidity was determined by the method of rod test. As a result of modification, the fluidity of alloys is increased by 5 ... 10%. The content of gases in alloys was determined by technological sampling. When the temperature of the liquid metal decreases, the solubility of the gas decreases in form, and thus the number of gas bubbles increases. Alloys АЛ4, 2219 доеетектического and eutectic composition have a good fluid flow, which reduces the likelihood of formation in the casting of gas shells.

The alloys were smelted in an electric stove, the resistance of the SAT - 0,15 capacity of 100 kg. After melting of the Al-Mg, Al-Mn alloys, the alloys were overheated to a temperature of 720 ... 760 ° C and subjected to modifications. The modifier was injected into the bottom of the crucible and mechanically stirred.

The results of the estimation of the gas content of the samples (Table 3) showed that the modification of the alloys provides a low gas content corresponding to 1 ball of porosity of castings of aluminum alloys according to DSTU 2839-94.

The works carried out in industrial conditions showed an increase in the mechanical properties of modified cast aluminum alloys AL4-M and AL4S to 270 MPa, which is 25% higher than the strength of the properties of unmodified alloys.

Table 3

Results of determination of gas content and fluid flow of alloys

Alloys are investigated	Porosity, ball	Liquid flow, mm
АЛ4	3	385
АЛ4-М	1	377
2219	1	225
АМг6	1	250

Conclusions

1. The choice of the type of the modifier of foundry aluminum alloys - powder composition of silicon carbide of modification β-SiC with average particle size up to 100 nm is substantiated. The industrial melting of alloys AL4, 2219, AMg6 with the use of a tableted modifier was carried out.

2. Technological properties of alloys are studied. In modified alloys, the porosity from the 3rd to the 1st ball and the increased liquid flow rate is reduced by 5 ... 10%.

3. As a result of modification, a uniform disperse structure of alloys was obtained and an increase in the strength of the properties was achieved by 20% compared to the unmodified state.

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