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CASTING ALLOYS OF THE Al-Si SYSTEM

It is known that with increasing fineness of the structural components of the alloys the mechanical properties of the obtained products are increased. It is noted that a sufficiently large parts, components engineering products, produced by the foundry, due to inherent in this method advantages compared with other technologies for the manufacturing of parts, the most significant of which is the relative simplicity of the technology, however, allows to obtain a complex configuration details, which are almost impossible to produce by other methods, while ensuring the required technical documentation characteristics. These details, in particular, are cast parts, which are parts of the components, mechanisms and machinery transport machinery. However, in the industry widespread aluminum die casting alloys has received. In the manufacture of cast parts one of the main ways of improving quality is a modification, the essence of which consists in the introduction into the molten metal substances, which serve either as crystallization centers, or block the growth of emerging crystalline formations. To date, the "chopping" the possibilities of applying the means of modification, has reached its limit. And in recent years for this purpose there are more effective modifiers in the form of nanopowders of refractory high-strength chemical compounds (nitrides, carbides, oxides, borides, and others), the application of which leads to a significant enhancement of the mechanical properties of molded products. The paper presents examples of the application of nanopowders in the manufacture of aluminum alloys castings vehicles, as well as their use during welding, a process which is almost identical with the casting [12, p.63; 13].

Aluminium alloys with silicon as the major alloying element form a class of material providing the most significant part of all casting manufactured materials. Al-Si alloys are widely used in different fields of industry. Mechanical properties of casting alloys of the Al-Si system are presented in the Table 1.

Table 1

Mechanical properties of the Al-Si system casting alloys

Alloy	**Ultimate tensile strength (UTS), MPa**	**Specific strength (UTS/ ρ), m^2/s^2**	**Density (ρ),kg/m^3**
AlSi12	150–160	1,0–4,0	50,0
AlSi13	180	1,5	60,0
AlSi9Mg	160–250	0,5–1,5	60,0–90,0
AlSi10Mg	150–240	1,5–3,0	50,0–70,0
AlSi8MgBe	180–340	1,0–6,0	70,0–90,0
AlSi7Mg	140–300	1,0–5,0	45,0–70,0
A-S5U3G	120–210	0,5–2,0	65,0–75,0

These alloys have a wide range of applications in the automotive and aerospace industries due to an excellent combination of castability and mechanical properties, as well as good corrosion resistance and wear resistivity. Various additives are usually used to modify industrial alloys [11].

In the production of cast parts, particular importance is given to such a type of melt processing as modification [1; 6; 7], the essence of which is the introduction into the liquid metal of small quantities of substances that serve as centers of crystallization or block the growth of the emerging crystalline formations. In a number of cases, as a result, both processes take place in the following sequence: nucleation of crystallization centers → blockage of crystal growth. A significant amount of substances and methods of performing this process is used, but the essence of all of them is the introduction into the liquid metal of particles serving the first mechanism – either independent crystallization centers ("direct" heterogeneous nucleation) or forming them as a result of interaction with the melt, and the second mechanism – blocking the growth of crystalline formations arising in the solidifying melt. As a result of the modification, either macromolecular or structural components at the micro level are crushed (or a combination of both processes), including a change in the geometry of the intermetallic phase separations from the needle-shaped phase, causing stress concentration and crack development to become globular or close to it, which prevents the risk of cracks. The result of modification of metal compositions is the improvement of technological properties at the stage of production of cast products, as well as an increase in the strength and plastic characteristics of finished products.

The "grinding" possibilities of the modifying agents used, which are reduced to the introduction of modifiers in the form of ligatures into the liquid metal (an intermediate alloy consisting of a base component identical to the main component of the alloy to be modified + a modifying additive) have reached their limit.

And in recent years more effective modifiers have been used for this purpose in the form of nanopowders (NP) of refractory high-strength chemical compounds (nitrides, carbides, oxides, borides, etc.) [3; 5; 9]. Nanopowders are crystalline or amorphous formations with particle sizes not exceeding 100 nm (1 nm = 10-9 m), which have unique physic, chemical and mechanical properties that differ significantly from the properties of materials of the same chemical composition in the bulk state, and these properties can be transferred to a certain extent by products obtained from the number of atoms in their surface layer and in the volume is commensurable [2; 8].

As atoms on the surface of nanoparticles have neighbors only on one side, their equilibrium is violated and structural relaxation occurs, which leads to a displacement of the interatomic distance in a layer 2-3 nm in thickness.

Therefore, the surface layers of the nanoparticles are stretched and the inner layers are compressed, since the excess Laplace pressure [10] on them ($P = 2\gamma/r$, where γ is the surface tension, r is the radius of the nanoparticle) reaches hundreds of kilobars, which leads to substantial distortion of the crystalline lattice and, as a result, to the fact that this affects the activation energy of most processes in which they participate, changing their usual course and sequence [8], which affects the characteristics of products manufactured with their use.

The application of nanopowders (NP) for the modification of the studied industrial alloys during casting into chill molds showed that all their types lead to an increase in mechanical properties. Thus, as a result of introducing into the liquid alloy AlSi12 after modification with a triple modifier:

a) NP vanadium carbide VC increases σ_v in comparison with the modification with the standard triple modifier (25% NaF + 62.5% NaCl + 12.5% KCl) to 228 MPa (in 3.2%), δ – up to 12.9% (in 4.4 times);

b) a mixture of NP 25% BN + 75% B_4C increases σ_v to 231 MPa (in 4.5%), δ – up to 13.5% (in 4.7 times).

Modification of the alloy AlSi9Mg with the NP of titanium carbonitride TiCN gives σ_v = 246 MPa, δ = 11.0%, and the NP of boron carbide B_4C – σ_v = 235 MPa, δ = 12.8% (according to GOST (State Standardization System) it is required $\sigma_v \geq$ 235 MPa, $\delta \geq$ 3.0%).

The introduction of AlSi7Mg alloy after the triple modifier:

a) NP vanadium carbide VC gives σ_v = 234 MPa, δ = 14.5%;

b) the NP of boron carbide B_4C is 194 MPa and 9.8%;

c) a mixture of 25% NP VC and 75% B_4C – 280 MPa and 13.8% (according to GOST – $\sigma_v \geq$ 210 MPa, $\delta \geq$ 2.0%).

On the alloy AlSi 11 when modifying with a triple modifier, σ_v = 227 MPa, δ = 2.9%, and the additional introduction NP of TiCN improves these characteristics accordingly to 284 MPa (in 2.5%) and to 4.1% (in 1.4 times) at the required GOST $\sigma_v \geq$ 210 MPa and $\delta \geq$ 1,0%.

During the modifying of AlSi7Mg alloy with the triple modifier σ_v = 205 MPa, δ = 3,6%, and as a result of the additional injection, the NP of VCN σ_v increases to 217 MPa (in 5.6%), and δ – up to 6.8% (in 1.9 times), NP spenzircon (mixture of oxides ZrO_2, Nb_2O_5, TiO_2) – up to 246 MPa (in 19.3%) and up to 5.8% (in 1.6 times). When the modification of the AlSi7Mg alloy is carried by potassium fluorozirconate K_2ZrF_6, σ_v is 246 MPa, δ – 17.1%, and the additional introduction of:

a) Al-Ti and NP of TiCN increases these characteristics to 256 MPa (in 4.1%) and up to 25.3% (in 1.5 times);

b) NP of B_4C – up to 264 MPa (in 7.3%) and up to 22.5% (in 1.3 times). According to GOST it is required $\sigma_v \geq$ 160 MPa and $\delta \geq$ 0,5% [4].

Thus, the use of nanopowder technologies in the production of parts using metallurgical technologies is shown their high efficiency as a grinding agent for the structure of products, which provides an increase in the level of mechanical properties of cast and welded products from aluminum alloys.

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