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INFLUENCE OF HETEROGENEOUS CRYSTALLIZATION CONDITIONS OF ALUMINUM ALLOY ON ITS PLASTIC PROPERTIES

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ВПЛИВ УМОВ ГЕТЕРОГЕННОЇ КРИСТАЛІЗАЦІЇ АЛЮМІНІЄВОГО СПЛАВУ НА ЙОГО ПЛАСТИЧНІ ВЛАСТИВОСТІ

Purpose. Determination of the influence of gas-dynamic treatment and inoculation of the metal with TiCN ultradisperse powders on its mechanical properties and formation of porosity in shaped casting of SC51A (AK5M) alloy solidified in the chill mold during implementation of the corresponding complex technology.

Methodology. Experimental thermographic studies using HA thermocouples were held. The temperature field of the casting was plotted. For the hardware determination of the components in the alloy under study, we employed the photoelectric spectral method of elements mass fraction measurement, a method of indirect measurements. The standard procedure of Brinell hardness test was applied to the samples of the cast metal. The mechanical properties, namely tensile strength at room temperature $\sigma_в$ (MPa) and elongation δ (%) were determined according to the State Standard (GOST 1497-84) by means of the Tensile Strength Test Machine FM1000 with the samples of 10 mm diameter cut from the body of casting. To simulate the SC51A (AK5M) aluminum alloy shaped casting solidification process we employed the Polygon system of computer modeling of casting processes (SCM CP).

Findings. The effect of implementation of the combined technology of aluminum alloy refinement with TiCN ultrafine modifier and gas-dynamic treatment on the mechanical properties of shaped casting metal solidified in the chill has been determined.

Originality. For the first time, we suggest the possibility and define conditions of the combined action of ultrafine modifier inoculation and gas-dynamic treatment on the solidifying SC51A (AK5M) alloy.

Practical value. Technological modes of the combined action on the melt during crystallization in the “supporting tip of conveyor bar” chill mold that weighted 1.1 kg made of SC51A (AK5M) alloy have been developed.

Keywords: *casting, hardening, gas-dynamic effect, modification, technology, mechanical properties*

Introduction. The highest quality metal and stable properties over the cross section castings are produced in the presence of a homogeneous and fine grain structure as well as the absence of macroscopic defects, such as porosity and the shell. Therefore, the task of interested specialists is invariably the improvement of existing and development of new effective casting processes. In this case, many methods of influence on crystallizing metal of both the physical and chemical or physico-chemical processes become available now. To improve the efficiency of the casting process it is very important to create new techniques and effects on the liquid metal crystallizes.

Modern technologies of formation of castings have an extremely labor-intensive, long-lasting, causing significant loss of metal on redistribution and do not always provide sufficiently high quality castings. The development of new directions in the theory of foundry processes and creation on their basis of effective technologies shaping is closely related, primarily, to the intensification of heat and mass transfer processes in hardening alloys.

Analysis of previous publications. Currently, the caster arsenal has a number of ways and solutions available, they can actively influence the process of structure formation, including by external physical impact or modification [1–7]. At the same time, these processes have their advantages and disadvantages.

One effective way to change the morphology of crystallizing phases is hardening under highly nonequilibrium conditions [2–4, 6]. Thus, a crystal structure refinement, increased solid solubility and increasing the density of the metal occur. In flow sheets casting alloys with crystallization under pressure the nature of crystallization changes significantly. By increasing the cooling rate of crystallization rate, which changes as a result of the pressure effect on the number of points increases the nucleation and growth rate increases. Currently, in many papers the way of obtaining of high-quality castings in crystallization under pressure created by the piston, punch, or a comprehensive gas pressure, is considered in details [1, 7].

As for all these methods the efficiency effects during solidification time is inversely proportional to the thickness of the solidified layer of metal, as external pressure in one form or another is applied to its surface. From the technological point of view, this process has limitations on weight, type of alloy castings configuration and requires special equipment and additional qualified personnel. Also, one of the ways of influence on the solidifying metal is gas-dynamic effect [5, 6].

Dynamics of changes in system pressure casting device for introducing gas is determined by the dynamics of change in the strength properties of the hardened layer of metal, which increases from the surface of the casting, under the conditions of implementation of the technology of gas-dynamic effects [7].

The value close to the value of tensile strength (σ_B) of the solidified layer with the temperature [7] and based on the tensile stresses generated in the solid cake, which depends on the configuration and size of the casting, can be considered as the maximum possible level of gas pressure (MPa) at the definite time. The tension in the rising crust during the hardening process is maintained at the highest level, which is prior to fracture. This embodiment of the technology is applicable in the metal mold; it allows to achieve the maximum result in terms of quality of the cast metal (mainly mechanical properties), however, leads to deformation of the casting due to the presence of the alloy elongation.

The material deformation resistance (σ) in the operating temperature range is used for gas injection molding under the conditions of dimensional stability of the casting which solidified in the chill or sand in a single form, as a parameter necessary for calculating the pressure rise of the dynamics in the casting device.

The traditional methods of inoculation belong to the methods of influence on the crystallization process, which are the most widespread in the practice of foundry industry. In recent decades, the fine particles of chemical compounds (nanopowders) are more and more used as modifiers of casting alloys; they act as additional nucleation during primary crystallization. Therefore, the researches aimed at identifying opportunities for joint application of modification and alloy solidification under nonequilibrium conditions, provided by the gas-dynamic effects, are considered as the urgent problem.

The aim is to determine the impact of the gas-dynamic effect and modification of soot TiCN on the mechanical properties of the metal and the formation of porosity in castings shaped alloy SC51A (AK5M) solidified in the chill in the implementation of the corresponding complex technology.

The main material. The technology of gas-dynamic effect on the melt in the production of castings parts “supporting tip of conveyor bar” is introduced in the JSC “Horizon” (Dnepropetrovsk) foundry. Castings of this range are made of alloy SC51A; domestic analogue, alloy AK5M, by means of chill casting. The distinguishing feature of this technology is the inclusion of the following steps: carrying out refining (Preparation DEGASAL T 200) and the input TiCN modifier in the melt, the introduction of a working mold cavity means for supplying gas of the original design, with the exposure apparatus of casting within a predetermined period of time, gas (argon) pressure buildup and subsequent holding pressure until solidification, into the manufacturing process of casting .

Casting of “supporting tip of conveyor bar” weighing 1.1 kg was poured into a preheated and painted metal iron mold with a minimum wall thickness of 40 mm. Pouring temperature is 640 ^{0}C. The chemical composition of alloys is tabulated in the table 1.

Table 1

Chemical composition of alloy SC51A (AK5M)

The content of elements, %							
Mn	Si	Fe	Al	Mg	Cu	Ti	Zn
0,5	5,5	0,6	bal.	0,6	1,45	0,15	0,3

Chemical composition of the alloys listed in the results of modeling of solidification shaped casting aluminum alloy SC51A (AK5M) (fig. 1) in the computer simulation of casting processes (SCM LP) “Range” (Simulation computer system of foundry processes (SCS FP “POLIGON”)) were the basis of the operating conditions of gas-dynamic effect in various embodiments of the technology. The simulation results in the form of thermal calculation (fig.1, *a*) were compared with those obtained by conventional thermoelectric, and presented in the form of contouring according to the well-known graphical method (fig.1, *b*). Further, on the basis of the data obtained, the kinetics of solidification mode was determined to calculate the gas-dynamic effect.

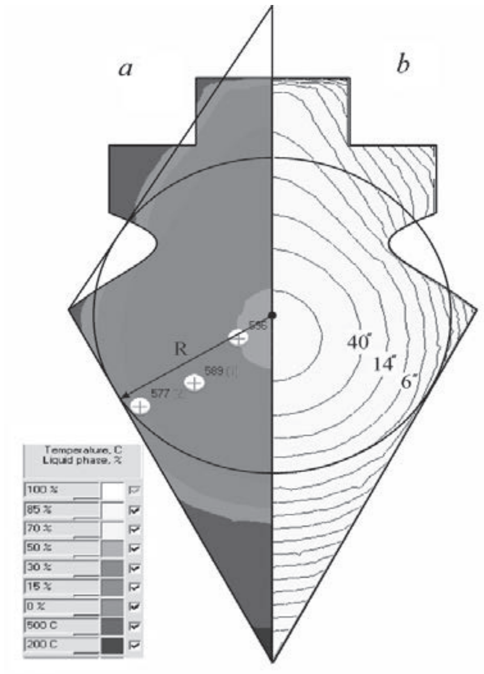

Fig.1. The results of calculations by the finite element method (SCS FP “POLIGON”): a – the temperature distribution on the 5th second; b – kinetics of solidification

The calculation of the values of tensile stresses in the layer of solidified metal casting under the influence of hydrostatic pressure was conducted in accordance with the kinetics of solidification by the method described in [7] in order to take into consideration the tensile stresses in the layer of solidified metal casting under the influence of hydrostatic pressure. Then the dynamics of changes in the maximum possible system pressure of casting device for gas injection were calculated based on the values of tensile strength casting material (σ_B) with an average temperature of the resulting solidified layer [7]. When calculating the average temperature of the solidified layer of metal casting, as much the solidus temperature was considered and as lower, the surface temperature of the casting.

Size and dynamics of changes in the operating pressure, in this embodiment of a gas-dynamic technology influence, was calculated as the difference between the values of tensile strength and tensile stress in the hardened metal layer.

To implement the technology option providing for minimum deformation of the metal casting, the hardening under controlled gas pressure, the calculation of the dynamics of its increase was carried out based on the values of resistance to deformation of the metal (σ) with an average temperature of the resulting solidified layer. Further, the size and dynamics of changes in the operating pressure values were calculated as the difference of deformation resistance and tensile stress in the hardened layer of the metal, resulting from hydrostatic pressure.

The fig. 2 shows the results of calculating of the value of stress in the solidifying metal layer resulting from the hydrostatic pressure as well as the tolerance range during the gas-dynamic pressure effect on the melt in the mold in different embodiments, the technology. The curve *1* in fig. 2 is the dynamics of change of values for the alloys (the dynamics of change of the maximum working pressure), the curve *2* is the dynamics of change for the alloys (the dynamics of change working pressure), shading is the range of allowable values for pressure.

The technological process of gas-dynamic effect on the melt in the metal chill mold was conducted with the initial parameters of pressure of 0.15–0.2 MPa and subsequent build-up of 2–3.5 MPa in accordance with the calculated dynamic pressure buildup in the casting device for gas injection.

Table 2 shows the results of tests to determine the mechanical properties of metal casting "supporting tip of conveyor bar", obtained using the technology of gas-dynamic effects (DTG), modifying TiCN (M), and the combined technology of gas-dynamic effects and modification (DTG +M) in comparison with the corresponding properties of cast metal produced by the conventional technology in die casting.

The porosity of castings was evaluated on a 5-point-scale developed by VIAM. The results showed that exposure to complex castings were mainly 3 point porosity, and after, 1 point porosity.

As a result of this technology implementation, the number of reject castings according to microporosity and blowholes decreased by 28%. The corresponding instruction was developed and applied in this process.

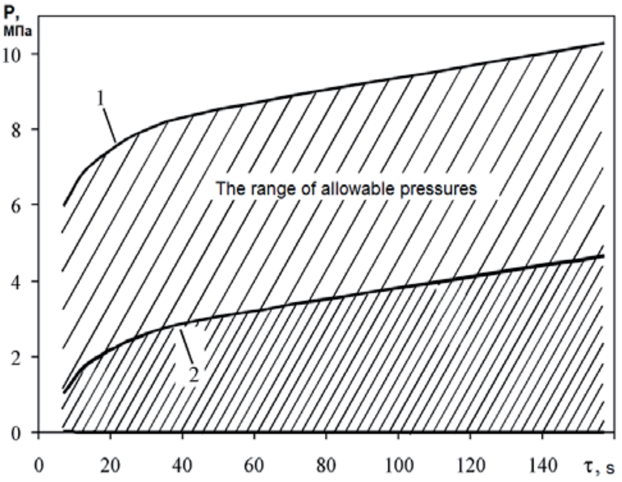

Fig. 2. The results of the calculation of the tolerance range of pressure during solidification chill shaped casting alloy SC51A (AK5M)

Table 2

Mechanical Properties of the Metal of Casting "Supporting Tip of Conveyor Bar"

Sample number		Temporary tear resistance ($\sigma_{в}$), MPa			Brinell hardness (HB)			Relative elongation (δ), %		
1	before treatment	162,2			70			1,0		
2		161,8			68			0,9		
3		162,1			68			0,9		
		DTG	M	DTG +M	DTG	M	DTG+M	DTG	M	DTG+M
4	after treatment	181,3			72			1,25		
5		180,9			71			1,24		
6		181,5			72			1,25		
7			185,2			73			1,27	
8			184,8			72			1,26	
9			185,3			73			1,27	
10				191,4			74			1,29
11				190,9			73			1,28
12				191,3			74			1,29

Conclusions.

1. In the conditions of industrial process the embodiments of production of the casting “supporting tip of conveyor bar” (weighing 1.1 kg alloy AK5M) were tested using inoculation soot TiCN, gas dynamic effect on the melt in the mold, as well as the complex technology and consisting of both processes.

2. The growth dynamics of the gas pressure in the casting device for gas injection technology for the realization of a gas-dynamic effects was calculated. It is established that the specified pressure range is 0.1–4 MPa.

3. The mechanical properties of metal casting “supporting tip of conveyor bar”, produced using the technology of gas-dynamic effects, modifying TiCN, as well as the combined technology of gas-dynamic effects and modification in comparison with the corresponding properties of cast metal produced by traditional technology chill casting have been defined. It was stated that tensile strength increases by 11–15%; hardness (HB), 4–8%; elongation, 27–30%.

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Мета. Визначення впливу газодинамічної дії та модифікування ультрадисперсним порошком TiCN на механічні властивості металу й утворення шпаристості у фасонних виливках зі сплаву SC51A (АК5М), що твердіють у кокілі за реалізації відповідної комплексної технології.

Методика. Проведені експериментальні термографічні дослідження з використанням ХА термопар, здійснена побудова температурного поля виливка. Для апаратного визначення вмісту компонентів у литому сплаві, що досліджується, використовували фотоелектричний спектральний метод вимірювання масової частки елементів – метод непрямих вимірів. Вимірювання твердості зразків литого металу проводили за допомогою методу Брінелля за стандартною методикою. Механічні властивості: тимчасовий опір розриву при кімнатній температурі σ в (МПа) і відносне подовження δ (%) визначали за ГОСТ 1497-84. Випробування проводили на розривній машині ФМ 1000 на зразках діаметром 10 мм, що були вирізані з тіла виливка. Для моделювання процесу затвердіння фасонного виливка з алюмінієвого сплаву SC51A (АК5М) застосовували систему комп'ютерного моделювання ливарних процесів (СКМ ЛП) „Полігон“.

Результати. Визначена ступінь впливу реалізації комбінованої технології модифікування ультрадисперсним модифікатором TiCN і газодинамічної дії на механічні властивості алюмінієвого сплаву фасонного виливка, що твердіє в кокілі.

Наукова новизна. Уперше визначена можливість і умови реалізації комбінованого впливу на сплав SC51A (АК5М), що твердіє, яка полягає в застосуванні модифікування ультрадисперсним модифікатором та газодинамічної дії.

Практична значимість. Розроблені технологічні режими здійснення комбінованого впливу на розплав у процесі кристалізації в кокілі виливка „опорний наконечник стійки конвеєра“ масою 1,1 кг зі сплаву SC51A (АК5М).

Ключові слова: *виливок, затвердіння, газодинамічний вплив, модифікування, технологія, механічні властивості*

Цель. Определение влияния газодинамического воздействия и модифицирования ультрадисперсным порошком TiCN на механические свойства металла и образование пористости в фасонных отливках из сплава SC51A (АК5М), затвердевающих в кокиле при реализации соответствующей комплексной технологии.

Методика. Проведены экспериментальные термографические исследования с использованием ХА термопар, осуществлено построение температурного поля отливки. Для аппаратного определения содержания компонентов в исследуемом литом сплаве использовали фотоэлектрический спектральный метод измерения массовой доли элементов – метод косвенных измерений. Измерение твердости образцов литого металла определяли с помощью метода Бринелля по стандартной методике. Механические свойства: временное сопротивление разрыву при комнатной температуре σ в (МПа) и относительное удлинение δ (%) определяли по ГОСТ 1497-84. Испытания проводили на разрывной машине ФМ 1000 на образцах диаметром 10 мм, вырезанных из тела отливка. Для моделирования процесса затвердевания фасонной отливки из алюминиевого сплава SC51A (АК5М) применяли систему компьютерного моделирования литейных процессов (СКМ ЛП) „Полигон“.

Результаты. Определена степень влияния реализации комбинированной технологии модифицирования ультрадисперсным модификатором TiCN и газодинамического воздействия на механические свойства алюминиевого сплава фасонной отливки, затвердевающей в кокиле.

Научная новизна. Впервые определена возможность и условия реализации комбинированного воздействия на затвердевающий сплав SC51A (АК5М), заключающаяся в применении модифицирования ультрадисперсным модификатором и газодинамического воздействия.

Практическая значимость. Разработаны технологические режимы осуществления комбинированного воздействия на расплав в процессе кристаллизации в кокиле отливки „опорный наконечник стойки конвейера“ массой 1,1 кг из сплава SC51A (АК5М).

Ключевые слова: *отливка, затвердевание, газодинамическое воздействие, модифицирование, технология, механические свойства*

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