METABK 53(4) 597-600 (2014)
UDC – UDK 621.74.04:669.7.018=111

LONG - RANGE FOUNDRY Al COMPOSITE ALLOYS

Received – Primljeno: 2014-02-06
Accepted – Prihvaćeno: 2014-05-30
Preliminary Note – Prethodno priopćenje

The technology of obtaining nanostructural composite aluminum alloys consists in the plasma injection of refractory nanometric particles with simultaneous two-plane magnetic dynamic mixing of the melt. Particularly important in obtaining composite aluminum matrix alloys is the provision of the introduced particles wettability with the matrix melt for forming stable adhesive bonds. Nanostructured powder components can be considered not only to be a starting product for producing nanostructural composite aluminum alloys but as an independent commerce product. Nanostructural composite metal matrix alloys make one of the most prospective structural materials of the future, and liquid-phase technologies of their obtaining are the most competitive in producing products of nanostructural composite aluminum alloys in the industrial scale.

Key words: foundry, aluminium, alloying, composite

INTRODUCTION

The most universal constructional materials on technological capabilities and fields of application are the dispersion-reinforced composites. The metalmatrix composite alloys a basis of which are foundry or deformable alloys are referred to this type of composites, and reinforcing elements are artificially input (ex-situ – processes) or initiated as a result of proceeding reactions (in-situ-processes, "reactionary molding"). Thus, as a rule, as reinforcing agents of micrometric sizes there are used hard-melting high-strength, high-modular particles of oxides, carbides, borides, nitrides (most frequent SiC, Al_2O_3, B_4C, TiC). The chemical reactions of in-situ which are realized in fusion at injection of chemically active metals, gases or chemical compounds form thermodynamically steady reinforcing phases moistened by fusion due to emergence of coherent borders and heat-resistant at increased temperatures of operation.

Essentially important at receiving of composite aluminium matrix alloys is ensuring of wetting quality of the entered particles with matrix fusion for formation of stable adhesive relations

There is actively carried out developments in the field of synthesizing of composite aluminum matrix alloys (CAA). Their properties are defined by the properties of the matrix material, the properties and sizes of the reinforcing introduced or initiated in the melt particles and the activity of the matrix and the reinforcing particle.

A. D. Mekhtiev, D.K. Issin, Zh. D. Zholdubayeva, Karaganda State Technical University, Karaganda, Kazakhstan
A. G. Kosnikov, St. Petersburg State Polytechnic University, St. Petersburg, Russia
B. D. Issin, Tomskij Politehnicheskij University, Tomsk, Russia

There are mainly used three technological schemes of producing composite aluminum matrix alloys:

- introducing of particles in the melt with intense mixing using an impeller;
- powder technology;
- impregnating disperse particle with the matrix melt.

In liquid-phase technology of obtaining composite aluminum matrix alloys provide introduction in the melt a significant amount (up to 20 %) of micrometric refractory particles. Mixing of refractory particles in the melt is performed in special devices of impeller type; provision of the particle wetting quality and their uniform distribution in the melt is defined by the mixer design and the processing modes, the conditions and method of feeding the particles into the mixer.

Under the mixer's optimal working mode in the melt there is provided emergence of shift strains, particularly, in the conditions of the melt mixing in the solid-liquid state, there is prevented agglomeration of the particles, increased their wettability and uniformity of their distribution in the melt. The following melt staying in the mixer at rather slow mixing permits to transport it in the molds at various methods of molding.

Depending on composition of the matrix allot and amount of the introduced particles there are obtained alloys with different complexes of mechanical and operational properties used for products with various purpose.

At mechanical mixing the powders of reinforcing particles can be introduced not only in the starting state, but also in the form of tablets, briquettes, powder wire, and extended compressed composites.

The method of composite casting includes mixing the reinforcing particles in the wide-range matrix melt (short fibers, thread-like crystals, particles) with the simultaneous gradual reducing of the temperature and the following casting of the obtained suspension in a mold, after cooling of which there is obtained a needed product. The main advantage of the method is possibility to introduce the unwettable particles that are mechanically caught by the fusion. The subsidence, flotation and conglomeration of the particles are eliminated by that the matrix fusion is in the liquid-solid state. A serious defect of the materials obtained by the method of composite casting is their increased porosity, caused by the gases catching when mixing and by difficulty of their emission due to high viscosity of the liquid-metallic suspension. Besides, a part of gases is introduced by the reinforcing particles themselves.

It is theoretically substantiated and experimentally proved increase of composites' properties at reduction of dispersion of reinforcing phases to nanometric level [1, 2]. Therefore the special attention is paid to development and deployment of the nanostructural materials possessing unique properties and opening prospects of development of technical progress boggling the imagination in various areas of human activity. In spite of a lot of works of foreign researchers in which there are made attempts to substantiate theoretically the processes taking place in nanotsructural composite aluminum alloys, there are certain attempts to explain the phenomena taking place in these alloys in the process of forming their structure and properties.

Obtaining a nanocomposite material is a complicated technological task. Thermal activation of the introduces particles at their preparation for introducing in the melt, and the processes taking place in a liquid composite at its staying, pouring in the mold and solidification of a ready product lead to the intensification of diffusion and recrystallization processes and to a partial or complete annihilation of their nanodisperse structure and, consequently, to disappearing of the unbalanced phases, relaxation of residual stresses and changing of their unique properties.

The problem of developing nanostructural metal matrix composite alloys is taken up by a lot of researchers at the world largest scientific centers and at a number of the Russian research and academic institutions [3 - 6].

When analyzing the published works we can note that only some of them are devoted to the development of casting composites, i.e. alloys possessing the level of casting properties permitting to obtain shaped castings of them. In these works the main requirement to such alloys and products is a certain level of tribotechnical properties. The products obtained have a simple shape and a small mass. There is no data on mechanical properties in the conditions peculiar for application of structural materials. The role of the introduced nanodimensional refractory particles is considered mainly from the point of view of their modifying effect on the formation of matrix structure and size of the formed intermetallic compounds.

The main method of preparation of disperse particles is mechanical alloying, and the main method of introducing in the melt is mechanical mixing of pressed tablets or briquettes.

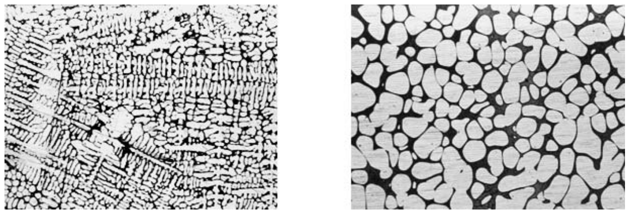

Figure 1 Structure of alloy A357 structure in the initial state (a) and after magnetodynamic mixing (b), x50

Increase of sedimentological stability of the metal suspensions consisting of matrix fusion and of entered nanodimensional particles, it is increased at viscosity increase of suspension, therefore for receiving products from foundry nanocomposites usage of processes of magnetohydrodynamical mixing of fusion in liquid and biphase states and liquid-and-solid molding (thixocasting) is perspective. At preparation of alloys for thixocasting in the wide-interval alloys (in hypoeutectic silumins of A357 type) (Figure 1) there is formed a structure of degenerate (spheroidized) dendritic crystals of the firm solution providing increase in properties of the alloy, and there are created conditions for their use at receiving the shaped products by a method of liquid-and-solid molding (thixocasting) [7, 8].

METHODOLOGY FOR CONDUCTING EXPERIMENTS

There were conducted the researches for influence assessment of quantity of nano-dimensional refractory particles and methods of their introduction in fusion on structure and properties of nanostructural composite aluminum alloys. The main objective of research was development of technology for producing the alloys, consisting in plasma injection of the nanostructured powder composite materials (NPCM) with simultaneous two-plane magnetodynamic (MGD) hashing of fusion [9 - 11]. NPCM consisted of microdimensional particles of metal powder carrier (Cu, Ni, Ti) with the ceramic nanoparticles distributed in them (SiC, Al_2O_3)

At *mechanical alloying* there takes place a number of structural processes as a result of which in the powder mix there are formed the composite material granules. Each granule acquires a structure consisting of the matrix and uniformly distributed ultra-disperse (nanodimensional) reinforcing particles. The matrix is characterized by a high density of crystal lattice defects caused by significant shift strains occurring at the place of contact of the powder and grinding bodies.

The preparation process of nanostructured powder composite materials by the *thermochemical method* (Cu + 4,5 % Al_2O_3) consists in the following [12]:

- preparation of water solutions of nitrates (Cu $(NO_3)_2$ $3H_2O$) and (Al $(NO_3)_3$ $9H_2O$;
- preparation of starting powders by spray drying;
- thermal treatment of powders in the air medium for elimination of water and volatiles, formation of aluminum and copper oxides;

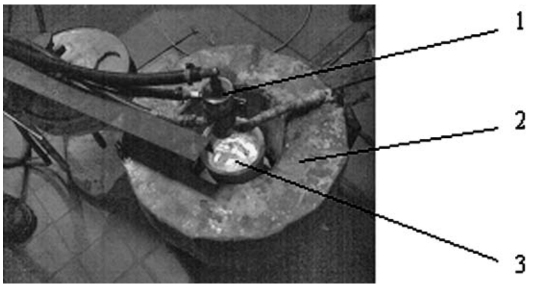

Figure 2 Installation of plasma synthesis: 1 – plasmatron; 2 – electromagnetic stirring; 3 – crucible with fusion

- copper oxide reduction to pure copper in the hydrogen atmosphere.

This technology provides uniform distribution of nanodimensional refractory particles in a micrometric basis directly in the course of synthesis of the nanostructured powder composite materials.

The created laboratory complex (Figure 2) consisted of a resistance furnace and installation of plasma synthesis.

The starting alloy A357 (mass. %) composition: 7,5 Si, 0,35 Fe, 0,45 Mg, 0,02 Mn, 0,06 Ni, 0,03 Cu, 0,08 Zn, Al res. The starting alloy A357 properties in the cast state: R_m = 155 MPa, A = 3,5 %.

In the first series of experiments the alloy A357 (2 kg) was heated in a resistance furnace up to 800 ^oC and there was mixed and removed the heated universal flux was, the crucible was brought to the electromagnetic stirring, in the process of mixing using a plasma facility there was introduced 5 % nanostructured powder composite material (62,5 % Cu + 28,1 % Ni + 3,1 % SiC). The introducing durability (work of plasmatron and mixer) was 50…60 s, the metal temperature in the process of the material introducing was reduced to 720…750 ^oC, after which in the chill mold there were poured samples with of diameter of 12 mm and 100 mm of length. The design assimilation of the material was 94%, before heat treatment at normal temperature R_m = 280 MPa, A = 3,5 %. After T6 at normal temperature R_m = 390 MPa, A = 7,5 %, at 350 ^oC - R_m = 160 MPa, A = 11 %.

RESULTS

Metallographic studies of the produced alloy A357 (SiC) confirmed the presence of nanodimensional inclusions SiC, invariability of the phase composition and dimension of these inclusions in the process of synthesizing nanostructural composite aluminum alloys (Figure 3).

In the second series of experiments the conditions were identical to the first one, however, in the melt using a plasma facility there was introduced 5% nanostructures powder composite material containing 95,5 % Cu + 4,5 % Al_2O_3. The design assimilation of this material made 92 %, before heat treatment at normal temperature R_m = 290 MPa, A = 4,5 %. After T6 at normal temperature R_m = 405 MPa, A = 8,5 %, at 350 ^oC - R_m = 165 MPa, A = 12,5 %.

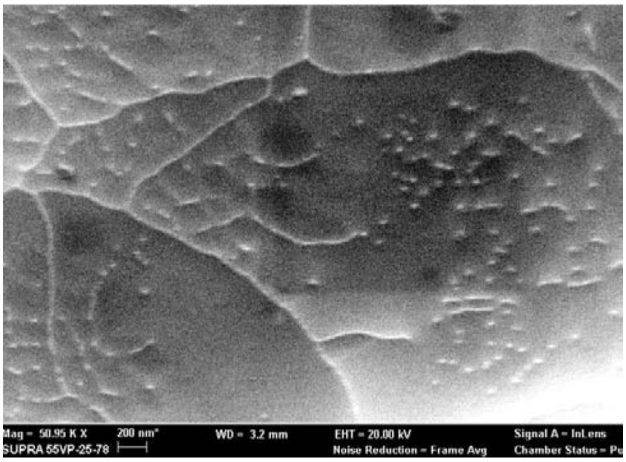

Figure 3 Microphotography of a nanocomposite A357/(SiC)

The plastic shaping of the derived cylindrical cast blanks in the liquid-solid state (585 ± 5 ^oC) proved the possibility of practical elimination of the original porosity, realization of the liquid-solid molding process (thixocasting) with invariable distribution of the reinforcing phase nanodimensional particles.

CONCLUSION

The obtained data, the results of the additionally carried out experiments and the analysis of literature sources permit to make certain conclusions, particularly:

- the developed compositions and technologies of obtaining a nanostructured powder composite material provide introducing nanodimensional reinforcing and modifying particles in the melt, it can be an independent type of commerce production;
- the most prospective compositions of NPCM are those containing microdimensional particles of transition metals that are the bearers of nanodimensional reinforcing particles and initiators of occurring in the melt intermetallides of endogenic origin;
- use of wide-range alloys as a basis for obtaining nanostructural composite aluminum alloys permits to intensify the effect of the particles wettability when mixing in the liquid-solid state, to ensure their uniform distribution in the melt and a casting, to use the melt in the liquid-solid state for obtaining sense products by the method of thixo-casting;
- two-plane electromagnetic stirring of the melt independent on the technology of nanoparticles introducing in the melt and the process of preliminary mixing ensures the possibility of mining the melt on both liquid and liquid-solid state;
- nanostructural composite metal matrix alloys are the most prospective structural materials of the future, and liquid-phase technologies of their obtaining are the most competitive in manufacturing products made of nanostructural aluminum alloys in the industrial scale.

LITERATURE

[1] Koch C. C. Nano structured materials: processing, properties, and potential applications', 423-526; 2002, Norwich, NY, Noyes Publications.

[2] Schurack F., Borпer I., Eckert J., and Schultz L: in «Metastable, mechanically alloyed and nanocrystalline materials)), [ed. A. Calka and D. Wexler), 312-314; 1999, Zurich, Trans. Tech. Publ.

[3] Petrunin A. V., Panfilov A. V., Panfilov A. A. O vlijanii modifici-rovanija nanorazmernymi tugoplavkimi chasticami na strukturu i svojstva aljumomatrichnyh kompozitov // Litejnoe proizvodstvo. (2009) 10.

[4] A. N. Kondratenko, T. A. Golubkova. Perspektivnye tehnologii poluchenija i oblasti primenenija nanostrukturnyh metallomatrichnyh kompozitov //Konstrukcii iz kompozicionnyh materialov. (2009) 1, 24-28.

[5] Kalashnikov, I. E. Struktura lityh aljumomatrichnyh kompozicionnyh materialov, armirovannyh intermetallidnymi fazami i nanorazmernymi tugoplavkimi poroshkami / I. E. Kalashnikov, L. K. Bolotova, T. A. Chernyshova // Cvetnye metally. (2010) 9, 67-71.

[6] Lilian Ivanchev, Sigqibo Templeton Camagu, Gonasagren Govender. Semi-Solid High Pressure Die Casting of Metal Matrix Composites Produced by Liquid State Processing // Journal Solid State Phenomena (Volumes 192 - 193), Semi-Solid Processing of Alloys and Composites XII, 61-65.

[7] Heinrich Möller and Gonasagren Govender. Production of A356/TiB2 Nanocomposite Feedstock for Thixoforming by an Ultrasonic Method // Journal Solid State Phenomena (Volumes 192 - 193), Semi-Solid Processing of Alloys and Composites XII, pp. 66-71.

[8] Kosnikov G. A., Kolesov S. S. Vlijanie MGD-peremeshivanija na strukturu splavov, obrabatyvaemyh v tverdozhidkom sostojanii. V sb.: Trudy VII s'ezda litejshhikov Rossii. Novosibirsk: 2005 g. -T.1. - S. 298-303.

[9] Borisov V. G. Razrabotka tehnologii plazmennogo sinteza aljuminievyh splavov kompozicionnogo tipa. //Metallurg, (2008) 11, 102-106.

[10] Baranov V. A., Petrovich S. Ju., Kalmykov A. V. Litejnye nanostrukturnye kompozicionnye splavy // Litejnoe proizvodstvo, (2012) 2, 4-9.

[11] Kosnikov G. A., Gazaliev T. A., Isin D. K. Sostojanie i perspektivy razrabotki aljumomatrichnyh kompozicionnyh splavov // Materiay Mezh-dunarodnoj nauchno-prakticheskoj konferencii "Gorno-metallurgicheskij kompleks Kazahstana: problemy i perspektivy", Karaganda. 29-30 November 2011 p. 135-142.

[12] D. W. Lee, O. Tolochko, C. J. Choi, B. K. Kim, Aluminium oxide dispersion strengthened copper produced by thermochemical process, Powder Metallurgy, 45 (2002) 1.

Note: The translation of the N. M. Drag, Karaganda, Kazakhstan