

CAST COMPOSITE ALLOYS BASED ON ALUMINUM: TECHNOLOGY, PROPERTIES, APPLICATION

ЛИТЫЕ КОМПОЗИЦИОННЫЕ СПЛАВЫ НА ОСНОВЕ АЛЮМИНИЯ: ТЕХНОЛОГИЯ, СВОЙСТВА, ПРИМЕНЕНИЕ

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Abstract: General problems, which restrict wide application of aluminum matrix composite alloys (AMCA) in production sector, are discussed. Possible ways of solving the problem are recommended: using of inexpensive fillers, secondary matrix alloys; development of new methods of complex reinforcing of matrix (*in-situ u ex-situ*); development and updating of technological decisions about multipurpose processing of aluminum matrix composite alloys; coordination and consolidation of scientific-technical potential of scientists and engineers of Scientific-Research Institutes (SRI), Institutions of Higher Education and enterprises on the field of development and research of aluminum matrix composite alloys.

KEYWORDS: ALUMINUM MATRIX COMPOSITE ALLOYS, LIQUID PHASE METHODS

1. Introduction

Modern tendencies of development of machine-building complex are inextricably linked with development and wide use of new highly-effective materials and new technologies of their obtaining. New materials should provide increased demands of techniques of strength, minimum of weight, increased reliability of the resource, durability of exploitation of details and structural components in extreme conditions of temperature-strength impact and aggressive surrounding [1]. Composite materials are most fully specified for this. That's why, last decades are characterized by constantly increasing interest in virtually all industrialized countries of the world to cast a discrete-reinforced composite alloys based on aluminum.

2. General Problems, which Restrict the Use of Aluminum Matrix Composite Alloys

Aluminum matrix composite alloys are perspective for widespread use in friction units of processing equipment, automotive, road construction equipment, and other areas instead of copper alloys or aluminum alloys antifriction. A pioneer in terms of industrial development of aluminum matrix composite alloys, reinforced by dispersed SiC particles and Al₂O₃, are well-known foreign companies DURALCAN, ALCAN and ALCOA.

However, it should be noted that the growth of the industrial use of aluminum matrix composite alloys is not yet adequate to technical and operational capabilities of these new materials. This is due to a number of objective and subjective reasons. One of the main reasons is the absence to the present moment of universal theory and practical suggestions, which help to predict guarantee choose the composition of ingredients of AMCA purposefully adjust the necessary degree of interfacial interaction and create the necessary framework to implement a given level of physical and mechanical properties and performance of products from AMCA available at their value.

It is well known that artificially synthesized AMCA have a higher cost when compared with conventional aluminum alloys, due to the relatively high cost of the reinforcing components and more complex production process of products from AMCA. Therefore, technical and economic factors are often a barrier to widespread use of the AMCA in mass industries. However, in most cases, the use of AMCA is not only advisable, but sometimes you just do not have alternatives, due to the unique operating characteristics, higher reliability and durability of their work in extreme conditions.

According to general opinion of experts, the further development of the application of the competitive AMCA today requires large-scale systematic studies and pilot projects in the following groups of problematic issues: the initial charge materials, production processes, technological aspects associated with the

complex treatment, including recycling; fundamental and applied research and development [1, 2].

3. Possible Solutions

3.1. Using Inexpensive Fillers and Secondary Matrix Alloys

As the high cost of most artificially synthesized reinforcing fillers, their scarcity make a negative contribution to the cost of AMCA, the first group of questions put forward the task of creating new economic game using as reinforcing fillers powders and fibers of cheap mineral - mullite, basalt, schungite, aluminosilicates and others, as well as matrix alloys – secondary raw materials, including scrap and chip wastes.

An example of a successful resolution of questions of the first group of problematic issues is the development of perspective AMCA by Physical-Technological Institute of Metals and Alloys of National Academy of Science of Ukraine, which are reinforced by relatively cheap and non-deficient nature of the oxide non-metallic particles (cupola slag, waste and fireclay stonemaking productions) [3].

Using AMCA as the matrix alloys rejects and low grade aluminum alloy requires the development of new highly refining methods, providing virtually complete absence of gas products and salt component of flux, because, otherwise, the absorption and uniform distribution of reinforcing components in the liquid phase becomes consolidation problematic. For this purpose, in the technology of refining VSU proposed new combined fluxes, where the main refining agent (up to 80-96%) are used dispersed particles of refractory oxides of aluminum and silicon [4].

These options will provide additional technical and economic benefits through more efficient recycling of aluminum alloys and non-metallic materials.

3.2. Complex Reinforcing of Matrix (*in-situ u ex-situ*)

Technological processes for the production of products from AMCA in industrial scale must perform the following basic tasks: provide given the physical and mechanical properties and performance of AMCA, to ensure the stability of product quality in terms of production.

Analysis of current scientific and technical information shows that currently the most intensively studied and applied in industry liquid phase methods for the AMCA. Various methods for combining a liquid phase of the matrix alloy with dispersed hardening phase impregnation melts (spontaneous in vacuo under pressure, combined) conglomerate fiber preforms (Praimex-process) or particles (Squeeze Casting Method); mechanical kneading of discrete particles or fibers in a metal melts (Compcasting Method);

Dimox-process allowing to obtain ceramic matrix composites by direct oxidation of the metal directly in the mold; processes based on the flow of controlled chemical reactions, high-temperature synthesis of endogenous strengthening phases in the matrix alloy (in-situ-process) and etc.

Of these modes of production of AMCA most technologically advanced and cheaper is the cast with a mechanical kneading the filler in the matrix melt. To improve wetting of the particles by the coating process is applied by chemical vapor deposition or the matrix or modify the surfactant additive (Mg, Ca, Li, Na, etc.). Technologically significant parameters is the design and installation of technological modes of mixing. However, this method of introducing the reinforcing phases in the molten matrix, and has a number of drawbacks: fairly strong gassing and oxidation of the melt during the mechanical mixing of the active and, as a consequence of insufficient quality adhesive bonds at the interface of the particle-matrix.

Structure refinement of the matrix alloy, increasing the density, providing a more uniform or a given distribution of particles in the volume of reinforcing, strengthening the adhesive interaction of particles with the matrix can be achieved through the use of external influences: pressure, ultrasound and centrifugal forces, electromagnetic fields and other technological methods.

The most perspective of manufacturing isotropic AMCA embodiments provide methods of synthesis or reaction molding (so-called in-situ process) when endogenous reinforcing fillers including nano-sized, formed as a result of controlled exothermic reactions between the starting components in the manufacture of directly AMCA [5]. AMCA obtained in such processes have a maximum level of bonds at the interface "filler - matrix" due to the small lattice mismatch contacting phases, thermal stability, better distribution and higher dispersion of the filler, which provides higher mechanical and performance properties.

Moreover, the exothermic reactions occurring in the melt in the synthesis of new endogenous phase of hardening, can improve the wetting of the matrix melts introduced exogenous addition of ceramic fillers, including nanoscale. Polireinforcing of matrix by endogenous and exogenous fillers of different nature and size opens another large reserves in the purposeful regulation given the physical and mechanical properties and performance of AMCA. [6]

With increasing concentration of reinforcing fillers in AMCA isotropic process and deteriorated mechanical properties and machinability pressure, the fluidity of the composition and the properties of the plastic material. In connection with this, a promising direction is the use of centrifugal casting methods for anisotropic functionally graded or reinforced composite materials [7].

Currently industrial synthesis technology products from AMCA are still under development or mining and industrial development. Such a state is partly due to the fact that technology is usually contain a know-how" and constitutes a commercial secret.

Further improvement of technologies for the production of game requires time and investment, and will be the accumulation of experience in the production and application of game based on fundamental metallographic studies.

3.3. Multipurpose Processing of AMCA

Another important area of research to expand the use of AMCA in real product engineering is the development and improvement of technological solutions for multipurpose processing of AMCA - thermal, thermal cycling and thermoplastic, mechanical, laser, fusion welding and surfacing etc.

Important area of work for the implementation of AMCA in production is to find the most efficient methods of machining of AMCA. Unfortunately, it must be noted that this issue is now being given very little attention.

Successful application of AMCA in the construction engineering and transport is often constrained by difficulties resulting from their specific connection between themselves or with alloys that do not contain reinforcing fillers. AMCA welds having

physico-chemical characteristics similar to the starting material can be obtained, provided the minimum degradation properties of the components of AMCA, preservation of code reinforcement volume fraction and distribution of reinforcing filler in the weld zone. In this connection, preference is given to the solid-phase welding methods of AMCA (diffusion, friction). However, is known positive experience making permanent connections fusion welding methods, which opens up prospects for expanding the range of welded structures of AMCA. Recently, much attention is given to developing ways surfacing composite layers with special properties. Surfacing of such layers can be one of the main ways to obtain functional gradient materials.

In the manufacture of products from AMCA are inevitably formed rejects defect of castings, gates, profits, bursts, and other exhaust components, so overall techno-economic balance of production and operation of game are important questions of recycling or recovery of products for reuse.

Choosing an effective method of processing depends on the composition and properties of AMCA reinforcing components.

For AMCA reinforced ceramic and thermally stable intermetallic phases can be applied to a limited extent the traditional method of refining, while keeping in mind that the 3-fold remelting of composite alloys can lead to significant degradation of the reinforcing phase and reduction properties of the composite. This brings up the problem of regeneration game in order to fully remove the reinforcing phase. This problem can be effectively solved with the use of new conceptual approaches that are based on the fact that the reinforcing phase performs refined function by adsorbing impurities themselves. [4]

AMCA reinforced by particles of metal-carbide TiC, ZrC, and borides TiB₂ and intermetallic TiAl₃, can be used as effective ligatures for modifying aluminum alloys.

Recovery of products from AMCA to the required dimensions can be accomplished by welding.

3.4. Coordination and Consolidation in Researching and Development of AMCA

Significant scientific contribution to the development of theory and practical use of AMCA are works of Gavrilin I.V. (Vladimir State University), Aksyonov A.A. (Moscow Institute of Steel and Alloys), Scheretsky A.A. (Physical-Technological Institute of Metals and Alloys, Ukraine), Chernyshova T.A. (Institute of Metallurgy and Metal Science named after A.A. Baykov, Russian Academy of Sciences) etc.

Obviously, the further development of the theory and practice of composite molding is impossible without a coordinated research, the effectiveness of which is greatly enhanced when the consolidation of scientific and technical potential of scientists and engineers of scientific research institutes, universities and businesses. An example of this fruitful scientific and technical cooperation is the long-standing successful joint activities of Vladimir State University and Institute of Metallurgy and Metal Science named after A.A. Baykov of the Russian Academy of Science. Combined efforts of research teams of these organizations conducted a large set of scientific studies on the interaction of metal matrix with reinforcing fillers, the choice of composition and manufacturing technology discretely reinforced AMCA, study tribological properties and physical mechanisms of wear, industrial testing and implementation of AMCA in friction industrial equipment and transport.

AMCA are relatively new functional materials and all their advantages, features and maximum operational capability not defined yet. Although today we can safely say that AMCA have significant advantages as wear-resistant tribological materials.

Reliability of work of AMCA in friction units of different kinds of technics proved by years of industrial testing and implementation in many enterprises. Small-scale production of castings and parts from AMCA on the orders of enterprises established on the base of

scientific-production enterprise "Aluminum Matrix Composite Materials" (Vladimir, Russian Federation).

4. *Conclusion*

Currently, in the field of composite materials science, development of efficient industrial technologies of production and application of AMCA working and have recognized achievements leading companies and research organizations of practically all developed and developing countries, including the U.S., UK, Germany, Japan, China, Russia, Ukraine etc.

Above are formulated only the most basic problems from solutions of which largely depend prospects and temps of implementation of discrete-reinforced AMCA in industrial production, as well as variation among consumers in a better way trust to AMCA, strengthening of motivation for their wider application in industry.

5. *Literature*

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