CURRENT STATE AND TRENDS OF DEVELOPMENT OF ALUMINUM MATRIX COMPOSITE ALLOYS

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Abstract

The last decades are characterized by constantly increasing interest of practically all industrialized countries of the world to the cast discrete reinforced aluminum matrix composite alloys (AMC’s). However, growth of volumes of industrial use of AMC’s for the present isn't adequate to technical and operational opportunities of these new materials. Further development of application of competitive AMC’s today requires conducting large-scale systematic researches and pilot projects in the following groups of problematic questions: the initial charge materials; technological processes of production; technological aspects of complex processing, including recycling; fundamental and applied research and development. Using as matrix alloys for AMC’s of low-grade and sub-standard waste of aluminum alloys requires development of new highly effective methods of their refinement, providing almost total absence of gases and products of a salt component of flux. Analysis of modern scientific and technical information indicates that at present time the most intensively studied and applied in industry liquid phase methods for AMC’s. The most promising methods of manufacturing of isotropic AMC’s are methods of reactionary molding or synthesis (so-called in-situ processes). Currently, industrial synthesis technologies of products from AMC’s still are at the stage of working off or experimental-industrial development. Such condition is partly due to the fact that technologies, as a rule, contain "know-how" and a trade secret. Other important direction of researches on expansion of use of AMC’s in real products of mechanical engineering is development and improvement of technological decisions on multi-purpose processing of AMC’s – thermal, thermocyclic and thermoplastic, mechanical, laser, fusion welding and built up welding, etc., and also search of the most rational ways of machining and recycling of AMC’s. Obviously, the further development of the theory and practice of composite casting is impossible without coordinated scientific researches, efficiency of which is significantly enhanced by the consolidation of scientific and technological potential of scientists and engineers, research institutions, universities and enterprises.

Keywords: aluminum matrix composite alloys, liquid phase methods, trends of development

INTRODUCTION

Current trends in mechanical engineering are inextricably linked to the development and widespread use of new high-performance materials and new production technologies. New materials should provide increased demands on technology strength, minimum weight, increasing resources, reliability, and durability of parts and components of structures under extreme conditions of temperature and force action and aggressive media [1]. Most fully meet the specified requirements composites. So the last decades are characterized by the growing interest of virtually all of the industrialized countries of the world to cast discrete reinforced aluminum matrix composite materials (AMC’s).

1. GENERAL PROBLEMS, LIMITING BROAD APPLICATION OF AMC’S

AMC’s promise for widespread use in the friction units of various technological equipment, automobile, road construction equipment, and other fields to replace copper alloy or aluminum alloy anti-friction. A pioneer in terms of industrial development issue AMC’s reinforced fine particles of SiC and Al₂O₃, are well-known foreign companies DURALCAN, ALCAN and ALCOA.

Note, however, that the growth in industrial uses of AMC’s is still not adequate technical and operational capabilities of these new materials. This is due to a number of objective and subjective reasons. One of the main - is the lack to date of the universal theory and practical suggestions on how to predict and are guaranteed to choose the ingredients of AMC’s, specifically regulate the necessary degree of interfacial interaction and create the necessary structure to implement a given level of mechanical and performance properties of the products available at AMC’s their value.
It is known that artificially synthesized AMC’s are more expensive than traditional aluminum alloys, due to relatively high cost of reinforcing components and more complex manufacturing process of products from AMC’s. Therefore, technical and economic factors are often a barrier to the widespread use of the AMC’s in mass industries. However, in most cases, the use of the AMC’s is not only advisable, but sometimes it just does not have alternatives because of the unique performance characteristics, reliability and durability of their work in extreme conditions.

The general opinion of experts, the further development of competitive AMC’s today requires conducting large-scale systematic research and pilot projects in the following groups of problematic issues: the initial charge materials, production processes, technological aspects of complex processing, including recycling, basic and applied research and development [1, 2].

2. POSSIBLE SOLUTIONS

2.1. Using of cheap reinforcements and secondary matrix alloys

Because the high cost of most artificially synthesized reinforcing fillers, their scarcity make a negative contribution to the cost of the AMC’s, the first group of questions put forward the task of creating new cost AMC’s using as reinforcing fillers and fiber powders from cheap mineral – mullite, basalt, shungite, aluminosilicates and others, and as matrix alloys – secondary raw materials, including scrap and waste of castings.

An example of a successful resolution of questions of the first group of problematic issues is the development of promising FTIMS NAS AMC’s reinforced relatively cheap and non-deficient non-metal oxide particles of nature (cupola slag and refractory waste of stone-casting productions) [3].

Use as matrix alloys and low-grade AMC’s substandard waste aluminum alloys requires the development of new highly efficient methods for their refinement, providing almost no gas and food component of the salt flux, because, otherwise, absorption and even distribution of the reinforcing components in the liquid phase of consolidation is problematic. With this end in Vladimir State University proposed refining technology and new combined fluxes, where the main refining agent (to 80-96%) used the dispersed particles of refractory oxides of aluminum and silicon [4].

The implementation of these options will provide additional technical and economic benefits through more efficient utilization of waste aluminum alloys and non-metallic materials.

2.2. Complex reinforcing of matrices (in-situ and ex-situ processes)

Technological processes of products from AMC’s commercially must address the following key objectives: to provide the specified physical, mechanical and performance properties of the AMC’s, to ensure the stability of product quality.

Analysis of the current scientific and technical information indicates that at present the most extensively studied and applied in industry liquid phase methods for AMC’s. Various methods of combining liquid-phase matrix alloys with dispersed hardening phase: impregnating melts (spontaneous, vacuum, pressure, combined) conglomerate fiber preforms (Praimex-process) or particles (Squeeze Casting Method); mechanical kneading discrete particles or fibers in the metal melts (Compocasting Method); Dimox-process, which yields a ceramic matrix composites by the direct oxidation of the metal directly into the mold, the processes, based on the flow of controlled chemical reactions of high-temperature synthesis of endogenous strengthening phases in the matrix alloy (in-situ-process) and etc.

Of these methods produce the most technologically advanced and AMC’s is cheap foundry with a mechanical mixing the reinforcement in the matrix melt. To improve the wetting of the particles is applied to the coating process or by chemical vapor deposition, or modify the matrix of surface-active additives (Mg, Ca, Li, Na, etc.). Technologically important parameters are the plant design and operating practices of mixing. However, this method of administration of reinforcing phase in the matrix melt has some drawbacks: sufficiently strong oxidizing gas saturation and melts in the process of active mechanical mixing and, consequently, the lack of quality of adhesive bonds at the interface between the particle-matrix.

Grinding structure matrix alloy, increasing the density, giving a uniform or a specified distribution of reinforcing particles in a volume increase of adhesive interaction between particles and the matrix can be achieved through the use of external influences: pressure, ultrasound and centrifugal forces, electromagnetic fields and other technological methods.
The most promising manufacturing methods for isotropic AMC’s are reaction molding or synthesis (so-called in-situ processes), when endogenous reinforcing fillers, including nanoscale, formed as a result of controlled exothermic reaction between the initial components directly in the manufacture of AMC’s [5]. AMC’s, obtained in such processes, have the maximum level of bonds at the interface “reinforcement-matrix” due to the small lattice mismatch of contacting phases, thermal stability, better distribution and a high dispersion of the reinforcement, which provides a good mechanical and performance properties.

In addition, the exothermic reactions occurring in the melt in the synthesis of new endogenous strengthening phases, allow to improve the wetting of the matrix melts additional exogenous input of ceramic reinforcements, including nanoscale. Complex reinforcing of matrices with endogenous and exogenous reinforcements of different nature and size opens up even more reserves in a meaningful regulation given physical-mechanical and performance properties of the AMC’s [6].

With increasing concentration of reinforcing fillers in isotropic AMC’s deteriorate technological and mechanical properties: machinability and pressure, the composition and fluidity of the plastic properties of the material. In connection with this, a promising direction is the use of rotational molding techniques to produce anisotropic functionally graded or reinforced composites [7].

Currently, industrial synthesis technology products from AMC’s still under mining or development of industrial development. Such a state is partly due to the fact that technology, as a rule, contain “know-how” and constitute a trade secret.

Further improvement of production technologies AMC’s requires time and investment, and will be the accumulation of experience in the production and use of AMC’s, based on fundamental researches in the field of material science.

2.3. Multi-purpose processing of AMC’s

Another important area of research to expand the use AMC’s in the actual product engineering is the development and improvement of technology solutions to multi-purpose processing AMC’s - thermal, thermal cycling, and thermoplastic, mechanical, laser, fusion welding and cladding, etc.

Important area of work for the implementation of the AMC’s in production is finding the most efficient methods of machining AMC’s. Unfortunately, we must note that this issue is now being given very little attention.

The successful application of the AMC’s in the construction machinery and transport is often constrained by difficulties caused by the specifics of their connection with each other or with alloys that do not contain reinforcing fillers. Welded joints AMC’s possessing physicochemical characteristics similar to the starting material may be obtained, provided the minimal degradation of the properties of components AMC’s, for maintaining, code reinforcement volume fraction and distribution of reinforcing filler in the weld zone. Therefore, preference is given to the solid-phase method of welding AMC’s (diffusion, friction). However, the known and the positive experience of producing permanent joints fusion welding methods, it offers the prospect of expanding the range of welded structures of AMC’s. Recently, much attention is paid to developing methods deposition of composite layers with special properties. Surfacing of these layers may be one of the main ways to obtain functional gradient materials.

The manufacture of products from AMC’s inevitably formed sub-standard waste in the form of marriage castings, gates, profits, spikes, used parts, etc., so overall technical and economic balance of production and operation of AKM are important issues of recycling or recovery of products for re-use.

Choosing an effective method of treatment depends on the composition and properties of the AMC’s reinforcing components.

AMC’s for reinforced ceramic and thermally stable intermetallic phases can be applied to a limited extent the traditional method of melting, keeping in mind that the 3-time remelting composite alloys can lead to significant degradation of the reinforcing phase and reduce the properties of the composite. Therefore, there is a problem of regeneration AMC’s to fully remove the reinforcing phase. This problem is effectively solved with new conceptual approaches that are based on the fact that the reinforcing phase performs refined function over adsorbing impurities [4].

AMC’s, reinforced by particles of metal-carbide TiC, ZrC, and intermetallic boride TiB$_2$ TiAl$_3$, can be used as effective alloys for modifying aluminum alloys.

Recovery of products from AMC’s to the required dimensions can be carried facing.
2.4. Coordination and consolidation of researches and development in the field of AMC's

Significant contribution to the theory and practical use of the AMC’s is I.V. Gavrilin (Vladimir State University), A.A. Aksenov (Moscow Institute of Steel and Alloys), A.A. Scheretkiy (Physical and Technological Institute of Metals and Alloys, Ukraine), etc.

Obviously, the further development of the theory and practice of composite molding impossible without coordinated research, efficiency is significantly enhanced by the consolidation of scientific and technological potential of scientists and engineers, research institutions, universities and enterprises. An example of such a fruitful scientific and technical cooperation is the long-term synergy Vladimir State University and Institute of Metallurgy and Material Science named after A.A. Baikov. 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 of discrete-reinforced AMC’s investigation of tribological properties and physical mechanisms of wear, industrial testing and introduction of the AMC’s in the friction of industrial equipment and transport.

AMC’s is relatively new functional materials, and all of their benefits, features, and maximum operational capacity is not defined. Although, today, we can say that AMC’s has significant advantages as tribological materials.

Reliability of the AMC’s in friction units of different types of technology proven by years of industry testing and implementation in many enterprises. Small-scale production of castings and parts from AMC’s on the orders of enterprises established on the basis of research and production enterprise “Aluminum matrix composite materials” (Vladimir).

CONCLUSION

Currently in the field of composite materials, the development of effective methods of manufacturing and industrial applications of AMC’s work and have recognized achievements leading companies and research organizations of almost all developed and developing countries, including the USA, UK, Germany, Japan, China, Russia, Ukraine etc.

Stated above only the most basic problems, the results of the solution of which depends largely on the prospects and pace of discrete-reinforced AMC’s in production, as well as changes of consumer products to the best of confidence in the AMC’s, strengthening of motivation to their more widespread use in the industry.

LITERATURE


