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Review of Centrifugal Casting of Aluminium Composites

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Abstract: *The aims of this review are to systematize the basic production techniques for manufacturing functionally graded materials. Attention is paid to the principles for obtaining graded structure mainly in the metal based functionally graded materials. Several unpublished results obtained by the authors have been discussed briefly. Experimental methods and theoretical analysis for qualitative and quantitative estimation of graded properties have also been presented. Today, production of graded structures can be considered as the next step in composite materials development. The elaboration of instruments for micro-and macro-structure design in FGMs is a challenge for modern industry.*

Keywords: *centrifugal casting, functionally gradient composites, aluminium alloy*

INTRODUCTION

Metal matrix composite have been gaining importance in engineering applications, because of their high specific strength, high modulus and high wear resistance [1-6]. Functionally graded metal matrix composites have a great significance for the use in automobile, aerospace and defence industries. A functionally graded metal matrix composite can be defined as its reinforcement particle's volume fraction varies continuously from the inner to the outer sections of the part. Therefore, their mechanical properties are different from the inner region and outer region accordingly [7, 8].

Many kinds of in situ alloy phases, with high hardness, excellent wear resistance and corrosion resistance, and small thermal expansion coefficient, can be used as strengthening phases. The hypereutectic Al-Si alloy, with a silicon content from 16% to 26%, is, in essence, a composite material with in situ particles of primary silicon as A reinforcement phase. This kind of Al-Si alloy is widely used in the automobile and other industries [1].

However, primary silicon, in a form of the thick polygonal plate, seriously reduces the strength and elongation of the material. If the distribution degree of hard silicon particles in the hypereutectic Al-Si alloy is changed and primary silicon will be concentrated in the inner layer of the cylindrical component, the inner layer will be more wear resistant, and the middle layer and the outer layer will have a good plasticity and toughness. This change will develop a new application domain [2] of the hypereutectic Al-Si alloy. At present, domestic and foreign researchers mainly pay more attention on the refinements of primary silicon and eutectic silicon, and on seeking highly effective modifiers of aluminum melts and modification mechanisms [3-6].

Production Technologies

All methods for the production of MMCs can be used in a more or less effective way of obtaining inhomogeneous structure, but not all of them have the potential for flexible impact on the structure obtained. It seems that centrifugal casting, and electromagnetic field utilization are the two methods to effectively control particle distribution in MMCs. Squeeze casting is the most popular casting

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technology for infiltration of molten metals into graded preforms. Special methods are also being developed for surface deposition of structured coatings. Mechanical and/or chemical surface treatment has also been used for production of gradually structured surfaces, although this approach is not much effective.

Generally, there are two methods of graded structure management in MMCs production. The first one consists of preliminary preparation and arrangement of composite components, after obtaining a final product by means of a certain melt processing technique. Typical examples are: melt infiltration in a graded preform, sintering of gradually stacked powders, and consecutive mold filling by melts of different composition. The second method is based on the application of one or more external force fields that exert different influence on the separate components in certain liquid composite slurry. Such fields can be gravitational, centrifugal, thermal, magnetic, electrical, electromagnetic, ultrasonic and others. Some techniques for surface treatment have also been developed in order to obtain thin surface layers with graded structure, which satisfies demands of specific applications. They involve chemical treatment [9], mechanical attrition treatment [10], severe plastic deformation[11] and are with limited application. Special instruments for management of porous structure in gas reinforced MMCs (gasars) are external gas pressure and solidification velocity. The fabrication of AlB_2 flake reinforced Al-4%Mg composites were prepared by the reaction of boron oxide (B_2O_3) with Al at a reaction temperature of $1400^\circ C$ as explained in detail elsewhere [10]. The composites were placed in a die and the die was heated at $800^\circ C$ in an electric resistance furnace to bring the composites to a semi-solid state (Al (liquid) + AlB_2 (solid)). Centrifugal action was then employed with the die containing semi-solid composite to drive the solid AlB_2 particles towards the outer region to produce a functionally graded $AlB_2/AlMg$ composite with even higher volume percent reinforcement. The centrifugation process was carried out under rotation speed of 600 rpm at $800^\circ C$. A schematic representation of the in-situ production and the following centrifugation process of the functionally graded $AlB_2/AlMg$ composite were shown in Fig. 1..

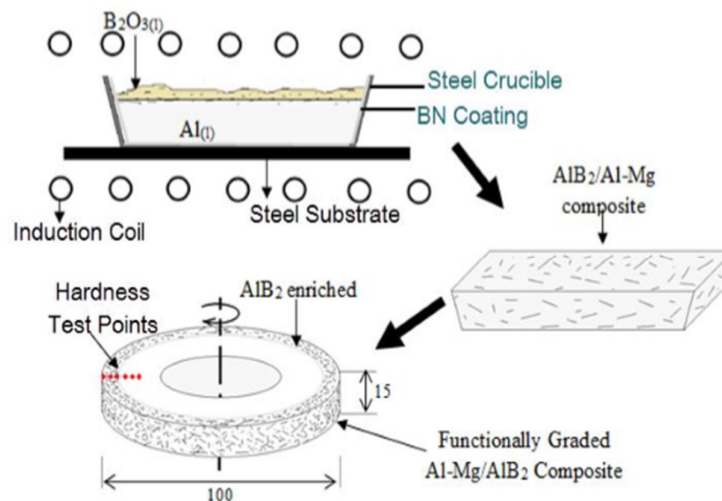


Fig. 1. Schematic illustration of $AlB_2 /Al-Mg$ composites production route

Production, structure and hardness of cylindrical cast parts from composites based on aluminum alloys and SiC particles have been discussed. Two different matrix alloys A356 (Al7.5Si0.35 Mg) and A2124 (Al4.5Cu1.6Mg0.25Zn0.2Si) have been used. Average particle size is 23 μm . Initial concentration of reinforcing phase is 15% in both cases. SiC particles have been accumulated during solidification in outer casting region because of centrifugal force.

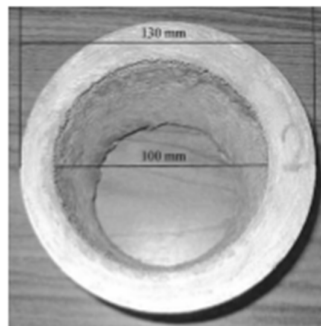


Fig. 2. Tubular piece prepared by centrifugal casting.

A standard heat treatment procedures for A356 alloy (solution treatment at 535°C for 10 h, quenching in warm water and artificially aging at 165°C for 8 h) and A2124 alloy (solution treatment at 495 °C for 4 h, quenching in warm water and aging at 190°C for 5 h) have been applied to the obtained composites castings. Brinell hardness measurements from the outer to the inner surfaces of as-cast and heat treated specimen have been carried out. The microstructure, the particle distribution, and the hardness measured for the A356 SiC composite are shown in Fig.2. Analogous results have been obtained for A2124 SiC composite. The maximum hardness measured at the outer periphery after heat treatment for Al356 SiC is 155 BHN and that for Al2124 SiC is 145 BHN. The two-phase region of the matrix alloy has been found to determine the nature of the transition from particle rich to particle free zone. These composites are suitable for production of functional components, which require very high surface hardness and wear resistance. The metallographic specimen, the gradient distribution characteristics of enhancement particles were observed with an optical microscope in the radial direction from the inner wall to the outer wall of the tubular.

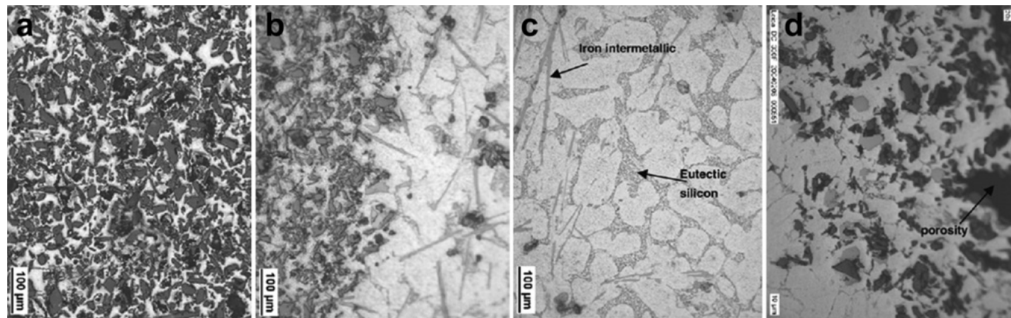


Fig. 3. Graded microstructure in different region of A356eSiCP composite obtained by centrifugal casting: (a) 1.5 mm; (b) 5.5 mm; (c) 6.5 mm; (d) 15 mm. All the distances are from outer surface of the cylindrical casting.

Conclusions

The composites of graded structure and properties focus attention of specialists in material science and technologies because of their specific characteristics. There is a great variety of production methods developed for synthesis of graded metal matrix composites. A large number of black Mg₂Si and grey primary silicon grains were concentrated in the inner layer of Al-Si7-Mg alloy tubular pieces prepared by centrifugal casting. These grains formed a very obvious gradient distribution in the inner layer, middle layer, and outer layer in the direction of thickness. This distribution gives an in situ functionally gradient composite. AlB₂ Reinforcing particles were produced by chemically reacting aluminium alloys with boron oxide at 1400 °C for 1.5 h. It was observed that the AlB₂ flakes in Al-Mg alloy have average 170 micron width, fine flake shape and volume fraction of AlB₂ flake is 2.6 vol.% in as cast condition. Results showed that volume fraction of AlB₂ flakes in external zone significantly increased under centrifugal force. The average volume fraction of AlB₂ flakes in the external region was 10 vol.%. However in the other region was decreased to almost zero

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