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Procedia Technology 24 (2016) 379 – 385

Procedia Technology

International Conference on Emerging Trends in Engineering, Science and Technology

(ICETEST - 2015)

Analysis of stir cast aluminium silicon carbide metal matrix composite: A comprehensive review

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Abstract

Aluminium silicon carbide metal matrix composites are used in various fields like aerospace, aircrafts, underwater, automobile, substrate in electronics, golf clubs, turbine blades, brake pads etc. Several fabrication techniques are available for the production of aluminium silicon carbide metal matrix composites (Al-SiC MMC). Among the various methods, stir casting route is simple, less expensive, and used for mass production. The main limitations of stir cast Al-SiC MMC are improper distribution of SiC reinforcement in matrix and less wettablity of SiC reinforcement particle with molten Al. Literature survey indicate that various properties of stir cast Al-SiC MMC depends upon fabrication method, volume fraction, shape, size of particles and distribution and properties of constituents. Since metal matrix composites (MMC) lack structural simplicity its analytical modeling is complex. Further, the involvement of several parameters which affect composite properties, makes the experiments difficult. This review paper contemplates the need of simulation or numerical methods for the prediction of mechanical characteristics of Al-SiC MMC.

Peer-review under responsibility of the organizing committee of ICETEST – 2015

Keywords: Aluminium silicon carbide metal matrix composites; Stir casting; Simulation;

1. Introduction

Scientists are continuously trying to improve various properties of engineering materials. This led to new category of materials called composite materials; they are composed of a combination of distinctly different two or more micro or macro constituents that differ in the form of composition and it is insoluble in each other. Composite

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Peer-review under responsibility of the organizing committee of ICETEST – 2015
doi:10.1016/j.protcy.2016.05.052

materials have a continuous, phase called the matrix; and a dispersed, non-continuous, phase called the reinforcement. The reinforcing phase material may be in the form of fibers, particles, or flakes. The matrix phase materials are generally continuous. In a composite, each material retains its original properties but when composited it yields superior properties which cannot be obtained separately [1]. Such types of material are developed to satisfy proper mechanical properties which can not be derived from conventional materials. And also composites meet the requirements of specific design and function, along with the desired properties.

According to matrix constituent, composites are classified into organic-matrix composites, metal matrix composites (MMCs) and ceramic-matrix composites. Among these composites, MMCs provide significantly enhanced properties such as higher strength, specific modulus, damping capacity, stiffness, good wear resistance and weight savings. The major disadvantage of MMC usually lies in the relatively high cost of fabrication and of the reinforcement materials. In terms of shape, the reinforcement material may be sub-divided into four major categories (i) Continuous fibres (ii) Short fibres (chopped fibres which are not necessarily having same length) (iii) Whiskers and (iv) Particles. Among various reinforcements, particles are the most common and cheapest reinforcement. While continuous fiber reinforcement MMCs provide the most effective strengthening (in a given direction), particle reinforced MMCs are more attractive due to their cost-effectiveness, isotropic properties, and their ability to be processed using similar technologies which are used for the monolithic materials. Among various matrix materials, aluminium alloy matrix materials possess high tensile strength, good corrosion resistance etc. Similarly among various reinforcements silicon carbide reinforcements are inexpensive; improve yield strength and elastic modulus at little expense of ductility. Silicon carbide as such, because of its high hardness, has got a number of applications such as in cutting tools, jewellery, automobile parts, electronic circuits, structural materials, nuclear fuel particles, etc. Like all composites, aluminum-matrix composites are not a single material but a family of materials whose stiffness, strength, density, thermal and electrical properties can be tailored. The Al-SiC MMC possess wide range of physical and mechanical properties such as high strength, stiffness, low density, high corrosion, wear resistance, low thermal shock, high electrical and thermal conductivity, good thermal properties and good damping capability. Among all materials, composite materials have the potential to replace widely used steel and aluminum, and many times with better performance. Al-SiC MMC's are used in various fields like aerospace, fuselage skins of high performance aircrafts, underwater, automobile, substrate in electronics, golf clubs, turbine blades, brake pads etc.

2. Manufacturing methods

The manufacturing methods available for Al-SiC MMC can be broadly classified into three types. They are solid phase processes such as powder metallurgy and diffusion bonding, liquid phase processes such as stir casting, infiltration of liquid matrix into the reinforcements and in situ processes, and semi-solid method such as spray and rheo casting and compo casting [2]. These manufacturing methods determine the microstructure and interfacial bond condition between reinforcement and matrix. The difficulty in fabrication of fiber reinforced plastics has made the use of metal matrix composite widely acceptable. Solid phase process such as powder metallurgy, diffusion bonding, are expensive because it needs expensive starting materials such as powder or foil matrix etc. Liquid phase process (casting process) is generally less expensive than solid phase process. In the casting process, high temperature melt is used. High temperature often promotes the chemical reaction between the melt and the reinforcements. The reaction leads to the degradation or disappearance of the reinforcements. The expected properties of the composite would not be obtained if this reaction occurs. So in order to obtain metal matrix composite with good characteristics special techniques are required. The comparisons of various processing techniques are discussed in Table I. Among various manufacturing methods stir casting is generally accepted as a promising route because of low cost, little damage to reinforcement and stir cast components are not restricted by its size and shape [3]. It also possesses advantages like simplicity, flexibility and applicability to large quantity production. [4].

Manufacturing methods used for production of MMCs should ensure uniform distribution of reinforcement in matrix. The non uniform distribution is due to density differences between the reinforcement particles and the matrix alloy melt. The distribution of reinforcement is influenced during several stages including (i) distribution in the liquid as a result of mixing, (ii) distribution in the liquid after mixing, but before solidification. Manufacturing