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jmr&t Journal of Materials Research and Technology

www.jmrt.com.br

Review Article

Characterization of hybrid aluminum matrix composites for advanced applications – A review

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ARTICLE INFO

Article history:
Received 2 December 2014
Accepted 5 May 2015
Available online 22 June 2015

Keywords:
Aluminum hybrid composites
Reinforcement
Mechanical behavior
Tensile strength

ABSTRACT

Hybrid aluminum matrix composites (HAMCs) are the second generation of composites that have potential to substitute single reinforced composites due to improved properties. This paper investigates the feasibility and viability of developing low cost-high performance hybrid composites for automotive and aerospace applications. Further, the fabrication characteristics and mechanical behavior of HAMCs fabricated by stir casting route have also been reviewed. The optical micrographs of the HAMCs indicate that the reinforcing particles are fairly distributed in the matrix alloy and the porosity levels have been found to be acceptable for the casted composites. The density, hardness, tensile behavior and fracture toughness of these composites have been found to be either comparable or superior to the ceramic reinforced composites. It has been observed from the literature that the direct strengthening of composites occurs due to the presence of hard ceramic phase, while the indirect strengthening arises from the thermal mismatch between the matrix alloy and reinforcing phase during solidification. Based on the database for material properties, the application area of HAMCs has been proposed in the present review. It has been concluded that the hybrid composites offer more flexibility and reliability in the design of possible components depending upon the reinforcement's combination and composition.

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http://dx.doi.org/10.1016/j.jmrt.2015.05.004

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1. Introduction

Metallic matrix composites (MMCs) reinforced with ceramic particles are very promising materials for structural applications due to excellent combination of properties. MMCs combine the properties of the metallic alloys (ductility and toughness) and the ceramic reinforcements (high strength and high modulus) leading to a superior profile of characteristics [1–2]. The aluminum matrix composites (AMCs) represent a class of MMCs possessing properties like low density, high stiffness and strength, superior wear resistance, controlled co-efficient of thermal expansion, higher fatigue resistance and better stability at elevated temperature. Due to this, these composites are used for the design of a wide range of components for advanced applications [3]. It has been found that the use of AMCs in engine applications can reduce the overall weight, fuel consumption and pollution in the automobiles and aircrafts [4,5]. AMCs reinforced with either silicon carbide (3.18 g/cm^3) or alumina (3.9 g/cm^3) particles are attractive materials for such applications [4–6]. These reinforcements are denser than those of aluminum alloys (2.7 g/cm^3) and increases the weight of the composites depending on the reinforcement's contents [7]. Moreover, the addition of ceramic particles to the Al-alloy increases the hardness of composite and makes machining of developed composite more difficult. Such problems can be solved by the use of multiple reinforcements in the aluminum alloy. The ceramic reinforcements possess superior strength than any other type of reinforcement and because of the fact, these are used as a primary reinforcement for development of hybrid composites. However, the secondary reinforcements reduces the cost as these are readily available and weight as they have lower density of the hybrid composites [8,9]. The properties of the hybrid reinforcements (primary and secondary) can be combined to achieve optimization of material properties. Moreover, the use of stir casting technique for fabrication of AMCs reduces the cost the composites, as it is economical, simple to perform and highly productive method [3,10].

Nowadays, there is growing concern in the production of HAMCs with better physical and mechanical properties [11,12]. Recent research investigations have revealed that agro/industrial waste materials such as fly ash, graphite, rice husk ash, etc., can be successfully used as a complementary reinforcement in AMCs [13–17]. In addition to this, two ceramic phases can also be used for development of hybrid composites [9]. Further, the use of hybrid reinforcements improves the performance of the composites by introducing new features. First of all, these materials can reduce the cost of aluminum composites [13,14]. Secondly, the weight of the composites can be controlled due to lower density of these materials [15]. Thirdly, these composites can also offer comparable or even superior physical and mechanical properties [16,17].

The present study deals with the characterization of aluminum based hybrid composites developed by stir casting for advanced applications. The potential of a wide range of secondary reinforcements has been explored for the development of HAMCs and the application area of these composites has been proposed. The focus is on the optimization of parameters for various properties of composites. Further, the influence of reinforcement's type and contents on the material properties has also been reviewed and discussed.

2. Literature review

2.1. *Microstructural features*

The first task during fabrication of composites is to obtain the uniform distribution of reinforcing particles in the matrix alloy. Secondly, it is also essential to prevent segregation/agglomeration of particles during the progress of solidification. Chawla and Chawla [18] have proposed that morphology, type of reinforcements and distribution of reinforcing particles have significant contribution in the aggregate characteristics profile of the composites. According to Hanumanth and Irons [2], the variables that govern the distribution of particles are solidification rate and fluidity of the melt, type of reinforcements, the method of particle incorporation and wettability of particles in the melt. The addition of magnesium can be useful in improving the wettability between the reinforcing particles and the alloy melt. In addition, mechanical stirring in the semi-solid state can also be used to obtain the uniform distribution of reinforcing particles. The study of microstructure is quite useful in evaluating the distribution of reinforcing particles in the matrix alloy. The results of various studies regarding the microstructural features of HAMCs have been presented below.

Boopathi et al. [19] have studied the microstructures of aluminum alloy (Al 2024) reinforced with different compositions