A Review on Mechanical Properties of Reinforced Aluminium Matrix Composites

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ABSTRACT
This paper presents a review on the effects of reinforced particles on Al MMCs mechanical and physical properties. The increasing demands of materials with high strength and endurance with variable loads and high temperature in various sectors like aerospace, military, electrical industries, and automobile, bring MMCs in spotlight. To increase the various mechanical properties like strength, wear resistance, temperature tolerance, hardness, fatigue resistance etc. to achieve the requirements of various industries, reinforcement of MMCs is done. Al is used in metal matrix composites mainly because of its light weight and ductility. Effects of various reinforcement materials like SiC, B_4C, Al_2O_3, fly ash etc on the mechanical properties of Al MMCs is discussed in detail.

Keywords: AMCs, Reinforcement materials, mechanical properties.

INTRODUCTION

When combined with the various ceramic reinforced particles, Aluminium shows very promising properties that make is very useful in the use of structural applications. In MMC's both the characteristics of Base metal and reinforced particles combines together to give a material of superior strength, ductility, toughness etc. [1,2]. Aluminium is used in MMC's not only because of its various properties like light weight, ductility etc to give a superior profile but the reinforced MMC's can be made through conventional process like forging, rolling and machining. Due to these various factors, Al MMC's are used in aerospace industries, automobile and other transport industries to prepare brake drums, pistons and electronic packaging and so on [3].

Various types of reinforcement material play important role in enhancing the properties of base metal. The most commonly used reinforced material in Al-MMC's are Silicon Carbide (SiC) and Aluminium oxide (Al_2O_3). Use of silicon carbide as reinforced material increase the tensile strength, wear resistance, hardness and density of Al and its alloys [4]. Use of Aluminium oxide in MMC's provides good compressive strength and wears resistance. Boron carbide is also used as reinforced material which increases the hardness and toughness but the wear resistance is not increased [5]. Wear resistance in Al-MMC's can be increased significantly by using Zircon as reinforced material. The use of fly ash is also increasing because of its high availability and low cost. Fly ash reinforcements increase the electromagnetic effects of Al-MMC's. In this paper various effects of the reinforcement on the mechanical properties of the Al-MMC's is discussed.

ALUMINIUM OXIDE REINFORCEMENT

Aluminium oxide (Al_2O_3) which is also known as Alumina, have strong ionic inter atomic bonds which provides it the significant material characteristics. Many researchers have done their work on the Aluminium oxide reinforced materials to study the mechanical effects of it on the AMC's. Kumar et al. [6] in his study says that the hardness and tensile properties of the AMC can be increased when Al oxide reinforced MMC is developed using the electromagnetic stir casting. His study also says that the grain size of the AMC produced is significantly smaller when electromagnetic stir casting method is used.

Kok [7] in his work finds out that the wettability and bonding are increased, and the porosity is decreased when the AMC is produced using vortex method. Abouelmagd [8] found out by studying the wear resistance and hot deformation of AMC's produced by powder metallurgy that Al_2O_3 increase the wear resistance and hardness of composite. Park et al. [9] found out in his study that when the volume fraction of Al_2O_3 is changed from 5 to 30% the toughness is decreased. This happens due to the decrease in the inter particle spacing. In his study, he also investigated the fatigue behavior of AMC reinforced with Al_2O_3. The fatigue behaviors were investigated on the samples of Al6061 alloy reinforced with Al_2O_3 by Park et al. [10]. It was found that the reinforcement increases the fatigue strength. Ceschini et al. [11] also studied the fatigue behaviors on the Al7005 alloy and Al6061 alloy reinforced with Al_2O_3.

BORON CARBIDE REINFORCEMENT

The properties like high strength, extreme high hardness, chemical stability, neutron absorption capacity and low density make Boron one very important ceramic material. However along with these various important properties, producing the boron carbide reinforced AMC is difficult due to problem in agglomeration of boron carbide particles and homogeneously mixing of it in AMC's. Producing Boron carbide AMC has always been a keen focus of the investigators. By using the accumulative roll bonding process, Yazdani et al. [12] prepared Al/B_4C composite in which reinforced particles were evenly distributed in the matrix. The results showed that when the boron carbide particles were increased in the matrix up to a limit then the hardness, wears resistance and compressive strength increases. Many methods like solid state consolidation and liquid state consolidation are used to develop the Al/B_4C composites. Krisna et al. [13] in his study on the Al6061 alloy reinforced with B_4C found that the tensile strength and hardness of the composite increases when the particle size and wt% of B_4C is increased. Berbara et al. [14] studied the difference between the wear resistance of SiC composites and B_4C composites and found out that the wear resistance of B_4C is less than that of SiC composites. Also the surface quality of the composites has been studied by many. Mahesh et al. [15] in his study on the hybrid Al-SiC-B_4C composite found out that the most important factors affecting the surface quality are feed rate and cutting speed.

ZIRCON REINFORCEMENT

Zircon also have very important properties but its use in the composites is very limited which means various investigation can still be done on how Zircon effects the properties of the base metal in the composites. Few studies have also been done on this. Scudino et al. [16] studied the Zircon reinforced composites and found out that the compressive strength can be increased upto 30% of Al metal by using Zircon reinforcement using powder metallurgy method. Girisha et al. [17] found out in his study that when weight fraction of Zircon is increased in composite, the hardness and wear properties improve. When Al6063 and Zircon reinforced composite was prepared by using stir casting method and then studied by Jenix et al. [18], he found out that tensile strength and hardness increases. Das et al. [19] carried out his study on the Al-Cu alloy reinforced with zircon and aluminium oxide. His study shows that the wear properties of the alloy increases when zircon and aluminium oxide was added to the composite. Zircon reinforced composites shows improved wear properties than that of aluminium oxide due to its superious particule matrix bonding.

SILICON CARBIDE REINFORCEMENT

The SiC reinforced composites have been studied alot. Various studies show that tensile strength density and hardness of AMC increases when the reinforcement ratio increases. But with increase in the reinforcement ratio the inpact strength decreases [20, 21]. Particle cracking, particle clustering and weak matrix bonding are the factors affecting the impact strength [22]. The study of the Al_2O_3 and SiC composites shows that the reinforcement improves the mechanical properties like hardness, tensile strength, impact strength and thermal capacity of the base material. It was also find out that the wear resistance of the SiC reinforced composites is more than that of Al_2O_3 reinforced composites [23]. Stir casting method was used

to prepare SiC reinforced composites by Prabhu et al. [24]. His study shows that stirring speed and stirring time have a great effect on the distribution of reinforcement particle in the matrix. More particle clustering was observed when the stirring speed was lower. But when the stirring speed is increased the distribution of particles is uniform in the composite.

Many investigations have been done on the machinability of the SiC based reinforced composites. Murty et al. [25] in his study on the Al6061-SiC- Al_2O_3 composite found that form productivity point of view, a high strain region with high mass and efficiency should be used for bulk operations and lower strain regions for secondary operations. During the study of the surface roughness, it was found that many factors like feed rate, cutting speed, % of SiC in composite effects the surface roughness. Response graph, probability plot, interaction graph and ANOVA techniques are used to optimize the parameters responsible to attain the minimum surface roughness [26]. It was found that feed rate followed by cutting speed and % of SiC has effect on the surface roughness. A low cutting speed, high feed rate are the recommended conditions for the low and medium turning process. Volume fraction of SiC and its size also affect the tool life [27].

FLY ASH REINFORCEMENT

Fly ash particles are used as reinforcement material due to its high availability and low cost. Fly ash is produced in huge quantity as waste by product of thermal power plants. Good interfacial bonding, higher mechanical strength, uniform distribution and minimum porosity are achieved when fly ash is used as reinforced material in composites. The constituents of fly ash are SiO_2, Al_2O_3, Fe_2O_3 and CaO. The effects of three different stir casting methods liquid casting, compo casting and modified compo casting followed by squeeze casting are studied by Rajan et al. [28]. He found out that the compression strength of composite formed by modified compo casting process is more than that of simple metal matrix but tensile strength is lower. The tensile strength is reduced when fly ash is added as reinforcement material. Ramachandra et al. [29] in his study observed that the wear resistance increases with increase in fly ash content but the corrosion resistance decreases with increase in fly ash content.

PROCESS FOR AMC'S MANUFACTURING

There are two main routes which can be used for manufacturing AMCs.

1. Liquid state processes
2. Solid state processes

Liquid state processes:- Liquid state process can be further classified into four categories which can be used for producing Al MMCs. Liquid state processes are:

- Stir casting
- Spray deposition
- Infiltration process
- In-situ reaction synthesis

Solid state processes: Two processes come under solid state processes which can be used for manufacturing Al MMCs.

- Powder metallurgy
- Diffusion bonding

The most commonly processes used for producing Al MMCs are stir casting and powder metallurgy.

CONCLUSION

Many challenges were faced and overcome by the researchers during the developments of AMC's and there are still chances of improvement in order to improve the usage of the AMC's in different sectors.

Reinforcement does affect the mechanical properties of the base metal in the composites. The conclusion from the prior works in the reinforcement field can be summarized as:

- The wear resistance of SiC reinforced Al composites is better than that of Al_2O_3 and B_4C reinforced Al composites.
- Mechanical and fatigue properties can be improved by increasing the reinforcement ration and decreasing the reinforcement particle size.
- Zircon reinforced composites compressive strength is greater than that of base metal.
- When volume fraction of the Al_2O_3 particles is increased in the composite than the fracture toughness decreases.
- To obtain high structural homogeneity, fly ash can be used as reinforcement material.
- The optimum conditions for fabricating Al2O3 reinforced Al MMCs manufactured by stir casting process are pouring temp. 700^0C, pre-heated mould temp. 550^0C, the stirring speed 900 rev/min, particle addition rate 5g/min, the stirring time 5 min and the applied pressure as 6 MPa.

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