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A Review on Mechanical Behavior of Aluminium Metal with Different Reinforcing Materials

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Abstract- In the past few years the worldwide need for high performance, low cost and good quality materials has caused a shift in research of composite materials. In case of MMC's, Aluminium matrix composite, due their low cost, high strength to weight ratio and high wear resistance are widely manufactured and used in structural applications along with aerospace and automobile industry. Also a simple and cost effective method for manufacturing of the composites is very essential for expanding their application. Reinforcement silicon carbide can easily be incorporated in the melt using cheap and widely available stir casting method. This paper presents a review on the mechanical properties of stir cast aluminium matrix composites containing synthetic materials, industrial waste , agro waste as reinforcement material. Red Mud is also an industrial waste and it can also be used as reinforcement to improve the properties of material. Fly ash is a bye product of coal combustion and is readily available in many industrialized nations. Rice HuskAsh is an agro waste and it is easily available.Addition of SiC in Aluminium as reinforcement also improves the properties of materials. Aluminium metal with such reinforcement materials have shown a high specific strength, low coefficient thermal expansion and high thermal resistance, good damping capacities, superior wear resistance, high specific stiffness and satisfactory levels of corrosion resistance.

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1. INTRODUCTION

Current engineering applications require materials that are stronger, lighter and less expensive. A good example is the current interest in the development of materials that have good strength to weight ratio suitable for automobile applications where fuel economy with improved engine performance is becoming more critical. In-service performance demands for many modern engineering systems require materials with broad spectrum of properties, which are quite difficult to meet using monolithic material systems. Metal matrix composites (MMCs) have been noted to offer such tailored property combinations required in a wide range of engineering applications. Some of these property combinations include high specific strength, low coefficient thermal expansion and high thermal resistance, good damping capacities, superior wear resistance, high specific stiffness and satisfactory levels of corrosion resistance.MMCs are fast replacing conventional metallic alloys in so many applications as their use have been extended from predominantly aerospace and automobile to defense , marine, sports and recreation industries.

2. ALUMINIUM MATRIX COMPOSITES (AMCS)

For the last few years there has been a rapid increase in the utilization of aluminum alloys, particularly in the automobile industries, due to low weight, density, coefficient of thermal expansion, and high strength, wear resistance. Among the materials of tribological importance, Aluminum metal matrix composites have received extensive attention for practical as well as fundamental reasons.

The different reinforcing materials used in the development of AMCs can be classified into three broad groups:-

- Synthetic ceramic particulates
- Industrial wastes
- Agro waste derivatives.

Parameters considered for design of AMCs are linked with reinforcing materials.

A few of such parameters are reinforcement type, size, shape, volume fraction, modulus of elasticity, hardness& manufacturing process.

Synthetic ceramic particulates-

Silicon carbide (SiC), alumina (Al_2O_3), boron carbide (B_4C),tungsten carbide (WC), graphite (Gr), carbon nanotubes (CNT)and silica (SiO_2) are some of the synthetic ceramic particulate that has been studied but silicon carbide and alumina are mostly utilized compared to other synthetic reinforcing particulates. [6]

Conventional AMCs reinforced with SiC orAl_2O_3 have shown improved strength and specific stiffness over the monolithic alloys but this occurs at the expense of ductility and fracture toughness [7, 8, and 9]. Ductility and fracture toughness are important material properties that are necessary for preventing failures under in service stress or shock load applications. These have necessitated the use of two or more synthetic reinforcing particulates for property optimization. Graphite or Boron carbide has been used alongside with SiC or Al2O3to optimize the performance of AMCs.

The composites had 5 wt% SiC with varied graphite content up to10 wt%. It was reported that tensile strength, wear resistance and hardness increased with increasing reinforcement. The hybrid composites had superior mechanical properties than the single reinforced Al/5 wt% SiC composite with Al/5 wt% SiC/10 wt% Gr. having the highest strength and wear resistance [10].

However, apparent from the literature that particulates offer greater flexibility in tailor making the properties of interest. Thus researchers have worked out separately to reinforce SiC, Al2O3 (i.e. carbides, Nitrides and oxides) TiB2, Boron and Graphite in to the Aluminium matrix to achieve different properties and are expensive.

Industrial wastes(Fly ash & Red mud)-

Reinforcement Fly Ash (FA) and Red Mud are typical industrial waste gotten from the power plant and Aluminium industry respectively [11,12]. These wastes have been suggested to be suitable for use as reinforcing materials in AMCs. Although research work reporting the use of red mud as reinforcement in MMCs are sparse, extensive studies have been carried out on the use of fly ash as reinforcement in both single and hybrid composites [11.13] . Fly ash is a bye product of coal combustion and is readily available in many industrialized nations[13].The preponderant oxides in the FA include Al2O3,SiO2, and Fe2O3while other oxides that are present in trace amount include K2O, NaO and MgO. The preponderant oxides make FA suitable for use in synthesis of AMCs. Moreover low-density and low cost are other attractive benefits of FA.

Red mud is the caustic insoluble waste residue generated by alumina production from bauxite by the Bayer's process at an estimated annual rate of 66 and 1.7million tons, respectively, in the World and India. It is estimated that two tons of alumina used to produce one ton of Aluminium and 58% of alumina and 42% of red mud come out from one ton of bauxite approximately. Under normal conditions, when one ton of alumina is produced nearly a ton of red mud is generated as a waste. In terms of metal production the ratio of aluminium to red mud is 1:2. This waste material has been accumulating at an increasing rate throughout the world.

Anikumar et al. [11] in contrast to the findings of Gikunoo et al. [13] reported that increased tensile strength, compressive strength and hardness was obtained by increasing weight fraction of FA up to 15% in Al(6061)based composites. Although uniform distribution of the FA was obtained in the Aluminium matrix, the ductility decreased with increase in weight fraction of FA. An increase in particle size of FA reduced the strength (tensile and compressive) and hardness of the resulting composites. It is reasonable to conclude that, like the synthetic ceramic particles, improved hardness and tensile strength is obtainable when FA is evenly dispersed without clustering or segregation in the matrix. Apart from the influence of FA on hardness, tensile and compressive strengths, several other authors have reported that FA improves the wear resistance and machinability of AMC composites due to the solid lubricating effect it possesses, low cost and low density. Consequently, FA has been used as a complementing reinforcement to synthetic ceramic particulates in the development of hybrid AMCs.

Prasatand Subramanian [14] studied the tribological properties ofAlSi10Mg/fly ash/graphite hybrid metal matrix composite. They found that the tensile strength, hardness and wear resistance were higher in the hybrid composite compared to unreinforced alloy and alumina–graphite composites. The improved wear resistance was attributed to load bearing capacities of FA and the lubricating effect of graphite; wear rate was also observed to reduce with increase in FA content.

Moorthy et al. [15] studied the dry sliding wear and mechanical behavior of Aluminium/Fly ash/Graphite hybrid metal matrix composites using Taguchi method and reported that load was the most influencing factor affecting the wear rate of the composites followed by sliding speed and fly ash content respectively. There was an increase in the hardness of the hybrid composites as fly ash content increases. FA can also be used to suppress interfacial reaction that exists between matrix and the reinforcing particulate.

Agro waste derivatives-

The advantages of agro waste are low cost, accessibility, low density, and reduced environmental pollution.

Examples-Bamboo leaf ash (BLA), Rice husk ash (RHA), Bagasse ash (BA), Palm kernel shell ash (PKSA), Maize stalk ash(MSA), Corn cob ash (CCA), Bean shell waste ash (BSWA)

Rice husk is unusually high in ash, which is 92 to 95% silica, highly porous and lightweight, with a very high external surface area. Its absorbent and insulating properties are useful to many industrial applications, such as acting as a strengthening agent in building materials. Rice husks are processed into rectangular shaped particle boards.

An overview of the recent studies on AMCs reinforced with agro waste derivatives and synthetic ceramic particulates is presented below. The fabrication characteristics and mechanical behavior of rice husk ash–alumina reinforced Al-Mg-Si alloy matrix hybrid composite produced via stir casting was studied by Alaneme et al. [16]. The 10 wt% reinforcing phase consisted of 2, 3, 4, and 6 wt% RHA as a complementing reinforcement to alumina. The authors reported that there was a slight decrease in hardness, ultimate tensile strength of the hybrid composites as compared with the single reinforced Al-Mg-Si/Al2O3composites. However, composites sample containing 2 wt% exhibited higher specific strength, percentage elongation and fracture toughness than the single reinforced AMCs. The slight reduction in yield strength, ultimate tensile strength and hardness was attributed to lower hardness value of silica, which is the predominant compound in the rice husk ash.

Prasad et al. [17] carried out an investigation on stir cast aluminium hybrid composite containing equal amount of rice husk ash and silicon carbide from 2% to 8% in step of 2. They found out that there was homogenous distribution of the reinforcement in the matrix .Hardness, yield strength and ultimate tensile strength increased with increase in the reinforcement while percentage elongation and CTE had inverse relationship with increasing reinforcement.

Considering the articles surveyed on hybrid AMCs, it is reasonable to conclude that using agro waste derivatives as a complementing reinforcement in the development of hybrid AMCs can improve the fracture toughness and ductility of AMCs without significant drop in strength. Despite the potentials of agro waste derivatives in cost reduction and maintaining performance levels in terms of mechanical properties, a few number of researchers were curious about the influence of agro waste derivative reinforcements on the corrosion and wear performance of AMCs when they are used in applications where they are exposed to corrosive and wear attacks. The agro waste derivatives are known to have the potentials of suppressing Al4C3phase due to presence of more than 50% silica in their composition just as in the case of fly ash. It was of interest to some researchers to find out if this phenomenon would help achieve improved corrosion resistance in hybrid AMCs reinforced with synthetic and agro waste derivative reinforcements.

Alaneme et al. [18] studied the influence of BLA on the corrosion performance of hybridAMCs reinforced with BLA and SiC using gravimetric analysis. They revealed that the BLA improved corrosion resistance in3.5% NaCl while the single reinforced Al-Mg-Si/10 wt% SiC had superior corrosion resistance in 0.3 M H2SO4. Similar observation of inferior corrosion resistance due to RHA was also reported for hybrid Al-Mg-Si/SiC-RHA composites in 3.5 wt%NaCl environment

Although RHA and BLA can effectively avoid the formation of Al4C3 phase during the fabrication of hybrid AMCs, the precipitation of Mg2Si in some cases enhance localized corrosion. In general, for most of the hybrid AMCs, the wear rates are comparable with the single reinforced AMCs.The wear performances of certain mix ratios of the reinforcements (agro waste derivatives + synthetic ceramic materials) are usually superior to that of the single reinforcedAMCs.

The hybrid AMCs reinforced with agro waste derivatives have shown that high performance levels can be maintained in AMCs at reduced production cost even at about 50% replacement of synthetic reinforcement with the agro waste. More agro waste should be investigated and further studies should be concentrated on how to optimize the production process to determine the optimum processing parameters. This will serve as a basis for producing hybrid MMCs on a commercial scale using agro and industrial waste.

3. CURRENT CHALLENGE

An MMC should consist of fine particulates distributed uniformly in a ductile matrix and with clean interface between particulate and matrix. However, the current processing methods oftenproduce agglomerated particles in the ductile matrix and as a result the MMC exhibits extremelylow ductility. Agglomeration is more severe when the particulate size is in sub-micronor nano-scale range. Severe agglomeration nature of nano-particles, due to high cohesive energy, combined with lack of dispersive technology for mixing poorly-wettable nano-particles havehindered the progress in fabrication of high performance nano-particulate MMCs with liquidprocessing routes.

4. CONCLUSION

From literature review related to the Aluminium metal matrix Composite material it is concluded that, the pure aluminium mixed with some other material through the process like stir.Synthetic ceramic particulateslike Silicon carbide (SiC), alumina (Al2O3), boron carbide (B4C), tungsten carbide (WC), graphite (Gr), carbon nanotubes (CNT)and silica (SiO2) SiC will increase tensile strength; wear resistance and hardness with increasing reinforcement. Agro waste derivatives like Bamboo leaf ash (BLA), Rice husk ash (RHA), Bagasse ash (BA), Palm kernel shell ash (PKSA), Maize stalk ash (MSA), Corn cob ash (CCA), Bean shell waste ash (BSWA) will increase Hardness, yield strength and ultimate tensile strength. Industrial wastes Fly Ash (FA) and Red Mud improved hardness and tensile strength and reduce wear rate.

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