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Analysis of mechanical and tribological behaviour of Aluminum metal matrix composite reinforced with graphene-A Review

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ABSTRACT

The drastic growth as well as progress of metal matrix composites are playing vibrant role in various sectors. Aluminum matrix composites have the impending of less density engineering materials through superior mechanical as well as tribological characteristics. Aluminum metal matrix composites is widely utilised in aeronautical, aerospace and automobile sectors due to its high strength and low density characteristics. This review article emphasis on the compilation of the work accomplished by various researchers on the aluminum metal matrix composite reinforced with graphene. As a matter of fact, graphene is reinforced with aluminum matrix composite subjected to numerous manufacturing routes like powder metallurgy, stir casting, in-situ processes for different applications. An endeavour is made to address the effect as well as influence of the graphene reinforced with aluminum metal matrix composite on the mechanical and microstructural characteristics are addressed in the literature. Further, the influence of various criterion like graphene percentage, processing method, process parameters adopted during the manufacturing process and behaviour of aluminum metal matrix composite is also presented.

KEY WORDS: Aluminium metal matrix composite, Graphene, Mechanical behaviour, Microstructure.

1. INTRODUCTION

Composite material entail of two or more materials added together to obtain superior properties of mechanical as well as thermal properties (Surappa, 2003). Composite materials are preferred to replace the traditional materials due to obtain high specific strength, high hardness, high creep resistance, high corrosion resistance and low density. The metal matrix composite properties could be changed / increased further by adding reinforcement particles to the base or matrix materials. Different methods were existing to formulate particle reinforced into metal matrix composites. Normally, categorized into following methods such as solid state synthesizing, liquid state synthesizing and vapour deposition methods. The straightforward route in the powder metallurgy method, in which all ingredients position in the dense state to achieve the least possible porosities as well as the highest possible density. Generally composite materials with a metal matrix are produced by different casting methods and powder metallurgy methods. In the casting method composite materials reinforced by dispersion particles, platelets, non-continuous fibres and continuous fibres. Reinforcing elements blending with matrix produced composite materials. Generally mixing process is performed under atmospheric pressure and reinforcing elements should be characterized by good wettability by the molten metal (Kaczmar, 2000). The mechanical characteristics of composite materials reinforced with metal, polymer and ceramic particles depend on the matrix properties, reciprocal wettability at interphase as well as the quantity of reinforcing phase and the scope of the reinforcing particles. During the process there is several casting defects are occurring in the casted part. Hamid (2014), investigated that the pores percentage increases with enhancing reinforcement (alumina) percentages because of the effect of low wettability as well as agglomeration at astronomical matter of reinforcement as well as pore nucleation at the matrix as well as alumina interfaces. These effects are mainly due to the process parameters of stir casting stirring time plays a significant role in the creation of porosity defect so that with increasing process parameter of stirring time proportionally porosity percentage increased. Gopalakrishnan (2012), studied stir castings with different volume fraction of reinforcement were synthesized in an argon mood to escape oxidation by a modified stir casting route. Stir casting method is the conventional as well as economical lane of fabricating aluminium matrix composite. Atkinson (1997), investigated diverse multipurpose hot isocratic pressing behaviours on porosity in the aluminum casting and optimum treatment was identified. Akhlaghi (2004), investigated on aluminium reinforced by means of compo-casting methods as well as the outcomes of casting temperature on the composites. Also tried in two different routes such as semi-solid and semi-solid to liquid routes. Microstructural result reveals that more similar dissemination of reinforcement obtained through semi-solid to liquid method rather than semi-solid to semi-solid method and less porosity content. This review is focused on matrix material is aluminum reinforced with graphene in different forms such as particles, sheets and platelets synthesized by different methods.

2. METHODS AND MATERIALS

Powder metallurgy technique: Jingyue Wang (2012), carried out work on aluminum as matrix material reinforced with graphene in the form of nano sheets (GNS) through powder metallurgy process as a flake form. Even though graphene has high fracture strength of 125 GPa, making it an ideal reinforcement for composite materials to achieve high fracture strength. Through powder metallurgy technique the ultimate tensile strength of 249 MPa were observed in the Al composite reinforced with adding only 0.3 wt.% GNSs, which is 62% enhancement when compared with the unreinforced Al matrix. Also discussed through experimental procedure appropriate strengthening methods concerned in the GNS/Al composites.

Yan (2014), investigated on aluminium matrix reinforced with nano graphene composites were successfully formulated over ball milling and subsequently followed powder metallurgy process. Adding of 0.3 weight fraction of graphene the mechanical belongings of tensile strength as well as yield strength were observed 454 MPa and 322 MPa which are 25% and 58% superior to the base material and ductility increases slightly.

Stir casting technique: Aluminium metal matrix composites prepared by stir casting method need to be considered following points such as identical scatter of reinforcement particle into matrix material, bonding between substances, minimised porosity level in the casted aluminum matrix composites and chemical reaction between reinforcement and matrix materials should be avoided.

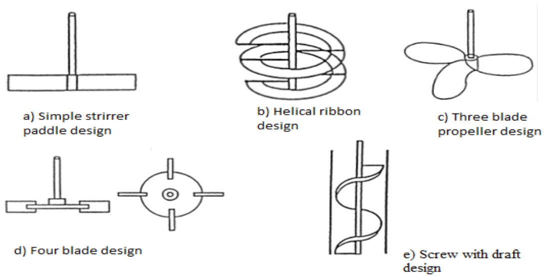

Figure.1. Design of mechanical stirrers (Hashim, 1999)

In the view of ensuring identical scatter of reinforcement particles settling during casting or melting this arises result of density transformations between reinforcement particle and matrix material. Though stir casting process following parameters is considered such as melt temperature, stirring time, reinforcement volume as well as nature of particles. The vortex technique is better approach to generate and sustain a good scatter of reinforcement in the matrix material. In the vortex technique, after the matrix material is reached as a liquids stage it is stirred continuously to form a vortex over the surface of the melt simultaneously reinforcement material is presented at the side of the vortex. Stirring process maintain stirring time 5 to 10 minutes before the slurry is casted. Hashim (1999), investigated diverse proposals of mechanical stirrers among them turbine model stirrer is popular as shown in fig.1 (a-e). Wettability is another suggestive problem in metal matrix composites which can be expressed as the capability of a liquid to spread on a solid surface. To improve wetting following assumptions has been considered such as (a) increasing solid surface energies (b) surface tension decreasing of liquid matrix alloy (c) solid-liquid interfacial energy decreasing at the particles matrix interface. The bonding force can be stated in terms of contact angle referred to Young-Dupre equation. The magnitude of the contact angles in the equation describes the wettability as shown in the fig.2. Faultless wettability $\Theta = 0°$, no wettability $\Theta = 180°$ and partial wettability $0° < \Theta < 180°$.In general a clean and clear surface delivers a better chance for melt particles interaction improves wetting based on ultrasonic techniques, various etching techniques and heating in a suitable atmosphere can be used to clean the particle surface.

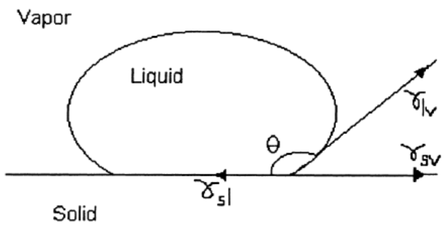

Figure.2.Wettability contact angle

Porosity defect cannot be completely escaped during the process of casting but it can controlled in some level. Porosity defect occur mainly due to (a) gas entrapment during mixing (b) hydrogen evolution (c) shrinkage during solidification. During stirring, process parameters of holding time, stirrer speed and location of the impeller will influence the progress of porosity. Some of the researchers prove that there is a decrease in the porosity level with increasing holding temperature. Baradeswaran (2014), studied about the influence of graphite on the wear behaviour of Aluminum 7075/Al_2O_3/graphite hybrid composite were prepared with 5wt% graphite particles and different wt % of Al_2O_3. Hybrid composites strength such as tensile, flexural, compression strength increased by increasing the reinforcement percentage. Also concluded that wear properties of the hybrid composites reveal superior wear resistance behaviour.

3. RESULTS

Graphene: Geim (2009), reviewed about graphene status and prospects also emphasize peculiar characteristics of graphene. It is a marvel material with numerous positive preferences like thinnest material in the globe and the strongest ever measured. Graphene is two dimensional single atomic carbon sheet of sp^2 bounded in which carbon atoms densely packed in a honeycomb lattice. It is a most common form of carbon is stacked of several graphene sheets with spacing of 0.34nm. The bonding between carbon atoms is very strong while there are wear vanderwaals interactions among the layers.

Several research papers are publishing in everyday the amount of literature on graphene trend is in incremental position. Still the scope of graphene is unlimited and preferred because of its superior properties. Afsaneh Dorri Moghadam (2015), reviewed the mechanical as well as tribological behaviours of metal matrix nano composites with adding of carbon nanotubes and graphene particulates. The result envisaged that joining of carbon nanotubes (CNT) as well as graphene reinforcements to metals diminishes both coefficient of friction and rate of wear also enhances the tensile strength simultaneously. Also mechanical and tribological behaviours were improved. Harshitporwal (2013), observed that the toughness of fracture composite materials increased 40% with addition of 0.8 vol% of graphene. The content of higher graphene improvement in fracture toughness limited. Also graphene transformed the crack propagation mechanism for the alumina matrix from intergranular to transgranular. Elastic modulus remained constant for upto 2 vol% and decreased 5vol% because of interconnecting graphene formation. Pulkit Garg (2016), investigated sintering temperature effect on aluminum matrix composite reinforced with graphene through powder metallurgy process. Addition of graphene reinforcement into aluminum matrix composite strength was increased.

Tribological property: Tribology is an investigation of wear as well as friction performance of materials. It dealt with science of interacting surfaces in relative motion when the external forces acting on the materials. When the sliding process of softer materials against harder materials the atoms will be taken off from the softer one and these atoms tend to locate themselves in the asperities of harder surface. Usually friction forces tend to shear at interatomic junctions during movement of two surfaces under an external applied force. Also metal matrix composites have lesser coefficient of friction compared to unreinforced matrix. Adding of reinforcement particles to the matrices leads to enhance wear resistance of composites. The main reason for enhancing the wear resistance of metal matrix composite is attributed to low friction coefficient of metal matrix composite compared to the unreinforced matrices.

Monikandan (2015), describes the tribological characteristics of hybrid AA6061- 10 wt% B4C- 7.5 wt % Gr composites used as a potential substitute for aluminum alloys used in automotive engines. The tribological experiments performed and result reveals that the wear loss increases with applied load and sliding distance and the friction coefficient increases with increase in applied load.

4. CONCLUSION

This paper summarizes the mechanical characteristics and tribological characteristics of aluminium metal matrix composite reinforced with graphene formulated by different process. The influence of various criterions and processing conditions on the aluminum metal matrix composite was analysed adequately. Also addressed the effect of the graphene percentage on the aluminum metal matrix composite processed by different methods.

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