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A Study on Mechanical and Microstructure Properties of Aluminium Metal Matrix Composite

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ABSTRACT

Aluminum based hybrid metal matrix composite with more than two particle reinforcement is very much popular for heavy duty application. In the present study, mechanical properties of AA7175 based hybrid composite synthesized using liquid metallurgy route with 3 to 12wt. % total reinforcement (B4C+SiC+Gr) with different proportions of B4C wt. %, SiC wt. % and Gr wt. % were investigated. Hardness measurement and uniaxial loading techniques were used to characterize the mechanical properties of the as-cast hybrid composites. The improvement in mechanical properties, such as Vickers hardness value, UTS, yield strength and elongation were tried to explain using various hypothesis proposed by previous studies. Scanning electron microscope were analyzed

Keywords: Composites, Casting, Reinforcement, Scanning, Strength

1. Introduction:

Al based Metal Matrix Composites (MMCs) are extensively used in automotive applications due its light weight and excellent mechanical properties. Despite having such outstanding property, continuous efforts are being made to improve its strength and stiffness, and as a result of this, researchers have tried to add numerous reinforcement (particle) into the base metal [1]. As far as reinforcements are concerned, variety of filler materials ranging from macro to nano size particles in both polymer and metal matrix composite, fiber type filling materials for laminated composites and some cry-treated particle hardened filler material are commonly practiced for the synthesis of composite material [1-4]. Out of these reinforcement discussed, Aluminum [MMCs] with particulate reinforcement showed promising results in the form of improved strength and high stiffness which are more desirable for automotive and aircraft industry.

While discussing about the particulate reinforcement, researchers from all over the world have worked with ceramic based hard particles (SiC, TiB_4, Al_2O3, Gr, MgO, WC, B_4C and Fly-ash) for Al based composite to strengthen the base material [5].

With the development in production technology, a new trend was adopted while preparing composites using two or more reinforcement to impart high specific strength, high toughness and better ductility property compared to conventional techniques [6-8]. As far as the use of SiC as a reinforcement to the base material (AA7175) is concerned, it substantially increased both the mechanical and tribological properties of the composite due to its high hardness [9-11]. In addition to the conventional liquid metallurgy route, researchers have also tried powder metallurgy route to produce *in-situ* hybrid composite of AA7175, SiC, B_4C and graphite particles [12].

A group of researchers have shown remarkable improvement in the tribological property of AA7175/SiC hybrid composite by adding a fixed proportion of boron carbide (B_4C) and Gr to the Aluminum metal matrix [13]. There are instances, where researchers have reported an increase in hardness and wear property of hybrid composite with the increase in SiC particle content [14-15]. The role of boron carbide (B_4C) is found to be identical to silicon carbide (SiC) and Graphite (Gr) particle which has also improved the tribological property significantly [16].

The improvement in tribological property due to boron carbide addition (B_4C) is due to its intersection bonding with Al matrix in comparison with SiC and Al_2O_3 particle [17]. Silicon carbide-based hybrid composites are also studied with other Al alloys such as A356 and they also show promising results [18-19]. A comparison of individual properties of AA7175 aluminum alloy, B_4C, SiC and Gr is given in Table 1, and the density of Al base alloy is almost equal to the boron carbide, whereas the SiC seems to be relatively dense. The hardness of boron carbide and Silicon carbide is much higher than Al base alloy and the presence of B_4C (hardest among all) may affect the hardness of the Al hybrid metal matrix composite. To enhance the overall properties of aluminium alloys, aluminium matrixis reinforced with a second phase which is hard and brittle and the new material formed is known as aluminium metal matrix composites (AMMCs). This new material called composite has excellent mechanical and tribological properties and found applications in aircraft and transportation sectors. Composites, the absolute and wonderful materials have low weight, high wear resistance, corrosion resistance and strength.With technology advancement it has become promising to manufacture novel composite materials, better than the existing composites; with improved physical and mechanical properties. An exclusive advantage of these material is that the characteristics of thesynthetic material can be tailored to a particular engineering application.

2. Literature Review

The composite manufacturing came into existence to manufacture a new material, the characteristics of which can be made-to-order according to the requirement, by mixing the ductile and tough matrix (Al, Mg etc.) with a highly wear resistant and strong ceramic particles (Taha; 2001). The aluminum matrix when reinforced with the particulates like SiC, Al_2O_3, B_4C etc. their strength and tribological properties enhanced as compared to pure aluminium metaland thesealuminium metal matrix composites (AMMCs) combined the metallic properties of matrix alloys (elongation and hardiness) with ceramic properties of reinforcements (high strength and high modulus), to form a new material with combination of properties of both matrix and reinforcement (Seo and Kang; 1995, Ramesh et al.; 2009 and Lashgari et al.; 2010).

Karamis et al. (2012) manufactured AMMCs by taking Al2124 as metal matrix and SiC, B_4C and Al_2O_3 (by varying the particle size and volume fraction of reinforcement) by the powder metallurgy process and compared the wear resistance of manufactured composites with conventionally used cam material (GGG40). Wear resistance of composites reinforced with Al_2O_3 decreased with increasing the volume fraction of Al_2O_3 whereas the wear resistance of composites reinforced with SiC and B_4C increased with increasing content of SiC and B_4C. Wear resistance of composites reinforced with SiC and B_4C was better than of cam material (GGG40).

AMMCs were recognized as the most important material in the present time and their applications are increasing with rapid rate because of their unconventional engineering properties, such as their improved wear resistance and strength as compared to conventional aluminium alloy (Bayhan and Onel; 2010). ParticulateAMMCs were recently used in the manufacturing of cylinder liners, crankshafts and the aircraft and transportation industries because of their high strength, low weight and high temperature stability (Liu et al.; 2010).

3. Methodology

Stir casting method of formation of composites: The piece of composite developed by the stir casting method using mechanical stirrer or sometimes it could be the manual stirring of the molten aluminium based alloys of any grade. The powder forms of the different reinforced materials were pre heated and being injected to the molten aluminium alloys around 710^0C-820^0C, at the any type of resistance under a controlled atmosphere of argon. The very fine powders of chosen reinforcements will be added to the molten metal has been taken as the weight percentage of the base material in a 0, 3,6,12 weight percentage or 3, 6, 9 and 12 weight percentage. As i discuss above the temperature of the furnace has been taken into the range of 710^0C to 820^0C and the stirring continued for almost 10 to 15 minutes for the production of a homogeneous molten metal mixture at a stirring speed of 450 rpm and after that the crucible taken out of the furnace and the molten metal had been poured into the desired shape of the mould and allowed to solidify and then it had been taken out of the mould.

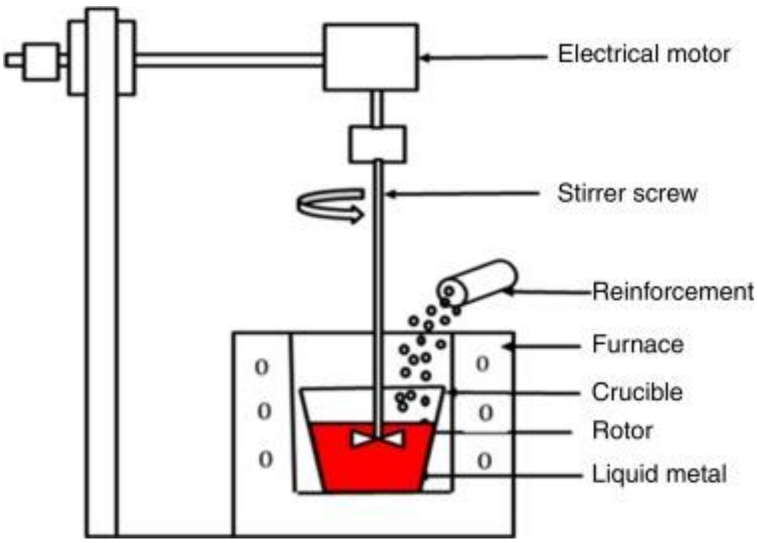

Figure 3.1: Stir Casting

4. Mechanical and Tribological Properties

4.1 Hardness and Brinell Hardness Tester

Hardness is a characteristic of a material, not a fundamental physical property of the material. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation.

More simply put, when using a fixed force (load) and a given indenter, the smaller the indentation, harder the material. Indentation hardness value is obtained by measuring the depth or the area of indentation using one of over 12 different test methods.

The Brinell hardness test method is used to determine Brinell hardness, is being defined in ASTM E10. It is used to test most commonly materials that have a structure that is too coarse or that have a surface that is too rough to be tested using another test method, e.g., castings and forgings. Brinell testing often use a very high-test load (upto 3000 kgf) and a 10 mm diameter indenter so that the resulting indentation averages out most surface and sub-surface inconsistencies.

The Brinell method applies a predetermined test load (F) to a carbide ball of fixed diameter (D) which is held for a predetermined time period and then removed. The resulting impression is measured with a specially designed Brinell Microscope or Optical system across at least two diameters- usually at right angles to each other and these results are averaged (d). Although the calculation below can be used to generate the Brinell number, most often a chart is then used to convert the average diameter measurement to a Brinell hardness number.

Common test forces range from 500kgf often used for non-ferrous materials to 3000kgf usually used for steels and cast iron. There are other Brinell scales with load as low as 1kgf and and 1mm diameter indenters but these are infrequently used. See fig. 13, Brinell test method below:-

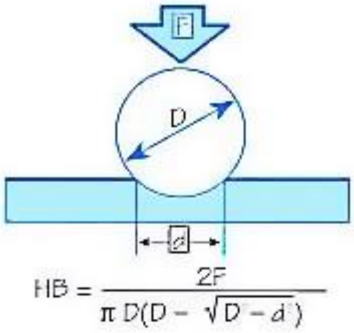

Figure 3.2: Brinell test method below

Test Method illustration

D = Ball diameter

d = Impression diameter

F = Load

HB = Brinell result

Typically the greatest source of error in Brinell testing is the measurement of the indentation. Due to disparities in operators making the measurements, the results will vary even under perfect conditions. Less than perfect conditions can cause the variation to increase greatly. Frequently the test surface is prepared with a grinder to remove surface conditions.

4.2 Tensile Test

Material to be tested for its tensile strength and for this we have to prepared our sample ready to test, the composite specimen prepared according to IS 1608(P-1) 2018'standard. The sample is of 6mm×5.90mm standard and in a dumbbell form where the two ends were wider because it needed to be gripped in the jaws of the tensile testing machine.

The dumbbell shape is being cut out from the heavy casting of A7175 composite and for this the method is being carried out is "Wire **EDM**" at the 'central tool room, nilokheri, haryana'. Electric discharge machining (EDM) is a manufacturing process that implements electrical sparks to form a metal shape. Because of these sparks, EDM is also sometimes referred to as spark machining. In this process, the desired shape is cut from the metal when current discharges, or sparks, occur between two electrodes, where the sparking occurs, cut are made into the metal, creating the desired shape and detaching it from the metal sheet.

4.4 Elongation Test

Elongation of the material is measured when it is under the tensile load, aluminium in its pure form has more elongation percentage but after reinforcement addition it had become more harder and least elongation percentage material.

Tensile elongation is the stretching that a material undergoes as it is pulled in tension. Tensile elongation is a measure of both elastic deformation and plastic deformation, and is commonly expressed as a percentage.

4.5 Microstructure Analysis

4.5.1 SEM

Scanning electron microscopy is utilised to determine the microstructure of material. In this process, the sample is scanned with electrons overall surfaces. All images show the particle distributions of all the metallic and non-metallic elements. In which three homogeneous, some areas of the image consist the agglomerated particles.

Conclusions

From the present study on the fabrication and mechanical properties of the aluminium metal matrix composite, following conclusion have been drawn:-

- The fabrication process of the AMMCs is very diverse and need more study that help during casting as well as precautions and safety procedures of the thermal labs needed to be follow.
- The hardness (HB) of the composite found more or the hardness of the composite improved with respect to the aluminium alloy as well as it will continue to improve with the increase in percentage of reinforcement.
- The tensile strength of the composite is found to be more with respect to the original alloy, and it has been more stronger at the highest percentage of the reinforcement.
- The elongation percentage has been found in a decreasing way which means one can say that, when percentage of reinforcement increases the composite tends to be harder and stronger.
- The Scanning Electron Microscopy shows the uniform composition of reinforcements.

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