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Evaluation of Mechanical Properties of Aluminum Alloy 6061-Glass Particulates reinforced Metal Matrix Composites

Madhu Kumar YC[1], Uma Shankar[2]
[1]P.G student Department of Mechanical Engineering, SIT Tumkur
[2]Professor, Department of Mechanical Engineering, SIT Tumkur

Abstract: *Aluminum matrix composites (AMCs) refer to the class of light weight high performance aluminum centric material systems. The reinforcement in AMCs could be in the form of continuous/discontinuous fibers, whisker or particulates, in volume fractions. Properties of AMCs can be tailored to the demands of different industrial applications by suitable combinations of matrix, reinforcement and processing route. This work focuses on the fabrication of aluminum alloy (6061) matrix composites (AMCs) reinforced with 3 to 12 wt% glass particulates of 75µm, 88µm, 105µm and 250µm using stir casting route. The microstructure and mechanical properties of the fabricated AMCs were analyzed. The mechanical properties like hardness and tensile strength of the unreinforced alloy and composites have been measured. The mechanical properties like hardness and tensile strength have improved with the increase in weight percentage of glass particulates in the aluminum matrix.*

Keywords: *Metal Matrix Composites, Glass particulate, Stir casting.*

I. INTRODUCTION

Metal matrix composites (MMCs) are increasingly becoming a new class of material in aerospace applications because, their properties can be tailored through the addition of selected reinforcements [1-2]. In particular, particulate reinforced MMCs have recently found special interest because of their specific strength and specific stiffness at room and elevated temperatures [3]. Applications of Aluminum-based MMCs have increased in recent years as engineering materials. The introduction of a ceramic material into a metal matrix produces a composite material that results in an attractive combination of physical and mechanical properties which cannot be obtained with monolithic alloys. Discontinuously reinforced aluminum matrix composites have emerged from the need for light weight, high stiffness materials which are desirable in many applications, mainly on automobile products such as engine piston, cylinder liner, brake disc/drum etc. The strengthening of aluminum alloys with a reinforcement of fine ceramic particulates has greatly increased their potential in wear resistant and structural applications [1–13]. There is an increasing interest in the development of metal matrix composites (MMCs) having low density and low cost reinforcements. Although these MMCs have better properties including high strength, high stiffness and better wear resistance their usage is limited due to their high manufacturing cost. Among the various discontinuous reinforcements used, glass particulate is one of the most inexpensive and low-density reinforcement. Incorporation of glass particles reduces the cost and density of aluminum and its alloys.

A. M. S. Hamouda, S. Sulaiman, T. R. Vijayaram, M.Sayuti, M.H.M.Ahmad.[1] discusses the processing and characterization of quartz particulate reinforced aluminum-silicon alloy matrix composite which were fabricated by stir casting technique with percentages of SiO_2 particle varying from 5 to 30 wt% with particle size of 65µm in steps of 5 wt%. Hardness values were measured for the quartz particulate reinforced LM6 alloy composites and it has been found that it gradually increases with increased addition of the reinforcement phase. The tensile strength of the composites decreases with the increase in addition of quartz particulate.

Sudarshan, M.K. Surappa.[2] in their paper deals with the mechanical properties such as hardness, tensile strength, compressive and damping characteristics of A356 Al and A356 Al-fly ash prepared using stir-cast technique and hot extrusion, in which 6-12 wt% of fly ash was dispersed in the base matrix. Bulk hardness, matrix microhardness, 0.2% proof stress of A356 Al–fly ash composites are higher compared to that of the unreinforced alloy. Additions of fly ash lead to increase in hardness, elastic modulus and 0.2% proof stress. Composites reinforced with narrow size range fly ash particle exhibit superior mechanical properties compared to composites with wide size range particles. A356 Al–fly ash MMCs were found to exhibit improved damping capacity when compared to unreinforced alloy at ambient temperature. Damping capacity of fly ash reinforced Al-based composite increases with the increase in volume fraction of fly ash.

Joel Hemanth.[5] Have studied the mechanical and abrasive, slurry erosive wear with chilling effect of fused silica (SiO_{2p}) as reinforcement and aluminum alloy (A356) as a base material. The chills used were metallic and non-metallic chills. The fused silica particles of size 50–100 µm were used as reinforcement varying from 3-12 wt% in steps of 3 wt% Strength, hardness and wear resistance increase up to 9 wt. % additions of dispersoid and copper chill was found to be the best because of its high volumetric heat capacity.

E. Mohammad Sharifi, F. Karimzadeh, M.H. Enayati. [3] Investigated the mechanical and tribological properties of boron carbide reinforced aluminum matrix nanocomposites were fabricated by mechanical alloying with percentages of boron carbide varying from 5 to 15 wt% in steps of 5 wt%. The sample with 15 wt % B4C had the optimum properties. This sample had a value of 164 HV which is significantly higher than 33 HV for pure Al. Also, ultimate compressive strength of the sample was measured to be 485 MPa which is much higher than that for pure Al (130 MPa). The wear resistance of the nanocomposites increased significantly by increasing the B4C content. Dominant wear mechanisms for Al–B4C nanocomposites were determined to be formation of mechanical mixed layer on the surface of samples.

In the present investigation, aluminum based metal matrix composite containing 3 to 12 wt% of glass particulates were successfully synthesized using stir casting method. Evaluating the mechanical properties of produced composites.

II. Materials

2.1 Matrix material

The matrix material used in the experimental investigation was an aluminum alloy (6061) whose chemical composition is listed in Table 1. It therefore has a low melting point 660°c. Aluminium alloy in its unmodified state is extensively used in sand casting and die-casting. The molten metal has high fluidity and solidifies at constant temperature.

Table.1 Chemical composition of Aluminum Alloy 6061 by wt%

Cu	Mg	Si	Fe	Mn	Cr	Zn	Aluminum
0.4	1.2	0.80	0.70	0.15	0.35	0.25	balance

2.2 Reinforcement material

The reinforcement material used in the investigation was glass particulates of particle size of 75µm, 88µm, 105µm and 250µm. Particulates size was estimated by sieve analysis. Chemical composition of reinforcement is listed in Table 2. Particle density is of 2.44 g/cm^3 and melting point is of 1400°c.

Table.2 Chemical composition of Glass particulates by wt%

Sio_2	Na_2o	Cao	Mgo	Al_20_3	K_2o	Tio_2	Fe_20_3
73	14	9	4	0.15	0.03	0.02	0.1

III. Experimental Procedure

The synthesis of the metal matrix composite used in the present work was carried out by stir casting route. Al alloy was used in the form of ingots. The cleaned metal ingots were melted to the desired temperature of 740°C in graphite crucibles. Cover flux was added in to the molten metal in order to minimize the oxidation. Electrical resistance furnace with temperature controlling device was used for melting. For each melting 0.250 kg of alloy was used. 3g of C_2Cl_6 – solid hexachloro ethane was added as degassing tablet in to the super heated molten metal at a temperature of 700°C. Glass particulates preheated to around 300°C for 30 mins were then added to the molten metal and stirred continuously for 5 min. During stirring, magnesium was added in small quantities to increase the wettability of glass particulates. The dispersion of the preheated glass particulates was achieved in accordance with the stir casting route. The melt with reinforced particulates were poured into the dried cylindrical permanent metallic moulds of size 12.5mm diameter and 160mm height. The pouring temperature was maintained at 680°C. The melt was allowed to solidify in the moulds.

3.1 Tensile strength

The tensile tests were conducted on servo hydraulic UTM at room temperature. The samples were prepared according to ASTM E8M. The tensile properties of the alloys were determined by performing the tension test on standard cylindrical tensile specimens. A typical tensile specimen as per ASTM standard is shown in Fig 1.

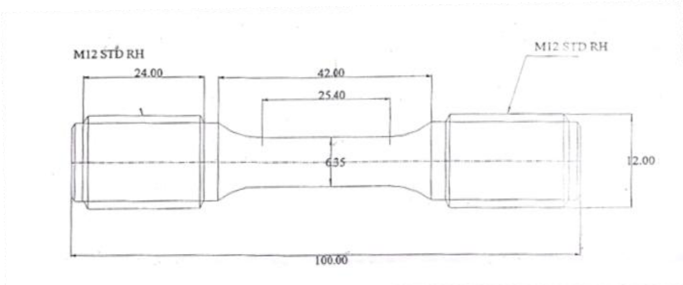

Fig.1. Tensile Specimen as per ASTM standard

3.2 Hardness testing

Micro hardness was calculated by using Zwick/Roell Micro Vicker's hardness testing machine. A precision diamond indenter is impressed on material at a load of 50 grams for 10 secs. In order to avoid the segregation effect of the particles, fifteen readings were taken for each sample and the average value is reported.

IV. Results And Discussion

4.1. Evaluation of microstructure

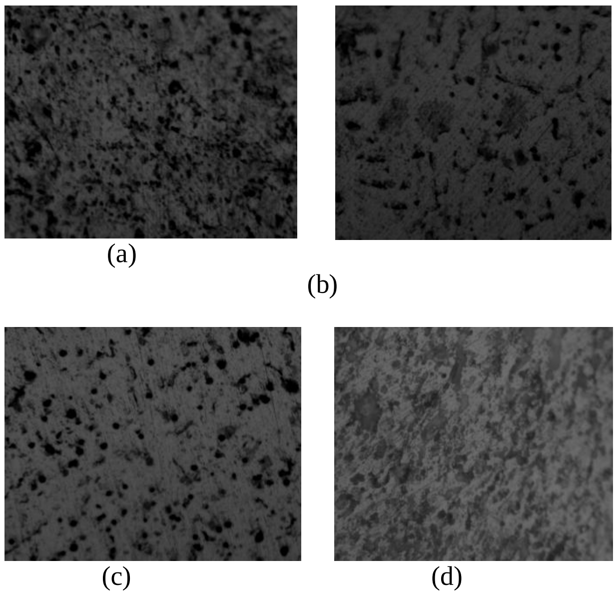

Fig.3. Photomicrographs of the cast Al6061–75µm glass particulate AMCs: (a) 3% glass particulate, (b) 6%glass particulate, (c) 9% glass particulate, (d) 12% glass particulate at 100x.

The optical photomicrographs of the fabricated AMCs are shown in Fig. 3. It is observed from the figure that glass particulate are dispersed uniformly in the aluminum matrix at all weight percentage. The size of the glass particles appears to be uniform throughout the aluminum matrix. This can be attributed to the effective stirring action and the use of appropriate process parameters. Homogeneous distribution of particles is to enhance the mechanical properties of the matrix alloy.

4.2. Evaluation of tensile strength

Fig. 4 shows the relation between weight percentage of glass particulates and tensile strength of fabricated composites. It is observed that the Al alloy (6061) has tensile strength of 119 Mpa. Tensile strength increases by adding the reinforcement up to 9wt% and then decreases with increasing wt% of glass particles. Increase in tensile strength (reinforcement up to 9 wt. %) is attributed to increase in grain boundary area due to grain refinement, at the interface and effective transfer of applied tensile load to the uniformly distributed well bonded reinforcement.

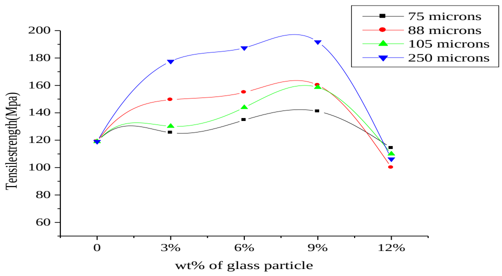

Fig.4. Shows the relation between weight percentage of glass particulates and tensile strength

4.3. Evaluation of hardness

Fig. 5. Shows the relation between weight percentage of glass particulates and hardness of fabricated composites. It is observed from the figure that the hardness of Al alloy (6061) is 75 and then hardness increases with increasing wt% of glass particulate upto 9wt% and then decreases with increasing wt% of glass particles.

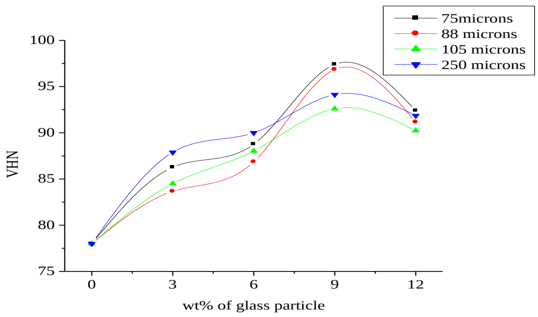

Fig.5. Shows the relation between weight percentage of glass particulates and hardness.

V. Conclusions

Aluminum-Glass particulate composite was successfully synthesized by the stir casting method. The tensile strength of the composite increased with increase in wt% of glass particulates up to 9%.The micro hardness of the composites increased with increase in wt% of the dispersoid upto 9 wt% and further addition of dispersoid showed that the hardness decreases. Microstructural observations show that the glass particulates are uniformly distributed in the Al6061 matrix.

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