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Experimental Study on Effect of Silicon Carbide and Graphite particles on Mechanical Behaviour of Alluminium-6061 Alloys

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ABSTRACT

In the past few years the global need for low cost, high performance and good quality materials has caused a shift in research from evaluation of purely metallic constituents into light weight composite structures. Considered with the matrix phase of pure aluminum or alloy of the same metal and the reinforcement material used is a non-metallic ceramic such as SiC, Al_2O_3, SiO_2 contribute greatly to the structural behavior once it is processed and tested in the standard conditions. Present work highlights the crucial effect of silicon carbide particulates and specified amount of graphite on aluminum 6061 matrix material. The fabrication of samples were done by most convenient technique called stir casting by adding reinforcing materials in the range of 3%,6%,9% by weight which is effectively mixed in to the matrix of aluminum 6061 alloys by maintaining the standard conditions. Rockwell hardness test is conducted and properties are evaluated experimentally to assess the influence of Silicon carbide with constant amount of graphite powder on the matrix material. It is observed from the results the addition of ceramic particles influence greatly on the hardness number which increases by increasing the silicon carbide content. Similar trend was observed while assessing the compressive strength of the composites along with considerable change incurred with shear deformation was properly recorded.This paper details only about the influence of graphite and silicon carbide mixture is added in varied proportion on aluminium-60601 composites.

Keywords: Silicon carbide, MMC's, Al-MMC's

I. INTRODUCTION

Composite materials have been widely used in engineering applications because of their advantages compared to conventional metallic materials. For instance, composite materials have high specific strength, high specific stiffness, and high resistance to chemical attacks. Especially, in certain application areas such as the petrochemical and gas industry, harsh chemicals cause corrosion and deterioration of the structures over the time. Investigation on the Mechanical Properties of Hybrid Metal Matrix Composites" have studied about the preparation and evaluation of mechanical properties of Al6061-SiC[1-5].The composites were prepared using stir casting method in which amount of reinforcement is varied from 5-15% in steps of 5wt%. The prepared composites are characterized by micro structural studies and density, and mechanical properties were evaluated as per the standards. Their studies revealed fairly uniform distribution of the particles in composites with clustering at few places. The experimental densities were found to be lower than theoretical densities in all the composites. From their research it is observed that the dispersed SiC in Al6061 alloy contributed in enhancing the tensile strength of the composites. Microstructures, mechanical properties and wear characteristics of as cast silicon carbide (SiC) reinforced aluminium matrix composites (AMCs)[6]. AMCs of varying SiC content (0, 5, 10 and 20 wt. %) were prepared by stir casting process. The results of their work showed that introducing SiC reinforcements in aluminium (Al) matrix increased hardness and tensile strength and 20 wt. % SiC reinforced AMC showed maximum hardness and tensile strength and the microstructures observation revealed clustering and non-homogeneous distribution of SiC particles in the Al matrix. Porosities were observed in microstructures and increased with increasing wt. % of SiC reinforcements in AMCs. From their research it is observed that by introducing SiC reinforcements in aluminium (Al) matrix increased hardness and tensile strength of the composite which can be used in our work. Microstructures and corrosion behavior of Al/SiCmetal matrix composites study shows that several Al/Sic volume fractions up to 15 vol% and different SiC particulates average sizes, typically fabricated using conventional powder metallurgy (PM) route[7]. The effect of the size and volume of fraction on the microstructure and corrosion behaviour of Al/SiC metal matrix composites. The results revealed that the Al/SiC MMC's exhibits higher density compare to pure Al matrix. Aluminum alloys reinforced with ceramics particulates have significant potential for structural applications due to their high specific strength and stiffness as well as low density[8]. At room temperature, the Al/SiC composites exhibits better corrosion resistance than the pure Al matrix in 3.5wt.%NaCl aqueous solutions. Increasing the volume fraction of the SiC particulates increased the corrosion resistance of the Al/SiC composites. Hereby reducing the SiC particles size enhanced significantly the corrosion resistance of the SiC composites. Increasing the duration exposure reduces the corrosion rate. At elevated temperature, the Al/SiC composites exhibited lower corrosion resistance than the pure Al matrix in 3.5 wt.%NaCl aqueous solution[9]. However, increasing the volume fraction and/or the SiC particles size reduce(s) the corrosion rates of the Al/SiC composites. The corrosion rates of the pure Al as well as the Al/SiC composites were found to increase linearly with the temperature [10]. A Review on mechanical and tribological Behaviours of Stir Cast Aluminium Matrix Composites study has been carried out to elaborate the essential properties of aluminium composites. Stir casting is a simple and cost effective method for manufacturing of these composites and is essential in expanding their applications. Reinforcements like particulate alumina, graphite and fly ash can be easily incorporated into the melt by this method. Alumina improves the composites mechanical properties, fly ash improves tensile and yield strength and graphite improves the machinability. From their research it can be concluded that Aluminium matrix composites reinforced with varying particles improves upon the mechanical &tribological properties of base aluminium and is suitable for future industrial applications. Preparation and Evaluating of Mechanical Properties of Aluminum Silicon carbide filled Al-6061 Metal Matrix Composites. Analysis of stir cast aluminium silicon carbide metal matrix shows that the Aluminium silicon carbide metal matrix composites are used in various fields like aerospace, aircrafts, underwater, automobile, substrate in electronics, golf clubs, turbine blades, brake pads etc. Several fabrication techniques are available for the production of aluminium silicon carbide metal matrix composites (Al-SiC MMC). Among the various methods, stir casting route is simple, less expensive, and used for mass production. The main limitations of stir cast Al-SiC MMC are improper distribution of SiC reinforcement in matrix and less wettablity of SiC reinforcement particle with molten Al. Literature survey indicate that various properties of stir cast Al-SiC MMC depends upon fabrication method, volume fraction, shape, size of particles and distribution and properties of constituents. Since metal matrix composites (MMC) lack structural simplicity its analytical modeling is complex. Further, the involvement of several parameters which affect composite properties, makes the experiments difficult. This review paper contemplates the need of simulation or numerical methods for the prediction of mechanical characteristics of Al- SiC MMC [11]. Achieving homogeneous distribution of reinforcement within the matrix is one such challenge, and this affects directly on the properties and quality of composite. The aluminium alloy composite materials consist of high strength, high stiffness, more thermal stability, more corrosion and wear resistance, and more fatigue life. Aluminum alloy materials found to be the best alternative with its unique capacity of designing the materials to give required properties. In their work a composite is developed by adding silicon carbide in Aluminium metal by mass ratio 2.5%, 5%, 7.5% and 10%. The composite is prepared by stir casting technique. Mechanical tests such as hardness test, microstructure test are conducted. It is proposed to use this material for power transmitting elements such as gears which are subjected to continuous loading. Finally modelling and finite element analysis of gear is done using CATIA and ANSYS 14.0. In case of increased silicon carbide content, the hardness, and material toughness are enhanced.

II. MATERIALS & METHODOLOGY

Materials Used

Aluminium 6061 (Al)

Fig 1. Aluminum Block

Figure.1 shows Al-6061 is a precipitation-hardened aluminum alloy, containing magnesium and silicon as its major alloying elements. Originally called Alloy 61S, it was developed in 1935. It has good mechanical properties; exhibits good weld ability, and is very commonly extruded. The mechanical properties of 6061 depend greatly on the temperature, or heat treatment, of the material [12-18]. It is one of the most common alloys of aluminum for general-purpose use.

Properties of Al 6061

Mechanical Properties

- Ultimate Tensile strength – 310 MPa
- Modulus of Elasticity – 68.9 GPa
- Hardness, Vickers – 107 Physical Properties
- Density – 2.7 gm/cc
- Elongation – 17% Chemical Properties
- Corrosion resistance

Silicon Carbide (SiC)

Fig 2. Silicon Carbide

Powdered Silicon carbide as shown in figure 2 is composed of tetrahedra of carbon and silicon atoms with strong bonds in the crystal lattice. This produces a very hard and strong material. Silicon carbide is not attacked by any acids or alkalis or molten salts up to 800°C. In air, SiC forms a protective silicon oxide coating at 1200°C and is able to be used up to 1600°C. The high thermal conductivity coupled with low thermal expansion and high strength give this material exceptional thermal shock resistant qualities. Silicon carbide ceramics with little or no grain boundary impurities maintain their strength to very high temperatures, approaching 1600°C with no strength loss

Properties of SiC

4. Density – 3.1 gm/cc
5. Elastic Modulus – 410 GPa
6. Compressive Strength – 3900 MPa
7. Hardness – 2800 Kg/mm2

Graphite Powder

Fig 3. Graphite

Graphite material powder which is as shown in figure.3 is generally greyish-black, opaque and has a lustrous black sheen. It is unique in that it has properties of both a metal and a non-metal. It is flexible but not elastic, has a high thermal and electrical conductivity, and is highly refractory and chemically inert. Graphite has a low adsorption of X-rays and neutrons making it a particularly useful material in nuclear applications.

Physical properties of graphite

1. It has a high melting point, similar to that of diamond.
2. It has a soft, slippery feel, and is used in pencils and as a dry lubricant for things like locks.
3. It has a lower density than diamond.
4. It is insoluble in water and organic solvents.

Methodology

Stir Casting

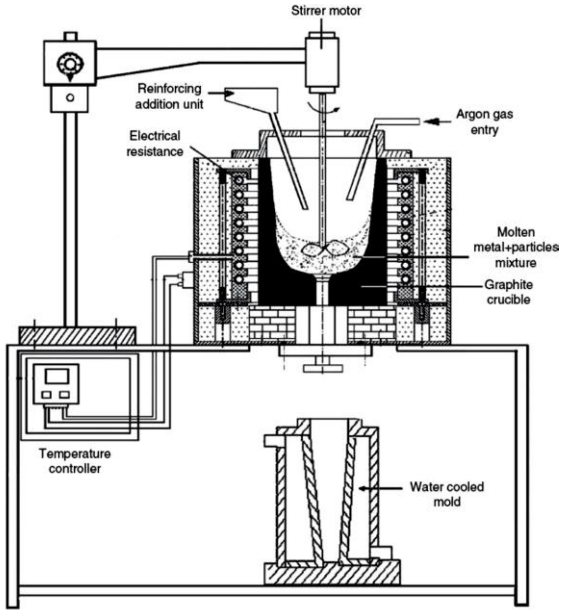

Fig. 4. Stir Casting Setup

SiC reinforced AMCs were prepared by stir casting process shown in figure 4. Al was melted in furnace and when the temperature of the liquid Al reached at 750°C, Mg was added in the melt [19]. Heat treated SiC particles were added in molten metal through funnel at 730°C. Silicon carbide particles were preheated at 800°C for about two hours. An electrical resistance furnace assembled with graphite impeller used as stirrer was used for stirring purpose. After SiC addition, the liquid metal-reinforcements mixture was stirred for 10 minutes at a rpm of 500. Finally composites were poured in preheated metal moulds at 670°C. The melt was allowed to solidify in the mould.

Heat Treatment

The mechanical properties of Al 6061 in T6 condition are better than the same of wrought Al 6061 [10]. Hence heat Treatment (T6) shown in figure.5 was carried out for the different composition samples in using a heat treatment furnace [20]. 1500W muffle furnace was used to heat treat the Al 6061-B4C-Graphite. In order to obtain T6 property of Al-6061 alloy, solution heat treatment was carried out over the material and it was heated up-to 520oC in muffle furnace. After reaching required temperature, the composite material was maintained for definite holding time at 520oC.With this procedure, all the samples were heat treated.

Fig 5. Heat Treatment

Die Casting

Die casting arrangement which is as shown in figure.6 is a metal casting process that is characterized by forcing molten metal under high pressure into a mold cavity. The mold cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mold during the process[21]. Most die castings are made from non-ferrous metals, specifically zinc, copper, aluminium, magnesium, lead, pewter and tin-based alloys depending on the type of metal being cast, a hot- or cold-chamber machine is used.

Fig 6. Die Casting

The casting equipment and the metal dies represent large capital costs and this tends to limit the process to high-volume production. Manufacture of parts using die casting is relatively simple, involving only four main steps, which keeps the incremental cost per item low. It is especially suited for a large quantity of small- to medium-sized castings, which is why die casting produces more castings than any other casting process. Die castings are characterized by a very good surface finish (by casting standards) and dimensional consistency. Two variants are pore-free die casting, which is used to eliminate gas porosity defects; and direct injection die casting, which is used with zinc castings to reduce scrap and increase yield.

Test Conducted

Rockwell Hardness Testing Machine

Fig 7. Rockwell Hardness Testing Machine

Rockwell test setup shown in figure.7 consists of forcing an indenter (Diamond Ball) into the surface of a test piece in two steps i.e. First with preliminary test force and thereafter with additional test force and then measuring depth of indentation after removal of addition test force (Remaining preliminary test force active) for measurement of hardness value. These machines are suitable for Rockwell tests. These are motorized digital Hardness Testers having LCD display for easy hardness measurement. The results are displayed in 0.1 Rockwell unit for more accurate measurement. This is motorized machine having automatic loading/unloading cycle suitable for production testing.

III. RESULTS AND DISCUSSIONS

Rockwell Hardness Test

Below figure.9 shows the varying hardness of the composite material for different ratios of Sic and also compares it with the base material Al 6061. The ball shaped indenter is used.

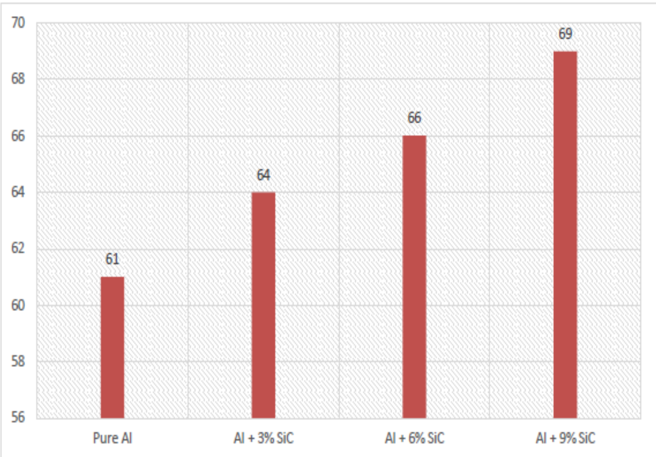

Fig 9. Hardness Number v/s Concentration of SiC

For pure Al 6061 the values obtained for harness test were 62 and 61, so the average Rockwell hardness is 61 .For Al 6061+3% Sic the values obtained were 65 and 63 so the average is rockwell hardness 64. For Al 6061+6% Sic the values are 67 and 66 so the average rockwell hardness is 66. The values obtained for Al 6061+9% Sic were 68 and 69 so the average rockwell hardness is 69.

IV. CONCLUSION

The outcome of the present investigation concludes for pure Al6061 the hardness test obtained values are 62 and 61. So the average Rockwell Hardness is 61. For Al6061+3% SiC the hardness test obtained values are 65 and 63. So the average Rockwell Hardness is 64. For Al6061+6% SiC the hardness test obtained values are 65 and 66. So the average Rockwell Hardness is 66. For Al6061 +9% SiC the hardness test obtained values are 68 and 69. So the average Rockwell Hardness is 69. So we can conclude that hardness of Aluminium composites is greater than hardness of pure Aluminium. When comparing the results obtained from Al6061+3% SiC , Al6061+6% SiC , Al6061+9% SiC the hardness of Al6061+9% SiC found to be better as compared to the combinations.

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