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Analysis of Graphite reinforced Aluminium-6061 Metal Matrix Composite using Stir Casting Method

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Abstract
Metal matrix composites (MMCs) have significantly improved properties such as high specific strength, specific modulus, damping capacity and high wear resistance compared to other reinforced alloys. Among various discontinuities occur in alloy used, graphite is one of the most inexpensive and low-density reinforcement material available in large scale as solid waste by-product during combustion of coal in the utilization at various thermal power plants. Hence, composites with graphite as reinforcement are likely to reduce the cost effect for wide spread applications in automotive and small engine applications. Now a day the particulate reinforced material as Aluminum matrix composite are gaining importance in the market because of their low cost with advantages like micro structural properties and the possibility of secondary processing facilitating fabrication of secondary various components. The present research has been focused on the utilization of large quantity available of graphite in useful manner by dispersing it into Aluminum to produce composites by stir casting method. In current work, the casting of three designed composites is being done. In this study, Graphite is reinforced on Aluminum. Fabrication is done by the use of stir casting method. Further, different mechanical testing like vicker Hardness test,Brinell hardness test and Tensile test on Programmable UTM were performed. On the basis of the change in results of mechanical testing, different conclusions were made.

Keywords: Metal matrix composites (MMCs), stir casting, mechanical properties, Graphite Powder.

Introduction

Metal matrix composites (MMCs) are one of the important modernizations in the development of innovative materials. Among MMCs available, aluminum and its alloy are extensively used in the fabrication of MMCs. Al based MMCs with various reinforcement like AL_2O_3, Sic, zircon, mica and graphite because of these combinations fashionable forming highly desirable composite. Aluminium element, whose symbol Al, is the most resourceful metallic element in the Earth. Pure form of aluminium element is very soft in nature, has the silvery colour, and possesses the high electrical conductivity. Aluminium is a very light metal in weight with a specific weight around the 2699kg/m3, which is very less as compared to the steel. For example, if we used aluminium material for the manufacturing of the vehicle it is become very light in nature and the dead weight is also very light, and side by side it increasing load capacity.

In the last few years, research has shifted to composite materials to fulfill the worldwide requirement for light weight, environmental friendly, high performance and corrosion resistant materials. It is suitable for applications requiring thermal conductivity, combined strength,low coefficient of thermal expansion with lower density.[9]

Metal Matrix Composites are prepared out of a metallic grid (Al, Mg, Fe, Cu Gr, etc.) and a shaped fired (oxide, carbides) or metallic stage (Pb, Mo, W and so forth.). Fired reinforcement material might be silicon carbide, boron, alumina, silicon nitride, boron carbide, boron nitride and so on while Metallic strengthening might be utilized as tungsten, beryllium and so on. MMCs are utilized for made Space Shuttle, business carriers, electronic substrates, bikes, vehicles, golf clubs and an assortment of different applications. In the field of automobile, MMCs are used for pistons, brake drum and cylinder block because of better corrosion resistance and wear resistance.[8,5]

Graphite is a crystal-like allotrope of carbon, a semi metal, a native element mineral, and a form of coal. Graphite is the most stable form of carbon under standard conditions. Therefore, it is used in Fabrication of MMCs has many challenges like porosity formation and improper distribution of reinforcement. Attaining uniform distribution of fortification is the primary important work. A new technique of fabricating AL matrix composite has been projected to improve the wet ability among alloy and strengthening. In this, all the materials are in graphite crucible and heated in an inert atmosphere until the matrix alloy is melted and tracked by two step stirring action to get uniform distribution of reinforcement. The manufacturing techniques of MMCs play a main role in the enhancement of mechanical properties. The performance characteristics of Al alloy reinforced with 5% volume fraction of SiC fabricated through stir casting and powder metallurgy have been analyzed and found that the stir casting specimen have higher strength compared to powder metallurgy example.[6]

Graphite has a high melting point, like to that of diamond. In order to melt graphite, you have to break the covalent bonding throughout the entire structure. Graphite has a soft, slippery feel, and is used in pencils and as a dry lubricant for things like locks. Graphite has a lower density than diamond. It has Lubricating feature because of this reducing friction during compaction. It has High resistant to corrosion resulting into long life of the components. Increases overall hardness of the aluminium upto certain level and increases the tensile and yield strength of the metal. And Superiorises the wear strength of the base metal with which it is reinforced. [1, 3].

Aluminum founded silicon carbide particulate MMC fabricated using two step mixing method of stir casting technique by varying the volume fraction of Sics (5%,10%, 15%, 20%, 25% and 30%) showed an increasing trend in hardness and impact strength values with increase in volume fraction of Sic.[4]

Methods

Al-6061 alloy is chosen as the base matrix and reinforcement is graphite. In the present work hardness and tensile properties of aluminium alloy 6061 enhanced by adding graphite powder by stir casting method.
The matrix material used for MMCs in this study is aluminum alloy (6061) . This alloy is best suited for lightweight metal castings. 6061 has abundant benefits like formability, corrosion resistance weld ability and low cost. Table-1 shows the chemical composition of aluminium alloy and figure-1 shows the stir casting set up and different processes parameters are identified in which Graphite wt.% 2%, 4% & 6% (1,2 & 3) of aluminium and Melting temperature of 670°C & 700°C. MMC manufacturing can be done in three types. i,e Solid, Liquid and Vapour
Table 1: Shows the chemical composition of Aluminium alloy:

Component	Amount (wt.%)
Aluminum	Balance
Magnesium	0.8-1.2
Silicon	0.4-0.8
Iron	Max. 0.7
Copper	0.15-0.40
Zinc	Max. 0.25
Titanium	Max. 0.15
Manganese	Max. 0.15
Chromium	0.04-0.35
Others	0.05

Stir Casting Methods of Fabrication of MMCs:

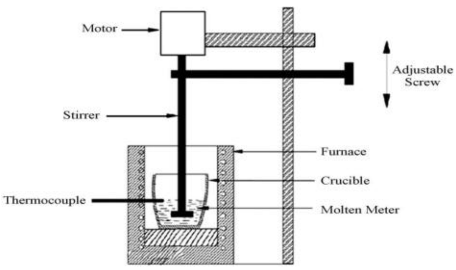

Figure 2: Schematic view of the furnace

Liquid state fabrication of metal matrix composite involves incorporation of dispersed phase into a molten matrix metal, followed solidification. In order to provide high level of mechanical properties of the composite, good interfacial bonding (wetting) between the dispersed phase and liquid matrix should be obtained. The simplest and the most cost effective method of liquid state fabrication is Stir Casting.[7, 2]

Mechanical Testing:
There are two types of the mechanical testing which are carried out in this work:
1. Tensile Testing on programmable UTM
2. Hardness Testing on Rockwell Hardness Testing Machine and Vickers Hardness testing machine.
Mechanical testing plays an important role in evaluating fundamental properties of engineering materials as well as in developing new materials and in controlling the quality of materials for use in design and construction. If a material is to be used as part of engineering structure that will be subjected a load, it is important to know that the material is strong enough and rigid enough to withstand and the loads that it will experience in service. As a result engineers have developed a number of experimental techniques for mechanical testing of engineering materials subjected to tension, compression, bending or torsion loading.
Tensile Specimens:
Figure shows a typical tensile specimen. It has enlarged ends or shoulders for gripping. The important part of the specimen is the gauge section. The cross sectional area of the gauge section is less than that of the shoulders and grip region, so the deformation will occur here

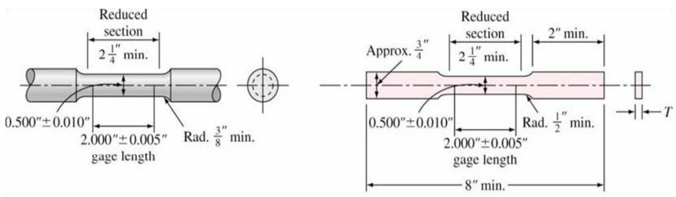

Figure 3: Tensile Test

Figure 4: Tensile Test specimen

Stress-Strain Curve
After testing, result will come out through stress-strain diagram.

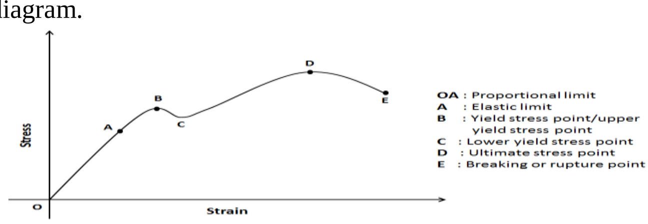

Figure 5 : Tensile Test specimen

Ductility :

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Two normal parameters are utilized to portray the flexibility of a material. One is the percent lengthening, which is basically characterized as,

$\%El = (Lf - Lo)/Lo \times 100\%$

Where, Lo is the underlying measure length and Lf is the length of the check area at crack.

The other basic measure of pliability is the percent diminishment of territory at crack, characterized as, $\%RA = (Ao - Af)/Ao \times 100\%$

The %El and %RA are never again straightforwardly related after a neck has shaped.

Hardness Testing:

Another mechanical property that may be important to consider is hardness, which is a measure of a material's resistance to localized plastic deformation (e.g., a small dent or a scratch). Early hardness tests were based on natural minerals with a scale constructed solely on the ability of one material to scratch another that was softer.

Rockwell Hardness Tests

The Rockwell tests constitute the most common method used to measure hardness because they are so simple to perform and require no skills. Several different scales may be utilized from possible combinations of various indenters and loads, which permit the testing of virtually all metal alloys (as well as some polymers). Indenters include spherical and hardened steel balls having diameters of 1.588, 3.175, 6.350, and 12.70 mm, and a conical diamond (Brale) indenter, which is used for the hardest materials.

Brinell Hardness Tests:

In Brinell tests, as in Rockwell measurements, a hard, spherical indenter is forced into the surface of the metal to be tested. The diameter of the hardened steel (or tungsten carbide) indenter is 10.00 mm (0.394 in.). Standard loads range between 500 and 3000 kg in 500-kg increments; during a test, the load is maintained constant for a specified time (between 10 and 30 s). Harder materials require greater applied loads. The Brinell hardness number, HB, is a -power microscope, utilizing a scale that is etched on the eyepiece. The measured diameter is then converted to the appropriate HB number using a chart; only one scale is employed with this technique.

Vicker's Hardness Test :

The Vickers hardness test method, also referred to as micro hardness test method, is mostly used for small parts, thin sections or case depth work. The Vickers method is based on optical measurement system. The micro hardness test procedure, ASME E-384, specifies a range of light loads using a diamond indenter to make an indentation which is measured and converted to a hardness value. It is very useful for testing on a wide type of materials, but test samples must be highly polished to enable measuring the size of the impressions. A square based pyramid shaped diamond is used for testing in the Vickers scale. Typically loads are very light, ranging from 10gm to 1Kgf, although macro Vickers can bear loads upto 30kgf or more.

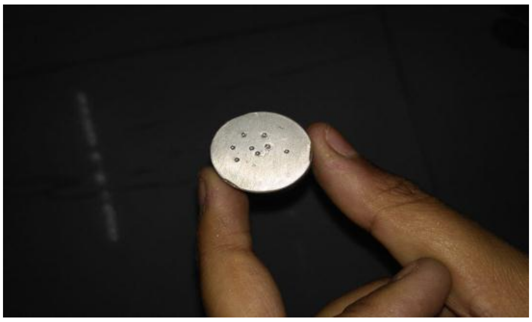

Figure 6 : Brinells Hardness test

Vickers Hardness Test

P=30kgf, Square base pyramidal diamond indenter

Table 2: Shows the vicker hardness number

SPECIMEN	VICKERS HARDNESS TEST
Al 6061	49VHN (d=1.069mm)
Al 6061+2%graphite (by weight)	53VHN (d=1.024mm)
Al 6061+4%graphite (by weight)	61VHN (d=.955mm)
Al 6061+6%graphite (by weight)	43VHN (d=1.633mm)

function of both the magnitude of the load and the diameter of the resulting indentation. This diameter is measured with a special low

Brinells Hardness Test

D=5mm, P=100kgf, Hardened Steel ball Indenter

Table 3: Shows the Brinell hardness number

SPECIMEN	VICKERS HARDNESS TEST
Al 6061	24BHN (d=2.24 mm)
Al 6061+2%graphite (by weight)	27BHN (d=2.11 mm)
Al 6061+4%graphite (by weight)	33BHN (d=1.92mm)
Al 6061+6%graphite (by weight)	21BHN (d=2.89 mm)

Result and discussion:

Tensile Test:

By observing the tensile test report it can be seen that the Ultimate tensile strength along with yield strength and percentage elongation increases upto a level on reinforcing graphite powder in Aluminium alloy 6061. Furthermore, the Ultimate tensile strength increases on increasing the graphite reinforcement in the Aluminium alloy, but would start to decrease after a certain level. Here, on adding graphite by the variation of 2% by weight to the aluminium alloy, it can be seen that the tensile strength increases upto the 4% graphite reinforcement with base metal but showed a fall/decrease in the same tensile strength when the reinforcement was made to 6% by weight fraction instead of 4%. Therefore, it can be observed and finally concluded that on adding or reinforcing 4%graphite by weight to Al 6061 alloy would result in an impressive increase in the Ultimate Tensile Strength.

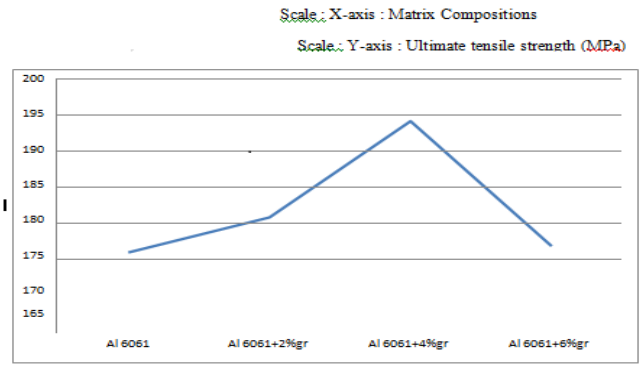

Figure 7: Graph showing variation of Ultimate Tensile strength on different specimens of Al 6061 and Graphite compositions.

Hardness Test:

As observed from the mechanical test report and practical experimentation, the variation among hardness of specimens with different compositions is having the same behavior as of Ultimate tensile strength for these compositions. That is, the hardness of base metal Al 6061 increases up to an optimum level on addition of graphite reinforcement in particular weight fractions. But again, after a particular composition, there has been seen a decline or fall in the hardness of the material. Such as, the hardness of the metal increases upto 4% of graphite reinforcement in the base metal Al 6061, but it is seen and observed that at 6% graphite weight there is a decrement in hardness of the metal. Thus, it has been concluded that the hardness of Al 6061 can be increased upto 4%graphite addition by weight and is reported to be maximum at this composition. Beyond this, the hardness decreases of the metal.

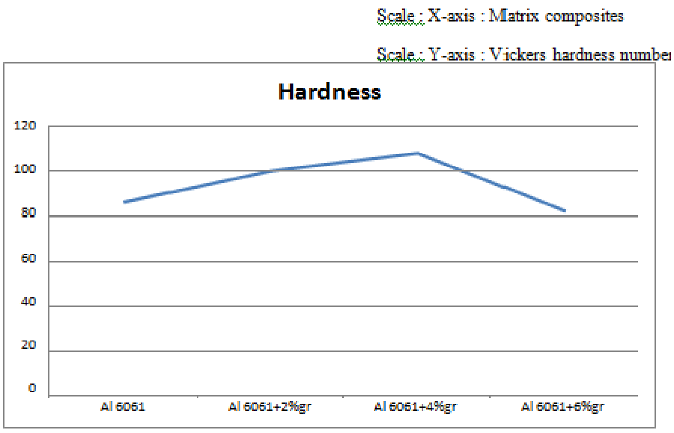

Figure 8: Graph showing variation of vicker hardness on different specimens of Al 6061 and Graphite compositions.

Conclusion

1.By observing the tensile test, ultimate tensile strength increases on increasing the graphite reinforcement in the Aluminium alloy, but would start to decrease after a certain level. On adding graphite by the variation of 2% by weight to the aluminium alloy, it can be seen that the tensile strength increases upto the 4% graphite reinforcement with base metal but showed a decrease in the same tensile strength when the reinforcement was made to 6% by weight fraction instead of 4%. It can be observed and finally concluded that on adding or reinforcing 4%graphite by weight to Al 6061 alloy would result in an impressive increase in the Ultimate Tensile Strength.

2. By observing from the hardness test, hardness of base metal Al 6061 increases up to an optimum level on addition of graphite reinforcement in particular weight fractions. But again, after a particular composition, there has been seen a decline or fall in the hardness of the material. The hardness of the metal increases upto 4% of graphite reinforcement in the base metal Al 6061, but it is seen and observed that at 6% graphite weight there is a decrement in hardness of the metal. Thus, it has been concluded that the hardness of Al 6061 can be increased upto 4% graphite addition by weight and is reported to be maximum at this composition. Beyond this,hardness of the matel will be decreases.

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