Enhancing the Mechanical Properties of the Aluminium 6061 Metal Matrix Composites

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Abstract **- The present study deals with the investigation of effect of reinforcement (Zirconium oxide & E-Glass Powder) particles on mechanical properties of aluminium alloy (Al6061) composites, fabricated by stir casting method. The MMC's specimens were prepared by varying weight fraction of the reinforcement of the zirconium oxide and E-glass as 2Wt. %, 3Wt. %, and 4Wt. % and keeping all other parameters constant. The microstructure and mechanical properties of fabricated MMC's were analysed. Microstructural studies of the MMC's reveal a uniform distribution of zirconium dioxide (ZrO2) and E glass particles in the Al6061 matrix. The mechanical properties like hardness, tensile strength and wear strength were improved with the increase in weight fraction of zirconium dioxide and E glass particles in the aluminium matrix. It was observed that the elongation decrease with increase weight fraction of zirconium dioxide and E glass particles in the aluminium matrix.**

Index Terms **- Aluminium 6061, Silicon Carbide, E-Glass, Hardness, Matrix.**

1.INTRODUCTION

1.1 Composite Material

Material which is composed of two or more materials at a microscopic scale and have chemically distinct phases. Heterogeneous at a microscopic scale but statically homogeneous at macroscopic scale.

Metal Matrix Composites (MMC's) are made by dispersing a reinforcing material into a metal matrix. The reinforcement surface can be coated to prevent a chemical reaction with the matrix. For example, carbon fibres are commonly used in matrix to synthesize composites showing low density and high strength metallic materials are essential consistent for fabrication of metal matrix composites which have potential for structural materials at high temperatures. Aluminium material has been most attracted as matrix element in composite due to its special properties such as lower density, higher ductility and high strength to weight ratio. In AMMCs, the major constituent is aluminium alloy, which forms percolating network and acts as the matrix phase.

This work of Al6061/Zirconium oxide, E-glass metal matrix composites the reinforcement percentage we used in 2, 3, 4 wt. % of reinforcement newly developed composite material to know about the mechanical performance.

2. MATERIAL PROPERTIES

2.1. Matrix

2.1.1. Aluminium 6061

Aluminium 6061 is a precipitation hardened aluminium alloy. It is containing magnesium and silicon as its major alloying elements. It is originally called as "Alloy 61S".

Table 2.1 Mechanical Properties of Aluminium 6061.

Properties	Values
Tensile strength	310 MPa
Density	2.6898 g/cm^3
Hardness	95
Poisons ratio	0.33
Coefficient of thermal expansion	23.6×10^{-6} $(℃)^{-1}$
Shear modulus	26 GPa
Stiffness/Young's Modulus	68.9 Gpa
Thermal conductivity	167 W/m .K

2.2. Reinforcement

2.2.1. Zirconium Oxide Powder

Zirconium oxide (ZrO_2) is also known as Zirconia and it is a white crystalline oxide of Zirconium. It's most naturally occurring form, with a monoclinic crystalline structure.

Table 2.2. Mechanical Properties of Zirconium Oxide powder.

Properties	Values
Density	5680 Kg/m^3

Poisons ratio	0.31
Thermal conductivity	3W/m.K
Stiffness/Young's Modulus	200 GPa
Flexural strength	750 Mpa

2.2.2 E-Glass Powder

It was first used as insulation material in electrical, thermal and acoustic uses. This is simply because it has good strength-to- weight characteristics.

Table 2.3 Mechanical Properties of E-Glass Powder

Properties	Values
Tensile strength	2000 MPa
Compressive strength	4000-5000 MPa
Density	2.55g/cm^3
Hardness	3000 -6000MPa
Poisons ratio	0.21-0.23
Bulk modulus	43-50 GPa
Shear modulus	30-36 GPa
Stiffness/Young's Modulus	80 GPa
Thermal conductivity	1.2-1.35W/m.K

3.FABRICATION

The simplest and most commercially used technique is known as vortex technique or stir casting method. The vortex technique involves the introduction of preheated ceramic particles into the vortex of molten alloy created by the rotating impeller. The conventional stir casting method has been an attractive processing method for producing AMMCs.

The stir casting method for the preparation of metal matrix composite Al6061/Zirconium oxide, E-Glass composites. The whirlpool technique provides the high strength homogenous set of aluminium composite material.

The present work deals with the fabrication and Mechanical Testing of a hybrid composite with the following constituents.

- Aluminium 6061 Matrix
- Silicon Carbide particulate reinforcements
- E-glass fibre reinforcements.

The compositions of the above materials were varied in the following manner:

- Aluminium 6061+2% ZrO_2+4% E-glass
- Aluminium 6061+3% ZrO_2+3% E-glass
- Aluminium 6061+4% ZrO_2+2% E-glass

Initially the weighed Aluminium 6061 ingots for a particular composition was placed inside a Graphite crucible and melted in a muffle furnace. The temperature of the furnace was made to reach 800°C. Aluminium melts at 660°C. The superheat was given to ensure liquid state of Aluminium 6061 during mixing and pouring. Along with this operation simultaneously, Zirconium oxide powder corresponding to that particular composition was preheated up to 500°C in a furnace and the split metal die where the final mixture would be poured was also preheated to prevent sudden cooling of the melt which causes brittleness.

4. EXPERIMENTAL TESTING

4.1. Tensile Test

One of the mechanical properties of a composite is tensile strength. Tensile test was carried out to determine the ultimate tensile strength and % of elongation under static loading of composite. Tensile test was done by using universal tensile testing machine at room temperature. The test specimens were prepared as per ASTM E8-16a standard.

Table 4.1 Tensile test Values

S. No	Designation of specimen	Yield stress(MPa)	Elongation%	Ultimate stress (MPa)
1	Aluminium 6061+2% ZrO_2+4% E-glass	135.20	4.20	153.91
2	Aluminium 6061+3% ZrO_2+3% E-glass	141.20	4.32	148.54
3	Aluminium 6061+4% ZrO_2+2% E-glass	140.60	4.82	148.52

Fig 4.1 Tensile test specimen

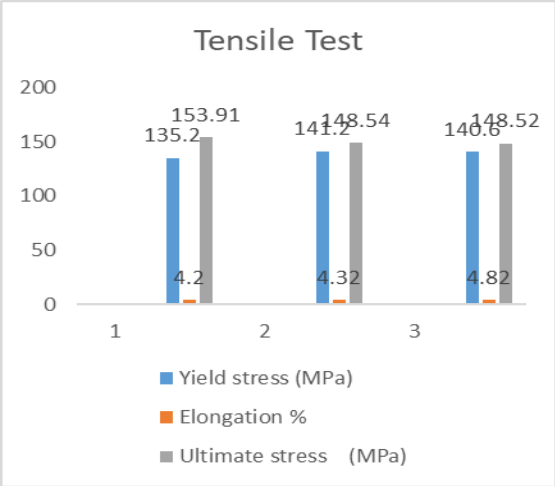

Fig 4.1 Tensile test Comparison

4.2. Compression Test

The tensile test also compression test is performed on UTM i.e. Universal Testing Machine. For compression test size of specimen is 19.5 mm Diameter and gauge length 36.4 mm. A compression test is a method for determining the behaviour of materials under a compressive load.

Table 4.2 Compression test values

S. No	Designation of specimen	Compression load (KN)
1	Aluminium 6061+2% ZrO_2+4% E-glass	82.45
2	Aluminium 6061+3% ZrO_2+3% E-glass	92.57
3	Aluminium 6061+4% ZrO_2+2% E-glass	80.34

Fig 4.2 Compression test specimen

4.3. Impact Test

Impact resistance is the ability of a material to absorb and dissipate energies under impact or shock loading. During impact loading fracture modes may be significantly different than static tensile failure. This is particularly true for strain rate sensitive materials.

Table 4.3 Impact test values

S. No	Designation of specimen	Energy Absorption J
1	Aluminium 6061+2% ZrO_2+4% E-glass	6
2	Aluminium 6061+3% ZrO_2+3% E-glass	6
3	Aluminium 6061+4% ZrO_2+2% E-glass	6

4.4. Hardness Test

The Brinell hardness test machine was used to measure the hardness of the prepared composite structure. The test was carried out at three different locations and average values are taken as the hardness of the specimen. Hardness of composite depends on the hardness of the reinforcement and the matrix.

Table 4.4 Hardness test values

S.NO	Designation of specimen	Hardness in HBW (∅10/1000kgf)
1	Aluminium 6061+2% ZrO_2+4% E-glass	83,80,79
2	Aluminium 6061+3% ZrO_2+3% E-glass	76,77,76
3	Aluminium 6061+4% ZrO_2+2% E-glass	76,77,76

4.5. Wear Test

Wear test is carried out to predict the wear performance and to investigate the wear mechanism. The test specimen machined as per standard size and used for wear test.

Table 4.5 Wear test values

S. No	Designation of specimen	Abrasion loss (g)	%	Initial weight (g)	Final weight (g)
1	Aluminium 6061+2% ZrO_2+4% E-glass	0.1802	3.68	4.8797	4.7168
2	Aluminium 6061+3% ZrO_2+3% E-glass	0.1217	2.59	4.6965	4.5748
3	Aluminium 6061+4% ZrO_2+2% E-glass	0.1473	2.88	5.1116	4.9643

5. CONCLUSION

The composites containing Al6061 and 2, 3, 4 wt % of Zirconium oxide with 4, 3, 2 wt % of E-Glass particulates were successfully developed by stir casting method. The tensile, impact, hardness, compression, wear tests were taken and the conclusion obtained is given as follows,

- Aluminium alloy 6061 had measured tensile strength of 141 MPa which was increased to maximum of 153.91 MPa having the increase in the range of 8.3%.
- Hardness value of 65-85 was increased to maximum of 75-85 and with the range of 15% increase with the addition of different weight % of Zirconium oxide & % of E-glass.
- Aluminium alloy 6061 had the measurable elongation of 5% which was considerably reduced to 4.2 % due to the addition of reinforcement material.
- In compression test, the addition of zirconium oxide and E-glass has reduced the compressive strength from 5Mpa to 1.6Mpa in the range of 65-70% due addition of reinforcement material.
- Aluminium alloy 6061 had the measurable impact strength of 8 J which was considerably reduced to 6 J due to addition of reinforcement material.
- In wear resistance test, the addition of zirconium oxide and E-glass has reduced the rate of corrosion in the composite material and has the lowest loss in weight percentage of 2.59 % in addition of reinforcement material.

Mechanical properties such as hardness and ultimate tensile strength and the rate of corrosion resistance were improved, when compared with the unreinforced alloy. It can be safely stated that with the increase in the reinforcement compositions, there have been notable improvements in the essential properties.

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