ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 1, Issue 4, December 2014

Experimental Investigation on Mechanical Properties of Aluminium 6061-Al_2O_3 Composites

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Abstract*:* In this work, the mechanical behavior of Aluminum Metal Matrix Composites has been investigated. Al6061 alloy was selected as matrix alloy and Al_2O_3 are used as reinforcements for fabrication of composites by Stir Casting Technique. The sample specimens are made by varying the percentage of reinforcements with respect to aluminium alloy. Four samples were fabricated and their mechanical properties were analyzed and results are obtained. The test results revealed that the increase in the reinforcement materials caused an increase in the tensile strength and hardness of the aluminium composites, except for the percentage of elongation, which is reduced with the addition of alumina particles.

Key words: Aluminum Metal Matrix Composites, Al6061, Al_2O_3, Alumina, Mechanical properties

I. INTRODUCTION

Composites are just a combination of materials in such a way that the resulting materials have desired/required properties. In the recent years, metal matrix composites materials are widely used for many number of applications. Aluminum is the familiar matrix for the metal matrix composites. Aluminum metal matrix composites is one of the best alternatives for researcher in various engineering fields like aerospace, automobile, engineering structures, marine application, sports because of their low density, high strength, good corrosion resistance etc.

Aluminium metal matrix composites reinforced with ceramic particles has improved strength, high elastic modulus, impact strength and increased wear resistance. Ceramic materials generally used to reinforce Aluminium alloys are Al_2O_3, SiC, B_4C, SiO_2, TiC, TiB_2, ZrB_2 and Si_3N_4. The manufacturing techniques of the aluminium metal matrix composites are classified into three types namely. There are liquid state methods, semisolid methods and powder metallurgy methods. The fabrication of metal matrix composites through liquid state processing is a cheap and best technique for the complex shaped objects.

Mechanical properties of aluminium metal matrix composites are depend upon many factors such reinforcement material, volume and size of the reinforcement, distribution of the reinforcement and fabrication method.

II. LITERATURE REVIEW

G.S.Kataiah et al [2010] have studied the effect of reinforcement on the mechanical properties of Al6061-TiO_2 composites. In his study Al6061– TiO_2 composites was fabricated by liquid vortex method with percentages of TiO_2 varying from 0 wt% to 20 wt% in steps of 5 wt%. After the fabrication of composites the mechanical properties are analyzed. From test results, it was observed that as TiO_2 composition was increased, there were significant increase in the ultimate tensile strength and hardness of the composite, accompanied by a reduction in its ductility.

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G. B. Veereshkumar et al [2010] fabricated the Al6061-SiC and Al7075-Al_2O_3 Metal Matrix Composites. The composites are prepared using the liquid metallurgy technique, in which 2-6 wt. % of particulates were dispersed in the base matrix in steps of 2. After the fabrication of aluminium matrix composites the hardness, tensile strength and wear resistance properties are analyzed. Results show that the vickers micro-hardness and tensile strength of the composites are higher than that of their base matrix also it can be observed that the increase in the filler content contributes in increasing the vickers micro-hardness and tensile strength of the composite.

Anil Kumar et al [2011] studied the mechanical properties of fly ash reinforced aluminium alloy (Al 6061) composites prepared by stir casting process. Three sets of composites with fly ash particle sizes of 4-25, 45-50 and 75-100 μm were used. Each set had three types of composite samples with percentages of fly ash varying from 10 wt% to 20 wt% in steps of 5 wt%. They reported that the tensile strength, compressive strength and hardness of the aluminium alloy (Al 6061) composites decreased with the increase in particle size of reinforced fly ash. Increase in the weight fractions of the fly ash particles increases the ultimate tensile strength, compressive strength, hardness and decreases the ductility of the composite.

R. Hariharan et al [2012] investigated the mechanical behavior and wear behavior of aluminium matrix composites reinforced with TiB_2. Four different volume fractions (2%, 4%, 6% and 8%) of particulate TiB_2 are used in production of aluminium matrix composite. It was observed that decrease in the tensile strength of the samples with TiB_2 weight fraction beyond 4% is due to the poor wettability of the reinforcement with the matrix. Also, the decrease in the percentage of elongation of the samples with TiB_2 weight fraction beyond 6%.

Prashant S N et al [2012] fabricated Al6061-Graphite and Al6061-SiC metal matrix composites. The composites were prepared using stir casting method in which amount of reinforcement is varied from 6-12% in steps of 3wt%. The prepared composites of Al6061-Graphite and Al6061-SiC are characterized by microstructural studies and hardness, density, mechanical, tribological properties were evaluated as per the standards. From test results, it was observed that micro-hardness of the Al6061-SiC composite found increased with increased filler content and whereas Al6061- Graphite composite found decreased with increased filler content. The addition of SiC/Graphite has resulted in increase in tensile strength of Al6061 alloy when compared to unreinforced alloy.

Dr. Jameel Habeeb Ghazi [2013] successfully developed composites containing 6061Al with 7, 14 and 21wt% of silicon carbide using stir casting technique to test the mechanical properties of composites. Results indicated that the hardness, ultimate tensile strength and yield strength of composite found increasing with increased reinforcements in the composites. Increasing the amount of SiC particles in composites caused the impact energy to decrease.

Dinaharan. I et al [2013] fabricated the aluminium (Al 6061) matrix composites reinforced with zirconium diboride (ZrB_2) composition of 10% weight fraction by the in situ reaction of K_2ZrF_6 and KBF_4. The microstructure, tensile strength, wear resistance and corrosion rate of the fabricated composite were compared with those of matrix alloy. It was observed that the fabricated composite improved tensile strength and wear resistance but reduced ductility and corrosion resistance.

Objective of the work

In this research, experimental analysis is done to find tensile strength, percentage of elongation and hardness by varying the weight percentage of Al_2O_3 in Al6061 composite.

III. MATERIALS AND METHODS

Matrix Material

The material selected as matrix for preparing the composites is aluminium alloy. Aluminium alloy 6061 is light weight material with density of 2.7 gm/cm^3. It has very good corrosion resistance, an excellent heat and electricity conductor. The table-1 given below shows the chemical composition of the parent material.

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Table-1: Chemical composition of Al6061 by weight percentage.

Component	Amount (wt.%)
Aluminium	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

Reinforcement

In this study, the alumina oxide particles were used as a filler material. Aluminium oxide is a chemical compound of aluminium and oxygen with the chemical formula Al_2O_3. Alumina is the most cost effective and widely used material in family of engineering ceramics. It has high temperature resistant good mechanical properties. It is reinforced in the Al6061 matrix to increase strength, hardness, stiffness, wear resistance and impact strength.

Fabrication of Composites

Stir casting is the most popular commercial method of producing aluminium based composites. Alumina was initially preheated separately at a temperature of 250°C to remove moisture. The Al6061 alloy billets were charged into the furnace and heated to a temperature of 770 ± 30°C. The preheated alumina is then charged into the melt at constant pour rate and stirred continuously for 8-10 minutes. Meanwhile the mould is preheated to avoid shrinkage of casting material. Then the melted matrix and reinforced particles are poured into the preheated mould.

Mechanical test

The aluminum alloy 6061 and composites specimens are further subjected to mechanical tests like tensile and hardness (Brinell hardness test).

IV. RESULTS AND DISCUSSION

The mechanical properties of Al6061 and its composites samples are shown in table-1.

Table-1: Mechanical properties of Al6061 and its composites

Weight percentage of Al_2O_3 particles (%)	Tensile Strength (MPa)	% Elongation	BHN
0.0%	149.7	15.2	72
2.5%	161.6	13.1	74
5.0%	164.3	11.5	77
7.5%	174.6	10.2	79

Tensile Strength

The results of the tensile strength of four samples show a gradual improvement in the tensile strength values of the specimens. From figure-1, it can be observed that the tensile strength of the composites are higher than

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that of their base matrix also it can be observed that the increase in the Al_2O_3 content contributes in increasing the tensile strength of the composite. It may be due to the fact that Al_2O_3 reinforcement exhibits a good bonding with Al-6061 alloy and also with each other which helps in withstanding more load as compared to Al-6061 matrix. A. Baradeswaran et al [2013] investigated the mechanical and wear properties of aluminium oxide and graphite reinforced aluminium metal matrix composites. The Al 7075/Al2O3/graphite hybrid composite was prepared with 5 wt.% graphite particles addition and 2, 4, 6 and 8 wt.% of Al_2O_3. From test results, it was observed that the tensile strength of the composite are found to be increased by increased weight percentage of ceramic phase. M. S. Sukumar et al [2014] investigated mechanical properties of aluminum Al_2O_3 composites. Results indicated that the tensile strength of the composite is higher than the base matrix. Also, the tensile strength of the composites increased with increase in filler content.

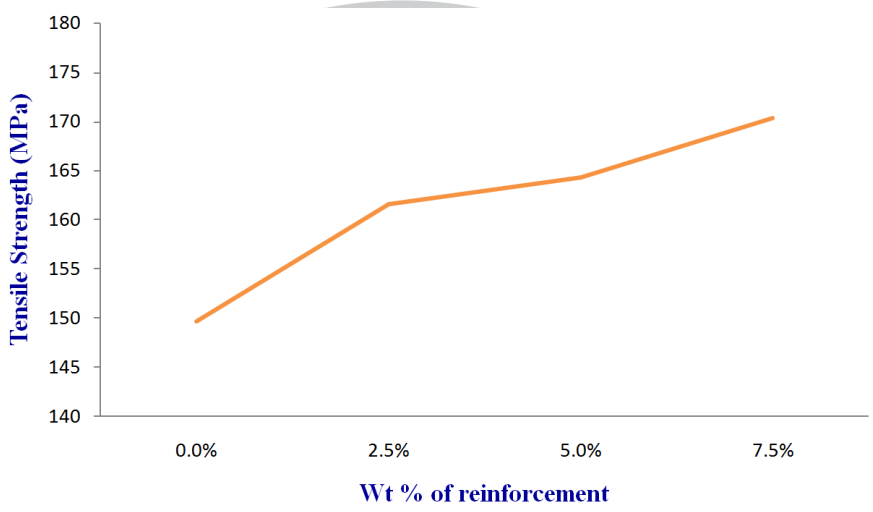

Figure-1: Tensile strength of Al6061 alloy and its composites

Percentage Elongation

Figure-2 shows the relation between weight percentage of Al_2O_3 particulates and the percentage of elongation of fabricated composites. It can be observed that percentage of elongation shows decreasing trend with increasing percentage of Al_2O_3 particulates. This could be due to the presence of Al_2O_3 particulates which are hard in nature, that is reduced the elongation of composites. GB Veeresh kumar et al [2012] investigated the mechanical and tribological properties of Al7075–SiC composites. He prepared Al 7075 with 2, 4, 6 and 8 wt.% of SiC. They reported that the percentage elongation of composites decreases with increasing SiC and it was lower than that of base alloy in all compositions. A. R. K. Swamy et al [2011] succesfully developed composites containing 6061Al with 0, 1, 2, 3 and 4wt% of Tungsten carbide (WC) particulates using the vortex method. The resulting composite showed that the elongation of composite material Al6061-WC is less as compared to that of the cast Al6061 alloy.

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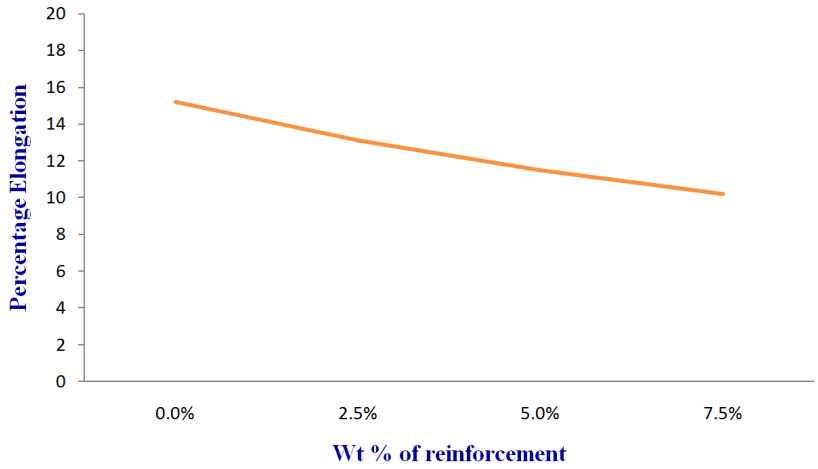

Figure-2: Percentage of elongation of Al6061 alloy and its composites

Hardness

Figure-3 shows the variation in the hardness of the samples with varying proportions of alumina. The analysis of the results clearly shows that the increment in the alumina content has improved the hardness of the composite. The presence of the hard ceramic (alumina) leads to a greater hardness of the composites than that of the base alloy. M. S. Sukumar et al [2014] investigated the mechanical behaviour of aluminium oxide reinforced aluminium metal matrix composites. The aluminum alloys Al6061 and Al7075 are used as the matrix metal for the fabrication of the composites that has been reinforced with 2 wt. %, 4 wt. %, 6wt. %, 8 wt. % and 10 wt. % of Al_2O_3. They reported that the hardness of the composite are found to be increased by increased weight percentage of Al_2O_3. Madhu Kumar YC et al. [2012] fabricated the aluminum matrix composites reinforced with different fraction of glass particulates by stir casting. After the fabrication of AMCs the mechanical properties are analyzed. From the experiment it was observed that the hardness increases with increasing wt% of glass particulate upto 9wt% and then decreases with increasing wt% of glass particles. The hardness of the composites are found improved than their base matrix.

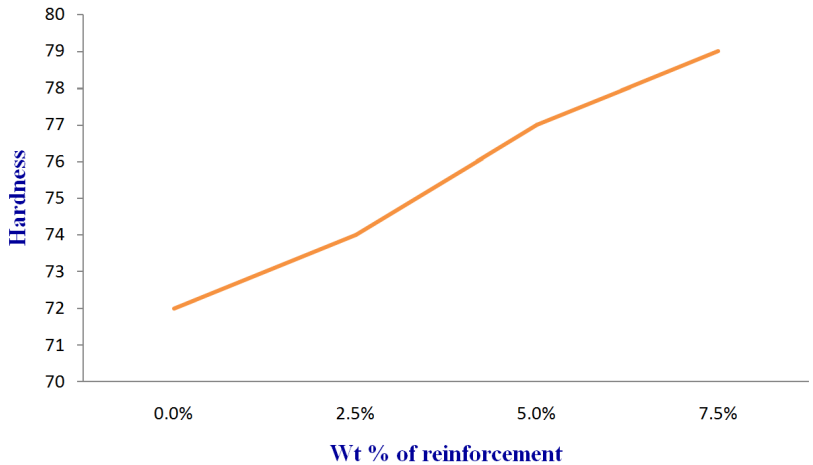

Figure-3: Hardness of Al6061 alloy and its composites

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V. CONCLUSIONS

The following conclusions have been drawn based on the experimental investigation on Al_2O_3 reinforced AMMCs at different weight fraction:

- The tensile strength of the MMCs is higher than the unreinforced matrix metal and the tensile strength of the composites increases with increasing the weight fraction of Al_2O_3.
- The Hardness of the MMCs are found higher than that of base matrix. Hardness is enhanced with increase of reinforcement percentage in matrix.
- The percentage of elongation of aluminum composite material is decreased by increasing the percentage of reinforcement material.

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Vol. 1, Issue 4, December 2014

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