



iJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 Issue: III Month of publication: March 2019

DOI: <http://doi.org/10.22214/ijraset.2019.3238>

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Development and Characterization of Aluminum 6061 - Zirconium Dioxide Reinforced Metal Matrix Composites by Stir Casting

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Abstract: The present work deals with the investigation is to discover the effect of reinforced particles on aluminum alloy Al 6061 properties which is fabricated or composited by using the stir casting technique [Liquid Metallurgy Process]. The present work is to fabricate Al 6061 - ZrO₂ composite and find out the mechanical properties like tensile, hardness and density of the prepared composite. All this fabrication process done by using stir casting in which the reinforcement varied from 0 – 3 wt% in steps of 1 wt% (i.e 0%, 1%, 2% and 3%). The result of this work is concluded that, there is a significant development in tensile and hardness values and there is decrease in density of composite. All these values are possible for increasing the weight percentage of reinforcement i.e zirconium dioxide particles in weight percentage of base metal.

Keywords: Al 6061, Hardness, Metal Matrix Composite, Stir Casting, Tensile, Zirconium Dioxide.

I. INTRODUCTION

In these days there is a far researching in the effects of reinforcement in aluminum alloy based composites. These composites are mainly used in the applications like automobile, defense equipment; aerospace's and in some daily used things. Because of their high strength, low in density and easy to use, high stiffness, hardness, wear resistance and high temperature resistance etc...A single metal or material doesn't express all the above properties so we need to combine two or more materials to produce the desired properties. Composite material is a combination of two or more constituents phase, i.e matrix phase and reinforcement phase. In composite continues phase is call matrix phase and discontinues phase is call reinforcement phase. The discontinues phase gives strength and additional properties to the continues phase in a composite. There are mainly three types of composites; they are

- 1) Metal Matrix Composite
- 2) Polymer Matrix Composite
- 3) Ceramic Matrix Composite

A. Need of Metal Matrix Composites

The need for composite materials has become a necessity for modern technology, due to the improved physical and mechanical properties. Metal matrix composites (MMC) have been developed in recent years. Metal Matrix Composites have emerged as a class of material capable of advanced structural, aerospace, automotive, electronic, thermal management and wear applications. A composite material is a material consisting of two or more physically And or chemically distinct phases. The composite generally has superior characteristics than those of each of the individual components. Usually, the reinforcing component is distributed in the continuous or matrix component. When the matrix is a metal, the composite is termed a metal-matrix composite (MMC).

Aluminum alloys posse's good strength to weight ration, excellent corrosion resistance and good ductility. In the present work we use metal matrix composites instead of other composites. So for the fabrication of these MMC's we are using different techniques they are as below;

- 1) Liquid state processes
 - a) Stir casting
 - b) Compo casting
 - c) Squeeze casting
 - d) Spray casting

- e) In-situ (reactive) processing
- f) Ultrasonic assisted casting
- 2) Solid state processes
 - a) Powder blending followed by consolidation
 - b) High energy ball milling
 - c) Friction stir process
 - d) Diffusion bonding
 - e) Vapors deposition technique

Selection of the process depends on the following factors

- 1) Type and level of reinforcement.
- 2) Loading and the degree of micro structural integrity desired.

II. RELATED WORKS

Dharmesh M.Patoliya.et al., For their work they use 2kg of Al6061 as a base material in solid form and zirconium dioxide ia a reinforcement in powder form. They melted their base material in furnace within the suitable crucible. Preheated ZrO_2 added to molten metal and stirred it for 30mins to remove moisture and gases. Inside the furnace they added C_2Cl_6 agent and then they stirred as 500rpm speed and for 15min.Then they poured these molten metal in sand mould to getting desired shapes. Through this composite they find out and concluded that the reinforcement equally distributed into the base metal with the help of microstructure, and with the increasing of wt% the tensile and hardness impact values are also increased. J.Jenix Rino et al., Observed the mechanical properties of Al6063 reinforced with zircon sand alumina particles with wt% of 8% by stir casting method. At 4wt% of $ZrSiO_4+4wt\% Al_2O_3$ there is a increased value in hardness and tensile strength. K.Aruna,et.al., They choose stir casting among MMC's fabrication techniques. For these they used ceramic coated stirrer for maintaining a uniform distribution of reinforcement throughout the base material. To increase the wetability and degassing they added hexa chloro ethane (C_2Cl_6).For their work they add different weight percentages of ZrO_2 in range of 0 to 10wt% in Al6061. After the completion of fabrication they did metallurgical tests examine the microstructure of fabricated composite, and tensile tests and hardness tests for observing the mechanical properties. From these tests they concluded that, for increasing the weight percentage of reinforcement gradually there is an increase in the property values. By increasing the ZrO_2 weight percentage there is a decrease in elongation value. K.B. Girisha,et al., They taken Al356 as a matrix material and zirconium oxide nano particles as a reinforcement material. These are composited by using stir casting. The reinforcement is added into the matrix material in the weight fractions of 0.5%, 1%, 1.5%, 2%. They find the increased value of hardness and wear resistance with the increasing of wt% fraction of zirconium oxide nano particles. Sachin malhotra et al., The influence of different wt% of zirconia and fixed wt% of fly ash in Al6061 by stir casting is observed in their present work. The varying wt% of zirconia in this investigation are 5% and 10% and the fixed wt% of fly ash is 10%. From these work they concluded that the hardness and tensile strength increased with increasing the wt% of reinforcement. The elongation is also decreased with increased weight percentage of reinforcement.

III. MATERIALS AND EXPERIMENTAL PROCEDURE

The base materials in the present work are Al6061 and whose chemical composition is shown in below Table 1.

Table 1: Chemical composition of aluminum alloy 6061

Constituent	Al	Mg	Si	Fe	Cu	Zn	Mn	Cr	Other
Wt. %	96.50	0.956	0.562	0.532	0.236	0.202	0.102	0.046	0.864

The mechanical properties of Al 6061 based on the temper or heat treatment of the material. It offers relatively high strength, good workability, high machinability, high resistance to corrosion and largely available in nature.

The reinforcement material used in the present work is ZrO_2 .The chemical composition of the ZrO_2 is shown in Table 2.

Table 2: Chemical composition of zirconium dioxide powder

Constituent	ZrO_2	SiO_2	TiO_2	Fe_2O_3	Other
Wt. %	99.5	0.10	0.007	0.002	0.39

Zirconium Dioxide is a white crystalline oxide of zirconium. The density of these material is $5.85 g/cm^3$ and melting point greater than 2600^0c . It exhibit high strength, high structure toughness, excellent wear resistance and high hardness etc....

A. Stir Casting

In this work we take Al6061 with ZrO_2 as weight 0%, 1%, 2% and 3% respectively. Composites are fabricated by using stir casting because of its simplicity, flexibility and easy for applicability to mass production. Al 6061 is taken in the form of bars for the experiments. Keep 600-700⁰c temperature in the furnace at this temperature the Al 6061 is melt and become as a molten metal. The bars are placed inside the graphite crucible. Once the melting point is reached at the certain temperature the presented aluminum begins to melt. After it become completely molten metal, we added the different weight percentages of reinforcement with in the presence of stirring. These stirring are done with the help of graphite stirrer as constant speed 500rpm. Stirring is the main phenomenon in the stir casting. Stirring is done very gently for 10 to 15mins because of proper mixing. After the stirring the below gate of the furnace is opened. There is a die below the gate, pour that molten into the desired shape of die. Before pouring the die will be preheated for some time to avoid flaws and provide continuous flow of molten. Wait for some time and open the die and remove the composite pieces from die. After that machining will held for the test process.



Fig – 1: Bottom pouring stir casting machine

Table 3: Composition of specimen

Weight Percentages %	Aluminum 6061 (Grams)	Zirconium Dioxide (Grams)
0%	1540	0
1 %	1526	14
2 %	1512	28
3%	1498	42

Composites are made for varied weight fractions in range of 0 wt% to 3 wt% reinforcement i.e ZrO_2 in Al 6061 base material. The four different compositions calculations are given in above Table 3.

The below figure is the mould which is used in the fabrication of composites. It was a six fingers die.



Fig – 2: Mould for specimen casting

IV. EXPERIMENTAL SETUPS

A. Tensile Strength

This is also known as tension testing, is a fundamental material science and engineering test in which a sample is subjected to a controlled tension until failure. Properties that are directly measured via a tensile test are ultimate tensile strength, breaking strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined: Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics. Uni-axial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials. Some materials use biaxial tensile testing.

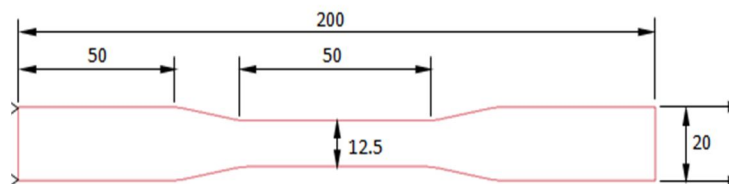


Fig – 3: Standard tensile test specimen ASTM E8

The following figure is the test specimens for tensile strength. These are machined as per the above standard figure.



Fig – 4: Tensile strength specimens

B. Density

Density is defined as, mass of a substance per unit volume. Mathematically it is donated as mass divided by volume. Theoretical density of aluminum 6061 is 2.7 g/cm^3 . For measuring of density, once we calculate the weight of substance at air and we again we calculate the weight of piece in water. In this is present investigation we need to decrease the density of composite. Light density materials are very useful and plays significant role in present society. For this we test the three composites to find out the density. The results which we gain from this test is described in results portion.



Fig – 5: Density measuring instrument

C. Hardness Measurements

The Vickers hardness test was developed in 1921 by Robert L. Smith and George E. Sandilands at Vickers Ltd as an alternative to the Brinell method to measure the hardness of materials. The basic principle, as with all common measures of hardness, is to observe a material's ability to resist plastic deformation from a standard source. The Vickers test can be used for all metals and has one of the widest scales among hardness tests. The unit of hardness given by the test is known as the Vickers Pyramid Number (HV) or Diamond Pyramid Hardness (DPH). The hardness number is determined by the load over the surface area of the indentation and not the area normal to the force, and is therefore not pressure.

This micro hardness test conducted on Al 6061 containing different weight percentages of ZrO_2 particles. The hardness were measured on the polished test pieces using diamond cone indenter with load of 1kg and the value concluded is average of 3 readings taken at different locations.



Fig – 6: Micro-vickers hardness equipment



Fig – 7: Hardness testing specimens

V. RESULTS AND DISCUSSIONS

A. Tensile Strength

In this chart shows the relation between tensile strength and wt. % of reinforcements of fabricated composites. From the tensile test results, it is observed that the tensile strength of composite is greater than unreinforced Al. Increase of tensile strength in composite can be attributed due to the applied tensile load transfer to the strongly bonded reinforcements in Al matrix, increased dislocation density near matrix-reinforcement interface, and grain refining strengthening effect. And it is gradually increased by increasing the weight percentage of reinforcement to matrix material.

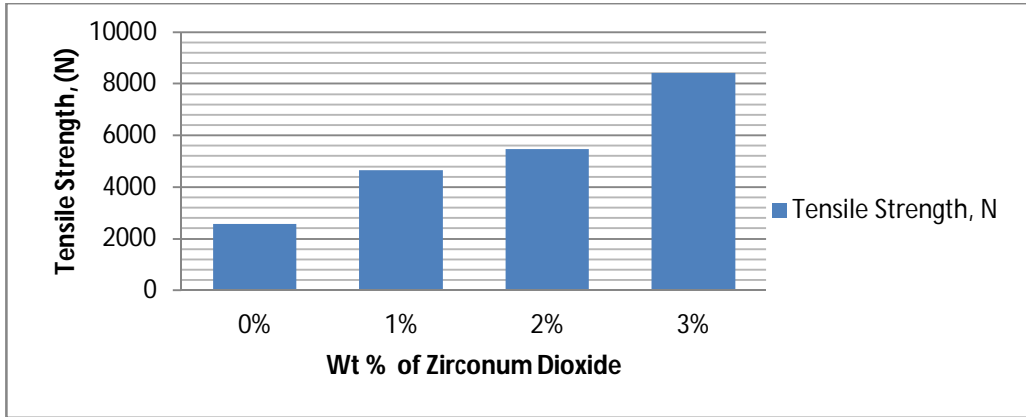


Fig – 8: Tensile Strength results

B. Density

That the experimental density of composite containing 1%, 2% and 3% zirconium dioxide is less when compared to the theoretical density. We can observe this decreased values in the below graph. The value is gradually decreased with increasing of reinforcement.

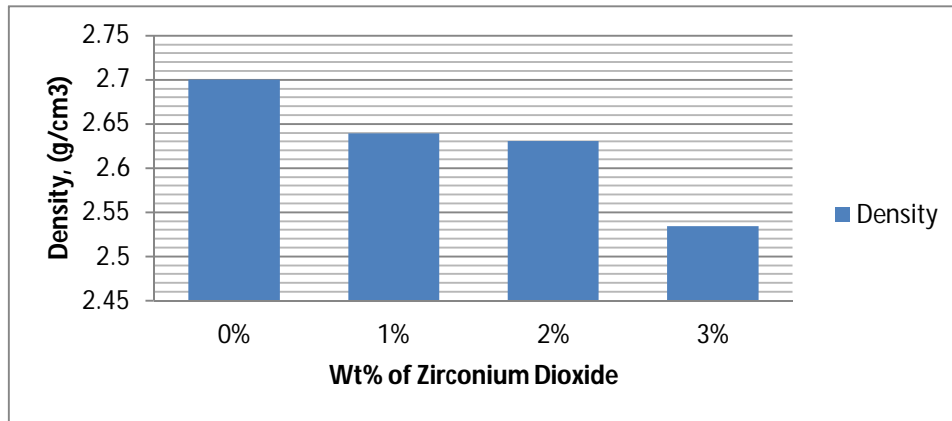


Fig – 9: Density results

C. Hardness Measurement

The variation in hardness with varying percentages of Zirconium Dioxide is shown in the below graph. From this graph we can observe that there is an increase in the hardness of composite compared with pure material. The optimum value of hardness for the composite is obtained at 3% of Zirconium Dioxide.

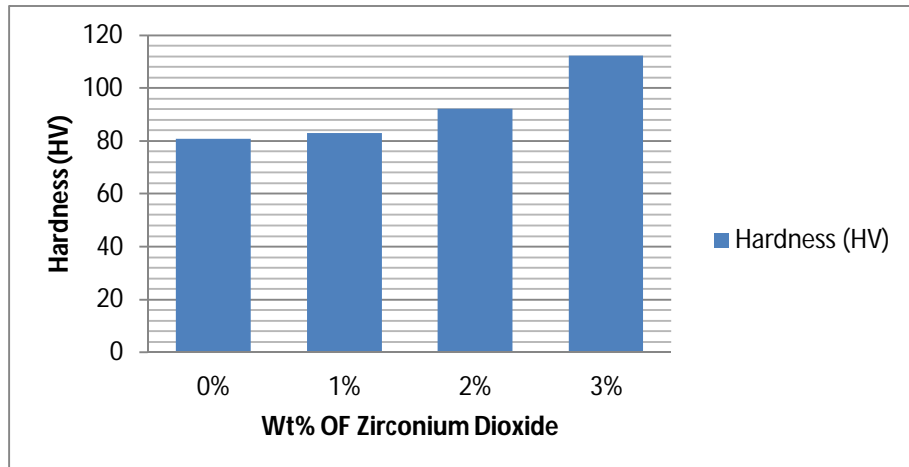


Fig – 10: Hardness measurement results

VI. CONCLUSION

Aluminum based MMC's have been fabricated successfully with the help of stir casting technique with uniform distribution of Zirconium Dioxide particles. And the composites were tested for measuring the tensile strength, hardness and density values. This values are increased with increasing of reinforcement and the density value is decreased.

- A. Tensile strength value is increased with increasing of reinforcement percentage.
- B. Density of pure Al 6061 is 2.7 g/cm^3 but it was decreased in the case of composite. If we added the more percentage of reinforcement the density value is also decreased gradually. At 3 wt% the density value is 2.5340 g/cm^3 .
- C. Hardness of the unreinforced Al 6061 is 80.85HV but at 3% reinforced composite the hardness is increased to 112.4HV.

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