Production and Characterization of Heat Treated Zirconium Dioxide Particulate Reinforced Al6061 Aluminium Alloy Composites

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Abstract - Aluminum MMCs are preferred to other conventional materials in the fields of aerospace, automotive and marine applications owing to their improved properties like high strength to weight ratio, good wear resistance etc. In the present work an attempt has been made to synthesize metal matrix composite using Al6061 as matrix material reinforced with Zirconium dioxide particulates using stir casting technique. The addition level of reinforcement is being varied from 3-12 wt% in steps of 3 wt%. The developed Al6061 alloy and Al6061- Zirconium dioxide particulate composites were subjected to T6 heat treatment. In the heat treatment of Al6061 Alloy and Al6061-Zirconium dioxide composites first solutionizing was carried out at a temperature of 530ºC for a period of 2 hours. After solutionizing the specimens were quenched in air and then artificially ageing was carried out at 175ºC. The specimens were prepared as per ASTM standards. Microstructural characterization was carried out for the above prepared composites. Hardness and tensile properties of the prepared composite were determined before and after addition of zirconium dioxide particulates to note the extent of improvement. Microstructural characterization of the composites has revealed fairly uniform distribution of Zirconium dioxide particulates in the aluminium matrix. Further, the hardness and tensile properties are higher in case of composites when compared to unreinforced Al6061 matrix. Also increasing addition level of reinforcement has resulted in further increase in both hardness and tensile strength.

Index Terms - **Heat Treatment, MMCs, Solutionizing, Al6061, Zirconium dioxide.**

I. INTRODUCTION

Metal matrix composites are gaining importance in several sectors due to its improved mechanical properties and light density when compared with metals and alloys, especially in applications where weight and strength are of prime importance [1]. Presently, Al alloy based metal matrix composites are being used in several applications like Cylinder, piston, pushrods and brake discs. Al 6061 is a popular matrix material owing to its good corrosion resistance and good mechanical properties coupled with good formability. Al 6061 is heat treatable and as a result further increase in strength is expected by adopting optimal heat treatment [2]. Use of Zirconium dioxide as reinforcement in aluminum metal matrix composites has received little attention even though it possesses high hardness used for hardening aluminum alloys .Heat treatment is an operation in the fabrication of an engineering material system. The main objective of heat treatment is to make the material system structurally and physically fit for engineering applications. Solution heat treatment of aluminum alloys allows maximum concentration of hardening solute to dissolve into solution. The process is carefully carried out by heating the alloy to a temperature at which one single, solid phase exists. By doing so, the solute atoms originally part of two phase solid solution dissolve into solution and create one single phase. Once the alloy has been heated to the recommended solutionizing temperature, it is quenched at a rapid rate such that the solute atoms don't have enough time to precipitate out of the solution. Due to quenching a super saturated solution now exists between solute and aluminum matrix. Quenching is the process of rapid cooling of material systems to room temperature to preserve the solute in solution. The cooling rate needs to be fast enough to prevent solid state diffusion and precipitation of the phase. The rapid quenching creates a saturated solution and allows for increased hardness and mechanical properties of the material system [3]. After quenching ageing is carried out at a particular temperature and duration. Although the combined effect of heat treatment and type of reinforcement plays a key role in dictating the final mechanical properties of composites, limited information is available regarding heat treatment of Al based composites that too with Zirconium dioxide as the reinforcement. In light of the above, the investigation was aimed at Production and Characterization of Heat Treated Zirconium dioxide particulate Reinforced Al6061 Aluminium Alloy Composites produced by Stir Casting.

II. MATERIALS AND EXPERIMENTAL DETAILS

2.1 Al6061 as Matrix

The matrix material utilized in experimental study is an aluminium alloy 6061 whose chemical composition is shown in Table 1. Al6061 is a heat treatable alloy, enclosing magnesium and silicon as its major alloying components. The mechanical properties of Al6061 rest on the heat treatment of the material. Compared to other material, it offers relatively high strength, good workability, high machinability, high resistance to corrosion, and is broadly available.

Table 1: Composition of Al6061 Alloy

Element	Al	Mg	Si	Fe	Cu	Zn	Ti	Mn	Cr
Quantity (wt.%)	Balance	0.90	0.50	0.50	0.30	0.20	0.10	0.10	0.25

2.2 Zirconium dioxide as Reinforcement

The reinforced material used in experimental investigation is zirconium dioxide powder whose physical properties are listed in Table 2. Zirconium dioxide (ZrO_2), sometimes known as zirconia, is a white crystalline oxide of zirconium. A typical properties exhibited by zirconium dioxide are high strength, excellent wear resistance, and high hardness, etc.

Table 2: Physical Properties of Zirconium Dioxide (ZrO_2)

Molecular formula	ZrO_2
Molecular mass	123.218 g/ mol
Appearance	White
Melting point	2715°C

2.3 Synthesis of Composites

The stir casting method is adopted to fabricate composites of Al6061-Zirconium dioxide. The Zirconium dioxide is added to the matrix with 3, 6, 9 and 12 wt%. The Al6061 is melted in graphite crucible using an electric resistance furnace. The degassing agent is added to the molten alloy to remove the gasses present. Before mixing of the Zirconium dioxide particles with the liquid Al6061 the Zirconium dioxide particles were preheated at 400°C to remove the moisture. The matrix alloy is heated to 750°C then the preheated Zirconium dioxide particles added to the liquid Al6061. After introduction of reinforcement particles stirring of the molten alloy for a period of 5 min was achieved by using stainless stirrer. Finally the melt was poured into a preheated metallic mould. The Al 6061-Zirconium dioxide composites were obtained in the form of cylindrical rods. The stir casting set up used for the development of Al6061-Zirconium dioxide composites is shown in the below Figure 1.

Figure 1: Electric Arc Furnace

2.4 Heat Treatment of Composites

The Al6061 alloy and developed Al6061-Zirconium dioxide composites were subjected to T6 heat treatment in a muffle furnace. The composites were introduced in the muffle furnace and solutionizing was carried out at a temperature of 530°C for a period of 2 hours. After solutionizing the specimens were quenched in air and then artificially ageing was carried out at 175°C. Figure 2 shows the muffle furnace used for the heat treatment process.

Figure 2: Muffle Furnace

III. Testing of Composites

The developed composites were machined and the samples for the estimation of Microstructure, Hardness and Tensile strength were made as per ASTM standards. Microstructure characterization was carried out using optical microscope. The Hardness test was conducted using Brinell Hardness testing machine. Tensile strength test was conducted using Instron testing machine. The ASTM sized standard specimen used for tensile test is shown in the below Figures 3.

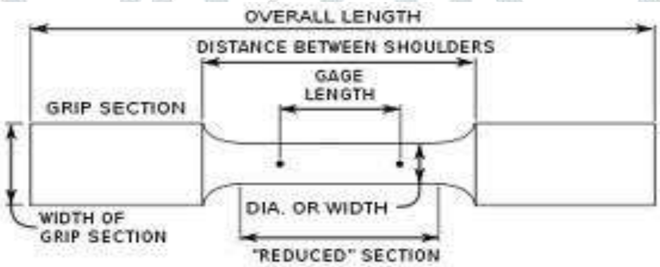

Figure 3: ASTM Standard diagram for Tensile Test

Gauge length =30mm Diameter=6mm Radius of fillet=6mm Reduced section=36mm

IV. RESULTS AND DISCUSSIONS

4.1 Microstructure Characterization

The Microstructural examination was conducted for Al6061 matrix alloy and Al6061-Zirconium dioxide particulate composite using optical microscope. From the figures 4, 5, 6, 7 and 8 it is clear that as the percentage of zirconium dioxide particulates increases the distribution of zirconium dioxide particulates in the Al6061 Alloy also increases. Figure 4 clearly reveals the distribution of zirconium dioxide particulates with uniform and good interfacial bonding strength in the composite. The heat treatment of Al6061-Zirconium dioxide composites with air as quenching media results in the grain refinement and leads to improvement in hardness and tensile strength properties than as-cast composites. Also from the above figures it is clear that as the percentage of zirconium dioxide particulates increases the distribution of zirconium dioxide particulates in the Aluminium Alloy Al6061 also increases.

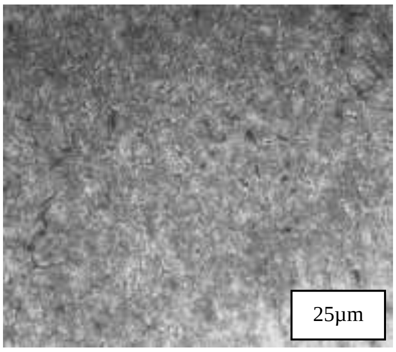

Figure 4: Al 6061-0% ZrO_2

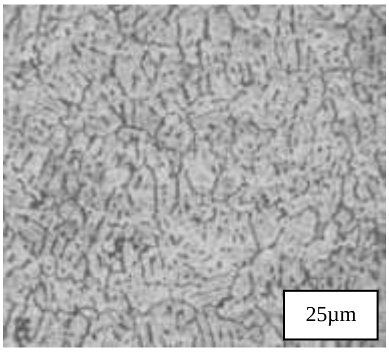

Figure 5: Al 6061-3% ZrO_2

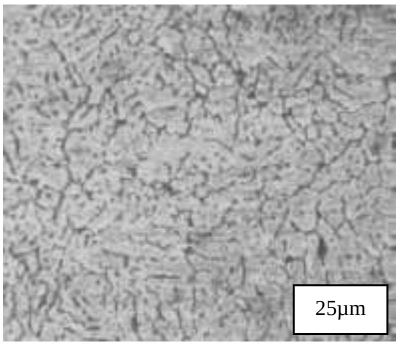

Figure 6: Al 6061-6% ZrO_2

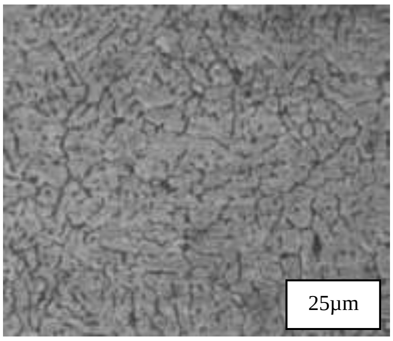

Figure 7: Al 6061-9% ZrO_2

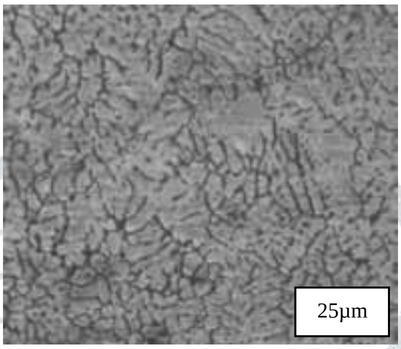

Figure 8: Al 6061-12% ZrO_2

4.2 Hardness Test

The below Figure 9 shows the relation between weight percentage of Zirconium dioxide and BHN of fabricated composites

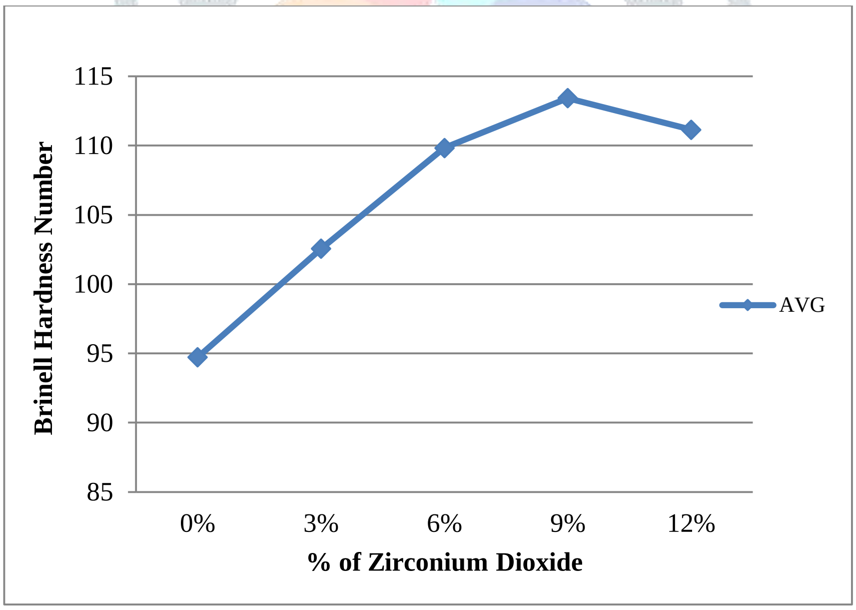

Figure 9: BHN variation v/s % of Zirconium dioxide

It is evident from the above figure that the hardness of the composite material is much higher than that of its parent metal. It is also clear that the hardness of the composite material increases with wt% of Zirconium dioxide content upto 9% and decreases there afterwards due to poor wetability and poor bonding between the Al6061 alloy matrix and Zirconium dioxide particulate. Also the addition of reinforcement makes the ductile Al6061 alloy into more brittle as hard Zirconium dioxide content increases. The heat treatment of Al6061-Zirconium dioxide composites with air as quenching media results in the grain refinement which increases the Brinell Hardness Number of the composites than as-cast composites.

4.3 Tensile Strength Test

Figure 10 shows the effect of Ultimate tensile strength of composites containing various amounts of Zirconium dioxide.

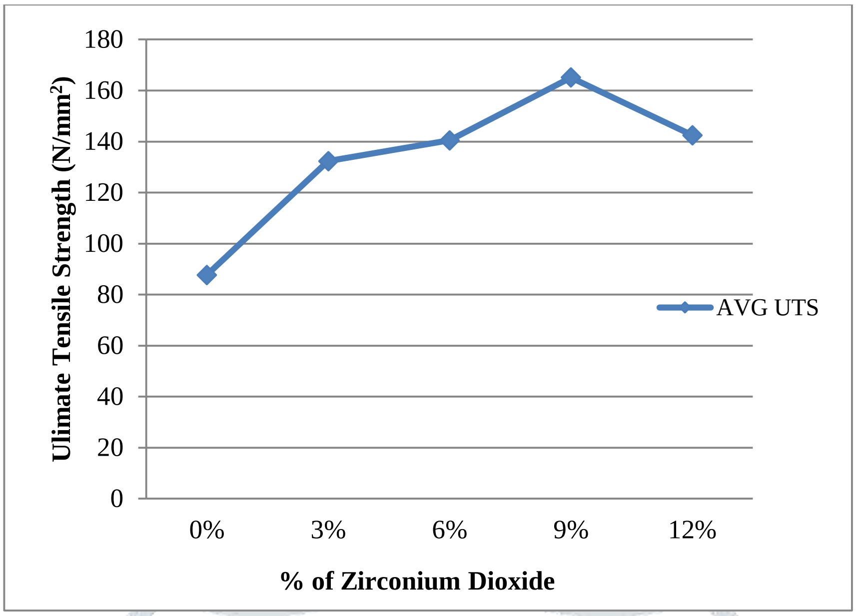

Figure 10: UTS Variation v/s % of Zirconium dioxide

It can be observed from the above Figure that as the Zirconium dioxide content increases, the ultimate tensile strength of the composite increases and decreases there afterwards due to poor wetability and poor bonding between the Al6061 alloy matrix and Zirconium dioxide particulate. Wetability is one of the dominating factors to ensure good bonding between the matrix and reinforcement. A good bonding between reinforcement and soft aluminium matrix favors an enhancement of the ultimate tensile strength of the composite. Optimum tensile strength is seen for composite specimen with 9% ZrO_2. The heat treatment of Al6061-Zirconium dioxide composites with air as quenching media results in the grain refinement which increases the ultimate tensile strength of the composites than as-cast composites.

V. CONCLUSIONS

- Using stir casting method, Zirconium dioxide can be successfully introduced in the Al6061 alloy matrix to fabricate the composite material.
- From the microstructure analysis it is evident that the composite fabricated have fairly even distribution of reinforcements in the composite material.
- Addition of Zirconium dioxide significantly improves the hardness of Al6061, when compared with that of unreinforced matrix. However the hardness begins to decrease above 9wt% of Zirconium dioxide. Heat treatment and aging has significant effect on hardness.
- Addition of Zirconium dioxide significantly improves ultimate tensile strength of Al6061, when compared with that of unreinforced matrix. However the ultimate tensile strength begins to decrease above 9wt% of Zirconium dioxide.

VI. ACKNOWLEDGEMENTS

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REFERENCES

[1] V. Bharath, Mahadev Nagaral and V. Auradi, "Synthesis and Characterization of Al6061/Al_2O_3 Particulate Metal Matrix Composites", International Conference on Challeges and opportunities in Mechanical Engineering and Management Studies, ISBN 978-93, July 2012.

[2] Ajay Singh, Love kumar, Mohith Chaudhry, Om Narayan, Pallav Sharma, Piyush, Manufacturing of AMMCS Using Stir casting Process and Testing its mechanical properties, International Journal of Advanced Engineering Technology, ISSN 0976-3945, 2013 PP 26-29.

[3] Shubam Mathur, AlokBarnawal, "Effect of Process Parameter of Stir Casting on Metal Matrix Composites", International Journal of Science and Research", ISSN, 2319-7094.

[4] Shivaprakash. Y.M, K.V Sreenivasa Prasad and Yadavalli Basavaraj, Production and Tribological Characteristics of Heat Treated AA2024-Flyash Composite, International Journal of Current Engineering and Technology, Vol.3, No.3, Aug 2013, pp 2227-4106.

[5] Sanjay Soni, S. Das, G. Dixit, Effect of Ageing on the mechanical properties of Al-Si-SiC particulate composite, N International Journal of Advanced Engineering Technology, Vol.II, Issue I/January-March 2011, pp 63-72.

[6] L.H. Manjunatha and P. Dinesh, Studies on effect of heat treatment and water quench age hardening on microstructure, strength, abrasive wear behavior of Al6061-MWCNT metal matrix composites, J. Acad. Indus. Res. Vol.1 (10), March 2013, pp 595-600.

[7] V S Ramamurthy, Fabrication and Mechanical Properties of chilledAl-12% alloy-Zircon particulate composites, Proceedings of the International and INCCOM-6 conference on future trends in composite materials and Processing, IIT-Kanpur, India, Dec 12-14, 2007, pp. 621-626.

[8] V S Ramamurthy, Investigations into mechanical properties of chilled Aluminium alloy-Zirconium silicate composites Proceedings of the International conference on emerging adaptive systems and technologies, NICE, kumarcoil, TN, 1617, Dec.2005, pp. 278-285.