

Development and Testing of Al 7075 / Al₂O₃ Composite fabricated by Electromagnetic Stir Casting Process

Rohan Kumar¹, Hitendra singh², Dr. Jagpal Singh³, Tarun Hiteshi⁴

^{1 2,3,4} Assistant Professor, Accurate institute of Management and Technology

ABSTRACT

This paper deals with the development of 7075 Aluminum alloy with 2%, 4%, 6% and 8% weight reinforcement of Al₂O₃ particulates of size (20-40) microns using electromagnetic stir casting process. The developed samples are studied for microstructure and mechanical properties (tensile strength, hardness and impact strength). The microstructure analysis revealed the homogeneous distribution of Al₂O₃ particulates in the 7075 Aluminum alloy. Tensile strength and hardness indicates increasing trend in their values with increase in percentage of reinforcement where as the impact strength decreased. The tensile strength increased by a maximum of 47.76% for 8% weight reinforcement of Al₂O₃ particulates when compared with base matrix alloy. The Rockwell's hardness (HRC) increased by a maximum of 90.9% for 8% weight reinforcement of Al₂O₃ particulates but the impact strength decreased by a maximum of 50% for 8% weight reinforcement of Al₂O₃ particulates.

Key words: 7075 Aluminum alloy, Al₂O₃, Mechanical properties, Micro structure, Electromagnetic stir casting.

I.INTRODUCTION

Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern technology, composites are most promising material of recent interest. The industries have begun to recognize that the commercial applications of composites promise to offer much larger business opportunities. Thus, the shift of composite applications from aircraft to other commercial uses has become prominent in recent years. The present paper states the development of Al7075 – Al₂O₃ composite by Electro Magnetic stir casting technique. This technique is selected because it provides a non intrusive stirring action which results in uniform dispersion of particulates. By this Technique, three samples of Al7075-Al₂O₃ composite with 2%, 4%, 6% and 8% weight reinforced Al₂O₃ particulates are developed and tested for microstructures analysis. The developed samples are also tested for mechanical properties like tensile strength, hardness and impact strength.

II.MATERIALS AND METHODS

2.1 Matrix Alloy and Reinforcement Material

In this study, Al7075 alloy is selected because of its good mechanical strength, ductility, hardness and fatigue strength.

Table 1: Chemical composition of Al7075 alloy (weight %)

Zn	Mg	Cu	Fe	Si	Mn	Ti	Others	Al
5.1-6.1	2.1-2.9	1.2-2.0	0.05	0.4	0.3	0.2	0.75	Balance

Table 1 show the chemical composition of the 7075 Al alloy. Aluminum oxide is a widely used reinforcement material because of its good wetability with the aluminum matrix owing to its hardness and strength. [10].

2.2 Electro Magnetic Stir Casting Process

Al7075/ Al_2O_3 particulate composite with different weight percentage of reinforcement have been developed by electromagnetic stir casting process. The experimental setup to develop the composite is shown in figure (1). The apparatus consisted of 3 phase induction motor (15 Kw, 440V) and a three line transformer. The rotor is removed from the motor housing. It is used to create an electromagnetic field around stationary melt conductor in the crucible. Magnetic field is induced in stator windings of motor, which induces a current in the melt. Due to Lorentz force, the stirring action of the melt is achieved. An insulation of glass wool is provided to protect the winding against the high heat of crucible carrying the molten material. A 3 phase Auto transformer of 20 Amp/line is used. It is used to control the flow of current by varying the voltage in the circuit. A K type chromel thermocouple (90% Ni and 10% Cr) is used. The temperature range is from -200°C to 1200°C . It is used to measure the temperature of the molten material. An inert gas cylinder filled with Argon gas is used it is used to prevent the oxidation of molten metal. Weighed quantity of cleaned Al 7075 alloy is loaded in the graphite crucible. It is melted to a temperature of 780°C in resistance heating muffle furnace. The temperature was recorded using K type thermocouple. Al_2O_3 particulates with an average size of 30 micron were chosen as the reinforcement. The 2%, 4%, 6% and 8% weight reinforced Al_2O_3 reinforcing particulates were added at the vortex formed on the surface of the molten liquid during stirring at 750°C in the crucible. The Al_2O_3 particulates disperses into the melt material and stirred by an electromagnetic field for around 5 minutes with stirring speed around 280 rpm. The samples were prepared from the cast composite ingots.



Figure 1. Experimental set up of Electromagnetic stir casting process

The figure 2 shows the four developed cast composite ingots with 2%, 4%, 6% and 8% weight reinforcement with Al_2O_3 .



Fig 2. The developed cast composite ingots

III. RESULTS AND DISCUSSIONS

3.1 Microstructure Analysis

The specimens of size 50x50 mm are prepared for micro structural characterization. Initially the face of the sample is conventionally polished using emery papers of various sizes, (Grit designation ranging from 150 to 1200). Then, it is further polished using surface polishing machine. Further, the polished face is etched using Kellar reagent (2.5ml HNO_3 , 1.5ml HCL , 1.0ml HF and 95.0ml of H_2O) for 30 seconds to reveal the microstructures. The samples are examined under metallurgical microscope, model number 6420, CCD camera at a magnification of 100X. The Figure 5 (a, b, c & d) shows the microstructure of 7075 Al alloy composites having 2%, 4%, 6% and 8% reinforcement materials.

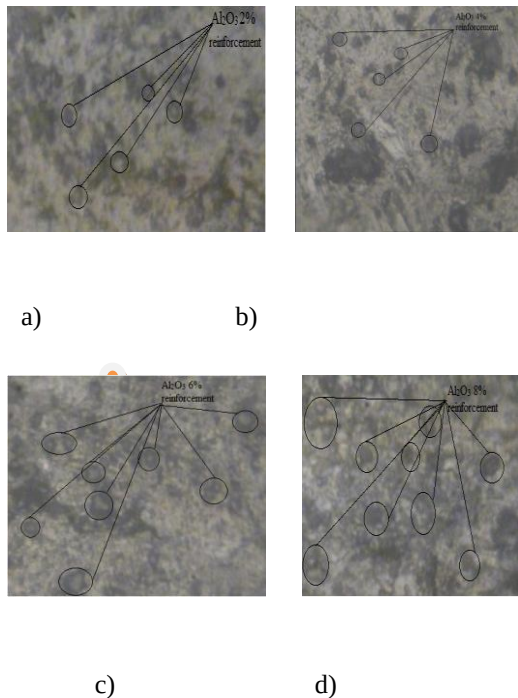


Figure 5. Microstructure of 7075 Al alloy composites having (a) 2% reinforcement material (b) 4% reinforcement material (c) 6% reinforcement material and (d) 8% reinforcement materials.

3.2 Tensile Testing Analysis

The tensile test is performed to obtain the tensile strength according to ASTM (American Society for Testing and Materials). The tensile strength is the ability to bear the tensile load before fracture. The test specimens of Al-7075 with 2, 4, 6, and 8 weight % of Al_2O_3 particulates are prepared as per dimensions shown in figure 6 from the cast ingots. The prepared specimens to conduct tensile test is shown in figure 7. The tensile tests were conducted at room temperature using computerized uni- axial tensile testing machine model KIC-2-FT-10 capacity 10 KN.

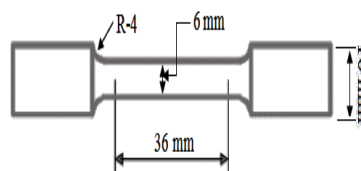


Figure 6. The Specimen dimensions for Tensile test

Table 3 Tensile Strength of the specimen

Specimen	Load (KN)	Tensile Strength (N/mm^2)	Elongation (mm)
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Al 7075	4.36	143.2	9.5
Al 7075 with 2% reinforcement	5.16	180.7	8.2
Al 7075 with 4% reinforcement	6.25	192.3	7.5
Al 7075 with 6% reinforcement	7.33	201.6	6.8
Al 7075 with 8% reinforcement	8.25	211.6	6.3

The results from the tensile strength of the specimen is shown in Table 3. From the result it is indicated that the tensile strength of Al7075-Al₂O₃ composite developed are higher than base matrix alloy. The results shows an increasing trend in tensile strength as the percentage of reinforcement increases. The tensile strength increased by 47.76% for 8% weight reinforcement of Al₂O₃ particulates. The dispersion of Al₂O₃ particulates in ductile matrix resulted in improvement of Tensile strength. The higher hardness of Al₂O₃ particulates increases the load bearing capacity and hence improves the tensile strength. As observed in microstructure, the increase in the strength can also be due to the closer packing of Al₂O₃ particulates with in Al7075 alloy.

3.3Hardness

The input parameters for the Rockwell hardness test are load applied (60Kgf), diameter of the indenter (2.5mm) and the loading time (30seconds) according to specifications. The Rockwell hardness test results of Al 7075 base matrix and their cast composites containing Al₂O₃ particulates are presented in table 3. The Rockwell hardness on C scale (HRC) is shown in table 4. It can be observed that the hardness of the composite is greater than base matrix Al 7075 alloy. The composite containing higher percentage of reinforcement exhibits higher hardness values. The hardness of non reinforced Al7075 is 86 in HRC. For 2% weight reinforcement of Al₂O₃ particulates the hardness increases by 9.3%. In case of 4% weight reinforcement of Al₂O₃ particulates the hardness increases by 19.76%. For 6% and 8% weight reinforcement of Al₂O₃ particulates the hardness increases by 31.39% and 46.51%. The increase in the hardness values corresponds to the presence of comparatively harder Al₂O₃ particulates.

3.3Impact Strength

Impact strength is the ability of the material to absorb mechanical energy in the process of deformation and fracture under impact loading. The absorbed energy is the measuring of materials notch toughness. The charpy test is used to determine the impact strength of the specimen prepared from the cast ingots. The shape of specimen sample is rectangular cuboid of size 10mm x 10mm x 55mm is prepared from Al7075 – Al₂O₃ composite ingots with 2%, 4%, 6%, and 8% weight reinforcement. A V-notch of size 2 mm deep and angle 45° included angle is made at centre of specimen. The hammer is dropped from an angle of 140°. The specimen dimensions for impact test are shown in figure 8.



Figure 8. The Specimen dimensions for Impact test

Table 5 – Impact strength of the various specimen

Sample	Energy in joules
Non reinforced Al7075	24
Al7075 + 2% Al ₂ O ₃	21
Al7075 + 4% Al ₂ O ₃	19
Al7075 + 6% Al ₂ O ₃	16
Al7075 + 8% Al ₂ O ₃	12

Table 5 shows the impact strength of the various specimens. The result indicates that the impact strength decreases with increase in the percentage reinforcement with Al7075 alloy. This is because increase in percentage of Al₂O₃ as reinforcement imparts brittleness.

Comparing the mechanical properties of the present investigation with the previous work conducted by other investigator like G. B. Veeresh Kumar [16] using mechanical stir casting technique. The present result gives superior mechanical properties. The percentage increase in tensile strength for 6% wt. reinforced Al₂O₃ particulates is 24% where as in the present research the tensile strength improved by 41% for the same weight reinforcement. The hardness value is also increased by 18% for the same wt. reinforced Al₂O₃ particulates as per Rockwell hardness test on HRC scale.

IV. CONCLUSIONS

From the present research work, the various conclusions are drawn as listed below:

1. The electromagnetic stir casting process is successfully developed and the cast Al7075-Al₂O₃ composite is fabricated.
2. The study of microstructure showed that Al₂O₃ particulates are uniformly distributed.
3. The tensile strength for base matrix Al7075 alloy is 143.2N/mm² which increases to 211.6N/mm² for 8% weight Al₂O₃ weight reinforced alloy. The tensile strength increases by 47.476% for 8% weight reinforcement of Al₂O₃ particulates.
4. The Rockwell hardness of base matrix Al7075 alloy is 86 on HRC scale, which increases to 126 for 8% weight reinforcement of Al₂O₃ particulates. The result indicates that the hardness value increases by 46.51% for 8% weight reinforcement Al₂O₃ particulates.

5. The impact strength of Al7075 alloy is 24 J which is reduced to 12 J for 8% Al₂O₃ weight reinforced composite.

REFERENCES

1. Lehu, H., Masounave, J. and Blain, J., (1985), "Rheological behavior and microstructures of stir casting zinc aluminium alloys.", Journal of material Science, Volume 20, Page No.- 105-113.
2. Moffatt, H.K., (1991), "Electro Magnetic Stirring". Journal of Physics Fluids A, Volume 3, Page No.-1336-1443
3. Komai, K., Minoshima, K., and Ryoson, H., (1993), "Tensile and fatigue fracture behavior and water-environment effects in a SiC-whisker/7075-aluminum composite", Journals of Composites Science and Technology, Volume 46, Issue 1, Page No.-59-66.
4. Takeuchi, E., Tanaka, H. and Kajioka, H., (1994), "Hydromagnetic separation of metal pool in the continuous casting strand", Proc. International symposium on electromagnetic processing of materials, Nagoya, Japan, Page No.-364-371.
5. Doel, T. J. A., and Bowen, P., (1996), "Tensile properties of particulate-reinforced metal matrix composites Composites Part A", Applied Science and Manufacturing, Volume 27, Issue 8, Pages 655-665.
6. Kaddah, N. Ei., and Natarajan, T.T., (1999), "Electromagnetic Stirring of Steel: Effects of Stirrer Design on mixing in Horizontal Electromagnetic Stirring of Steel Slabs- Second International Conference on CFD in the Minerals and Process industries CSIRO, Melbourne, Australia", Page No.-339-344.
7. Kim, S. W., Kim, D. Y., Kim, W. G., and Woo, K. D., (2001), "The study on characteristics of heat treatment of the direct squeeze cast 7075 wrought Al alloy", Materials Science and Engineering A, Volumes 304-306, Pages 721-726.
8. Brabazon, D., Browne D.J., and Carr, A.J., (2002), "Mechanical Stir Casting of Aluminum alloys from the mushy state: process, microstructure and mechanical properties", Journals of Materials science and Engineering, Volume- A326, Page No.-370-381.
9. Goldschmit, Mercela, B., Ferro, Sergio P., Príncipe, R. Javier. and Coppola Owen, A Herbert., (2003), "Numerical Modeling of Liquid Steel Continuous Casting Processes", International Journal of Heat and Technology", Volume 21, Page No.- 43-50.
10. Kook, M., (2003), "Production and Mechanical Properties of Al₂O₃ Particles Reinforced 2024, Al Alloy Composites", Journal for Materials Processing Technology, Volume 161, Page No.- (385-387).
11. Milind, S. and Ramanarayanan, V., (2004), "Design and Analysis of Linear type Electromagnetic Stirrer", IEEE Industry Applications Conference, Volume-1, Page No.-188-194.
12. Clark, R., Jr, Coughran, B., Traina, I., Hernandez, A., Scheck, T., Etuk, C., Peters, J., Lee, E.W., Ogren J., and Es-Said, O.S., (2005) "On the correlation of mechanical and physical properties of 7075-T6Al alloy", Journal of Engineering Failure Analysis, Volume 12, Issue 4, Pages 520-526.
13. Yang, Z., Seo, P.K., Kang, C.G., (2005), "Grain size control of semisolid A356 Alloy manufactured by Electromagnetic Stirring". Journal of Material Science and Technology, Volume 21, Page No.-219-225.

14. Kim, T.W., Kim, H.H., Bae, J.W., Lee, S.M. and Kang, C.G, (2008), "Semi-solid die forging of Al-6061 wrought aluminium alloy with electromagnetic stirring", Journal of Engineering Manufacture, Part B, Volume- 222, Page No.-1083 – 1097.
15. Stransky, Karel., Kavicka, Frantisek., Sekanina, Bohemia., Stetina, Joset., Dobrovska, Jana., Stransky, Lubomir., (2009), "Electromagnetic stirring of the melt of concast billets and its importance". Journals of Hradec nad Moravicoi, Volume-19, Page No.-1-6.
16. Veeresh Kumar, G.B., Rao, C.S., Selvaraj, N. and Bhagyashekar, M.S., (2010), "Studies on Al6061-SiC and Al7075-Al₂O₃ Metal Matrix Composites". Journal of Mineral and Materials Characterization & Engineering, Volume-9, Page No.-43-45.
17. Karthigeyan, R., Ranganath, G., and Sanakaranarayanan, S., (2012), "Mechanical properties and microstructure studies of aluminum (7075) alloy matrix composite reinforced with short basalt fiber." European Journal of Scientific Research, Volume- 68 Page No.-606-615.
18. Bhusan, R.K., Kumar, S. and Das, S., (2012), "Fabrication and characterization of 7075 Al alloy reinforcedwith SiC particulates". International Journal of Advance Manufacturing Technology, DOI 10.1007/800170-012-4200-6.