An Investigation of Alumina Reinforcement Effect on Mechanical Properties of Al 356 Based Metal Matrix Composite

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***Abstract* —** *The Zeal for composites has been increasing day by day due to their abnormal properties when compared with metals and alloy. The global era has been shifted from matrix composites to the Metal Matrix Composites. Due to their diversified properties they are being used in different sectors including majors as in automobile, aerospace and defense. Some most important properties includes good mechanical properties, its low density and better corrosion properties as compared to conventional metals and alloys. This research work has been an attempt and investigation is made to understand the mechanical behaviour of composite, aluminium A356 alloy reinforced with alumina powder. To know the extent of agglomeration of Al_2O_3 particles in the A 356 matrix a study on microstructure had done. Composites are casted using stir casting method with fine mesh alumina powder as reinforcement to achieve the advantage of fine size reinforcement. Casting prepared without and with reinforcement (percentile range from 2% to 3% with increment of 0.5%). And also mechanical properties of composites compared with aluminium 356 alloy.*

Keywords — *Aluminium A356alloy, alumina powder, stir casting, Metal Matrix composites, Compression strength, Hardness.*

I. INTRODUCTION

The curious to search for composite material arises due to highly specific properties can be achieved in composites for a specialized task. As we now composite material can be defined as a combination of two or more distinct materials at a macroscopic level to attain new properties that can't be achieved by those of individual components acting alone. Matrix is continuous and uniform. Reinforcement is the material that is embedded in the matrix. Reinforcements can be added in the form of monofilaments or discontinuous form of short fibers, whiskers, particulates etc [1-2]. Also the rising necessity for higher resources in the areas of aerospace and automotive industries had led to a rapid growth of Metal matrix composites (MMC's). Allison et al. (1993) and Narula et al. (1996), they can be customized to have better properties such as good specific strength and stiffness, improved amount of wear resistance, and exhibits high temperature performance, sound thermal and mechanical fatigue and creep resistance compared to monolithic alloys. In the process of reinforcement of aluminium alloy composites, Silicon Carbide, Aluminum oxide, Silicon oxide, Boron carbide, etc... Al_2O_3 is the particulate reinforcing agent among above. Yar et al. (2009) conveyed that the hardness and compression strength of the composite made of Al 356 reinforced with MgO nano particle is more than alloys. Various techniques are developed to manufacture metal matrix composites but out of them stir casting method is most commonly used process because it is simple and cost effective [4]. Sajjadi et al. (2011) studied that the hardness and compressive strength of the composite increased with increasing the weight percentage of Al_2O_3 and also by decreasing the particle size [3]. Hanumanthe Gowda and el al. studied the Mechanical properties like Tensile strength and Hardness of the Al 356 alloy have been significantly improved with Hybrid reinforcement in the Composite at Different Aging Conditions [9]. H. R. EZATPOUR and et al. Studied that the Porosity in the composite can be decreases with extrusion stir casting process. Also hardness, yield strength and ultimate strength increases with this extrusion stir casting process [12]. Practical reinforcements, improves the mechanical properties of Aluminium based matrix composites, the numerous advantages of the constituting

materials can be achieved by advance of composite materials. Metal Matrix Composites reinforced with various particles results in improvement in the properties processed by traditional routes [13].

II. EXPERIMENTAL CONFIGURATION

A. Materials and Methods

Fig 1. Al 356 ingots

Fig 2. Alumina powder

A356 is a light weight aluminum alloy that has containing the most common alloying elements like silicon and magnesium. It shows extraordinary mechanical properties and good wettability. Aluminium alloy surfaces exhibits apparent shine in a dry environment due to formation of defending aluminium oxide layer in a clear form. The general chemical composition of A356 is tabulated below.

Table I: A356 Composition

S.no	Element	Composition(% wt)
1	Si	6.5
2	Mg	0.45
3	Cu	0.20
4	Mn	0.10
5	Fe	0.35
6	Cr	0.10
7	Ni	0.10
8	Zn	0.10
9	Ti	0.10
10	Pb	0.10
11	Sn	0.05
12	Al	Balance

B. Experimental set up

Experimental setup consists of electrical furnace, which is used to melt aluminium ingots. This electrical furnace is fully covered in order to avoid heat loss by convection. Temperature of the electric furnace is monitored by a thermocouple. This thermocouple measurement is input to controller unit which controls temperature at set value.

Fig 3. Bottom pouring type stir casting machine

C. Methodology

An amount of 1.2 kgs of A 356 alloy was placed in stir casting machine to heat up to 800^0C, along with degassifier C_2Cl_6, and wt.% reinforcement at 250^0C in an oven. Argon gas is send into the furnace and atmospheric pressure is maintained to avoid oxidation. The furnace temperature was maintained at 800^0C. A tea spoon of flux MgO is added to the molten metal and allowed to homogenize for a time period of 6 min by agitating of stirrer in the melt. After removing the waste material pre heated Al_2O_3 particles were added into vortex, addition of alumina powder was done by stirring the molten metal. Then the speed of the stirrer is increased up to 650 rpm and this process was continued for 10 min. Then the liquid is allowed into the die of 250mm length and 20mm diameter of 3 fingers while stirrer is rotating. The same process is repeated for pure A356 alloy and also for reinforcement Al_2O_3 particles 2%, 2.5% and 3%. Then the composite specimens and pure A356 alloy specimens were subjected to homogenation and a temperature of 250^0C is maintained for 9 hrs in muffle furnace. Bottom pour stir casing machine (shown in fig.3) has been used to prepare castings.

III. RESULTS AND DISCUSSION

i. **Compression Test:** To determine the load carrying capacity of the composites when compared with the alloy compression test is done. The sample were prepared by polishing the surface using emery papers of various grit sizes and tested as per ASTM E9 standard in Universal testing machine. Compressive stress was determined. The results are tabulated in table 2.

It is clear that an increase in strength of composites to compression has been raised gradually with the raise in percentage of Al_2O_3. Microscopic images(Fig 6,7and9) shows formation of Al_2O_3 obstacles in aluminum alloy matrix and also find the refinement of grains and uniform distribution of Al2O3 in A356 matrix and that lead in enhancement of compression strength. The percentage rise in compression strength at 3% reinforcement is more compared to other percentages, shown in fig.5.

Table II: Compression Strength Values

S.no	Composition	Compression stress values (Mpa)			
		Trail 1	Trail 2	Trail 3	Average
1	Pure A356	474	442	462	459.96
2	2% Al_2O_3	480.57	516.24	492.32	496.37
3	2.5%Al_2O_3	635.3	610.38	628	624.79
4	3%Al_2O_3	803.57	687.25	712.51	734.42

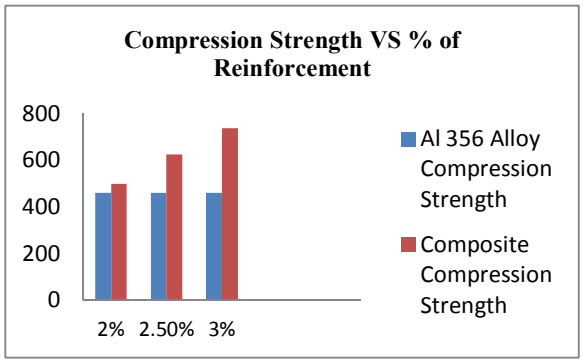

Fig 4. Compression strength w.r.t wt % of Al_2O_3

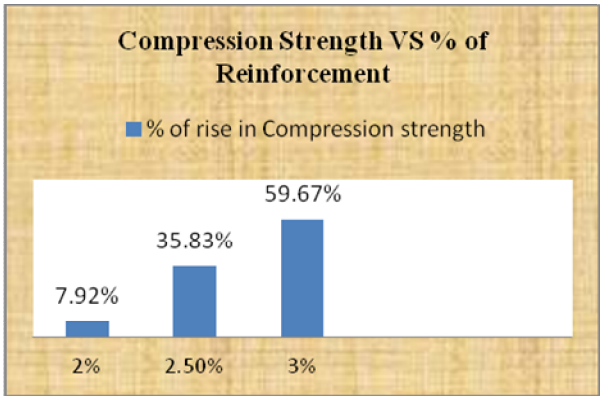

Fig 5. % of Rise in Compression strength w.r.t wt % of Al_2O_3

ii. ***Micro Structure:*** Micro structure is a tool to know the reinforcement distribution in matrix to some extent and it also reveals the grain boundaries of the composite and alloy. Care should be taken while preparing the surface for micro structure. Proper etchant is to be applied on the surface of the specimen. Optical Inverted metallurgical microscope used for visual impact at the magnification of 500X as per ASTM E112-63 standard.

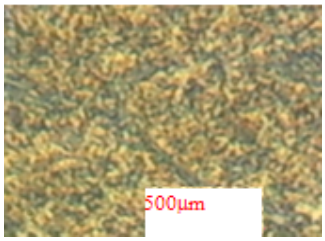

Fig 6. Micro structure of Pure Al 356

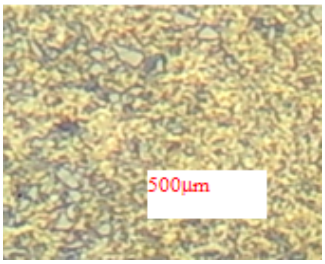

Fig 7. Micro structure of 2% Al_2O_3

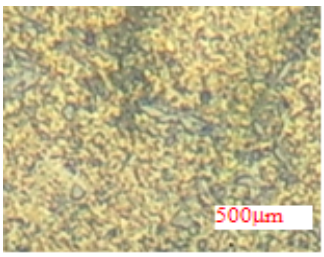

Fig 8. Micro structure of 2.5% Al_2O_3

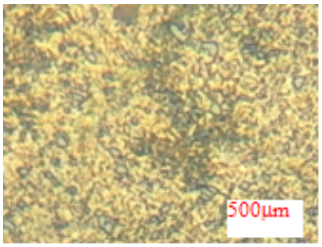

Fig 9. Micro structure of 3% Al_2O_3

Hence it showed that the mechanical properties of the composites are mostly dependent on the microstructure.

iii. Hardness Test

Micro hardness is one of the mechanical property of the material. When compared with Brinell and Rockwell hardness, the load acting on the Vickers is very less. A 10 X 10 specimen is prepared for micro hardness. A diamond indenter of 136^0 conic angle and a load of 100gms is applied on the specimen.

Table III: Hardness Values

s.no	Composition	Hardness test values VHN			
		Trail 1	Trail 2	Trail 3	Average
1	Pure A356	93.15	90.75	89.11	91.00
2	2% Al_2O_3	95.7	94.93	93.74	93.80
3	2.5%Al_2O_3	97.67	97.22	96.74	97.21
4	3%Al_2O_3	100.09	109.78	104.54	105.07

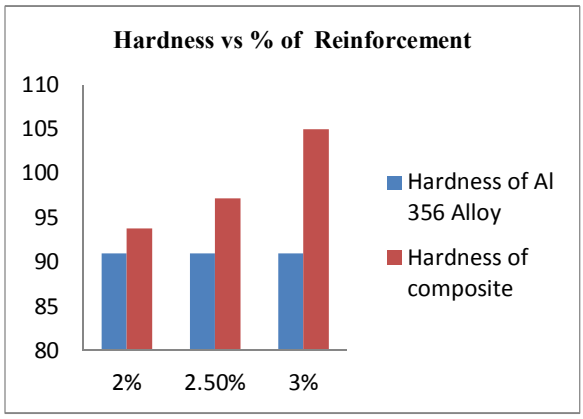

Fig 10. Hardness with respect to wt % of Al_2O_3

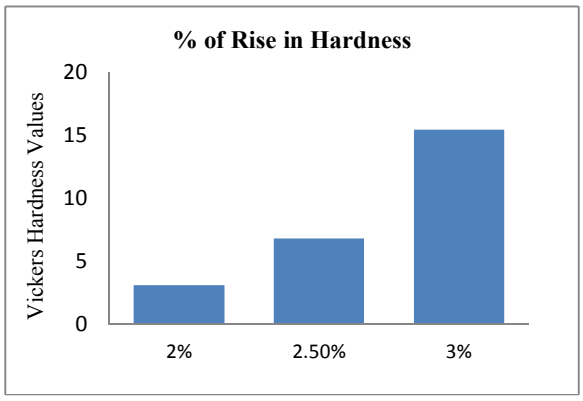

Fig 11. % of rise in Hardness with respect to wt % of Al_2O_3

The hardness values were tabulated in table 3. And graph hardness verses weight percentage of Al_2O_3 in fig 10, it shows increment of hardness is observed with reinforcement and the hardness is also improved with the increasing of reinforcement percentage from 0 to 3. Percentage 3 is the best compared to remaining percentages 0, 2 and 2.5.

IV. CONCLUSION

From the investigation made on A356 reinforced with alumina the conclusions are:

- Composites of A 356 were successfully fabricated by stir casting method with different percentile of Al_2O_3 particulate reinforcements.
- From the microstructure analysis, it is noticeable that reinforcement is distributed uniformly.
- It is observed that there is an increase in compression strength of composite as there is an increase in percentile of Al_2O_3.
- There is tremendous enhancement in the hardness of the composite when compared with the alloy A 356.

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