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A Study on Mechanical Behaviour of Hot Extruded Aluminium based MMC Reinforced with Varying Alumina Particles (A356-Al_2O_3)

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***Abstract* — Aluminium alloys are widely used in aerospace and automobile industries due to their low density and good mechanical properties, better corrosion resistance and wear, low thermal coefficient of expansion as compared to conventional metals and alloys. The excellent mechanical properties of these materials and relatively low production cost make them a very attractive candidate for a variety of applications both from scientific and technological viewpoints. The aim involved in designing metal matrix composite materials is to combine the desirable attributes of metals and Ceramics. Present work is focused on the study of mechanical behaviour of Aluminium Cast Alloy (A356) with Al_2O_3 composite produced by the stir casting technique. Particles with varying sizes are used. Tensile test and hardness test are performed on the cast and extruded A356-Al_2O_3 composites. Scanning electron microscope analysis was performed to know the presence of the phases of reinforced material.**

Key words: Stir casting, Alloy A356, Al_2O_3, MMC's, Composites, Mechanical Property.

I. INTRODUCTION

There have been tremendous strides in engineering materials since 1950s. Several super alloys and heat resistance materials have been developed for various industrial applications, especially aerospace/aircraft and defense. Automotive, medical and sport equipment industries pushed advances in materials further to introduce new generation materials particularly having low density and very light weight with high strength, hardness and stiffness. One of the important of these advanced materials is composites.

Composite materials are important engineering materials due to their outstanding mechanical properties. Metal matrix composite (MMC) materials are one of the widely known composites because of their superior properties such as high strength, hardness, stiffness, wear and corrosion resistances. Silicon carbide and Alumina particle reinforced aluminium-based MMCs are among the most common MMC and commercially available ones due to their economical production. Aluminium alloys are extensively used as industrial materials because of their excellent characteristics such as low density, high specific strength and thermal conductivities. Aluminium alloy, which has the highest tensile strength compared to other alloys, is used as structural components in aircrafts, automotives, and hobby goods. More excellent mechanical properties are strongly required for further applications.

Aluminium oxide commonly referred to as Alumina, possess strong ionic inter atominc bonding giving rise to its desirible material characterstics. It can exists in several crystalline phase which all revert to the most stable hexagonal alpha phase at elevated temperatures. Alpha phase aluima is strongest and stiffest among the oxide ceramics. Its high hardness, excellent dielectric properties, refractoriness and good thermal properties make it the material of choice for a wide range of applications.

An economical way of producing metal matrix composite is the incorporation of the particles into the liquid metal and casting. In cast aluminium alloy based composites, a moderate improvement in strength over the un-reinforced alloy is obtained. On the other hand when particulate reinforcement is added to improve stiffness, strength and tribological properties, a substantial decrease in ductility is observed. Inferior ductility of these materials limits their performance and application. The ductility is affected by various factors such as the matrix micro structure, heterogeneous reinforcement distribution, porosity content and the strength of the interfacial bond between the matrix and the reinforcement.

Secondary process like extrusion is performed to enhanced properties like higher strength, stiffness and weight savings in comparison to other materials. Particle reinforced MMCs are attractive due to their cost-effectiveness, isotropic properties, and their ability to be processed using similar technology used for monolithic materials.

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II. EXPERIMENTAL DETAILS

2.1. Work Material Details: The details of the material selected for present investigation are as discussed below. Aluminum (A356) based metal matrix composite reinforced with alumina particles of 23µm, 45µm, 75µm, 120µm size are selected for the present study. The reinforcement is done with a volume fraction of 109%. The composition of A356 mmc is given in detail in the table2.1.

Table 2.1 Composition of Work Material

Elements	Percentage
Al	91.1-93.3
Cu	<=0.2
Iron	<=0.2
Mg	0.25-0.45
Mn	<=0.1
Other each	<0.05
Silicon	6.5-7.5
Titanium	<=0.2
Zinc	<=0.1

2.2 Processing Details: The casting unit consists of a graphite crucible of about 5 kg capacities, which is heated by electrical resistance type heating coils. The temperature level of the heating unit is controlled by thermocouple activated controlling unit. Duration of heating is determined based on the quantity of material to be melted. The furnace used in the present work is of bottom pouring type, which is regulated using a valve operated from the bottom. A motor operated stirrer is provided at the top, for mixing the particulate reinforcement with the molten metal. The mechanical stirrer used for stirring the molten alloy during fabrication of composites is made of steel blades coated with Alumina powder and sodium silicate mixture to withstand high temperature and to avoid iron pickup by the melt. Arrangement is made at the bottom of the crucible for exact positioning of the mould below the valve as shown in Figure2.1.

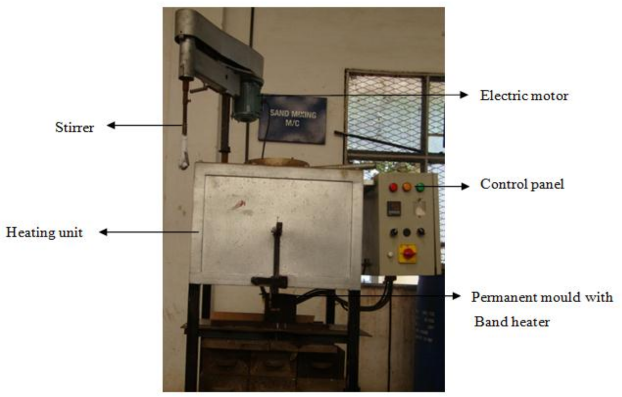

Fig 2.1: Electrical Heating Furnace

Procedure to Fabricate Composites:

- Cleaned A356 ingot of required quantity is to be placed in the melting crucible. The furnace top is to be closed by refractory material and heater is to be switched on and set to the required temperature (800^0C). Heating is to be continued for about 3 hrs
- The 10% by weight, 23 µm size Al_2O_3 Reinforcement particulates are to be heated to 300^0C for about 30 minutes in another closed furnace.
- Add the Slag remover to the molten metal to remove the slag.
- Chlorine based solid degassing tablet hexachloroethane – C_2Cl_6 Tablet is to be added to remove gasses entrapped during melting and Magnesium of about 0.3% is to be added to the melt to improve the wettability.
- Stirrer is to be immersed up to ¾ height of the molten metal and start the stirring action and at the same time Al_2O_3 powder is added slowly and stirring action is carried up to 4 minutes.
- After stirring the molten composite metal is poured into pre heated mould (400^0C) by opening the bottom valve of the furnace.
- After allowing the mould to cool at room temperature, the cast material is taken out, by opening the mould halves.
- Same Procedure was repeated for 45 µm, 75 µm and 120 µm size of reinforcement with same 10% of weight.

2.3 Extrusion Die Details

In the present work the cast Al composite is hot extruded from 35mm diameter to 10mm diameter with an extrusion ratio 12.25 Extrusion die assembly consist of Ram, Die bottom, Die top, Die support and Guide plate. Extrusion die assembly is shown in Fig.2.2. & Fig 2.3 shows the sample extrusion specimen (35mm dia and 35mm length) and extruded component.

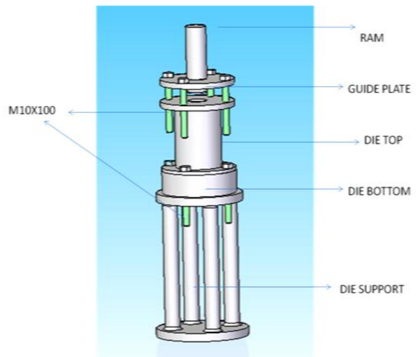

Fig 2.2: Extrusion Die Setup

Fig 2.3: Extrusion Specimen (Before & After Extrusion Process)

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III. RESULTS AND DISCUSSIONS

3.1 Brinell hardness number

Table.3.1 and Fig.3.1-3.5 illustrate the variation in BHN of as cast and extruded test specimen of different composition. It can be observed from the results that there is an increasing trend in the hardness values of the composites, both in as cast and extruded specimen. The increase in hardness can be attributed to the uniform distribution of reinforcement particulate in A356 matrix, forming strong interfacial bond between the matrix and the reinforcement. The results also indicate that the extruded composite specimens are exhibiting marginally higher order hardness compared to cast specimen of the same material.

Table 3.1: Results of Hardness Test

Sl. No	Specimen	BHN as cast composite	BHN of extruded composite
1	A356+0% Al_2O_3	79.25	82.15
2	A356+10% Al_2O_3 (23µm)	121.64	127.62
3	A356+10% AL_2O_3 (45µm)	110.36	114.86
4	A356+10% Al_2O_3 (75 µm)	101.15	104.23
5	A356+10% Al_2O_3 (120 µm)	93.5	96.04

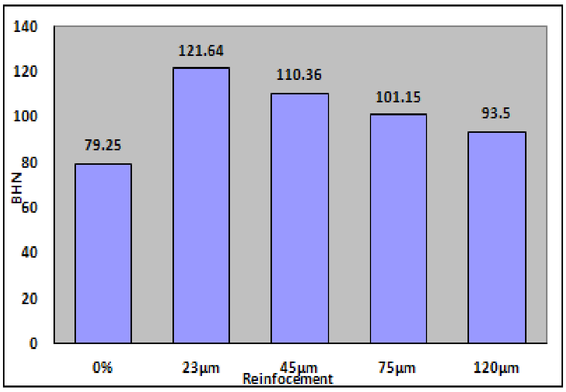

Fig 3.1 BHN Hardness Number V/S Size of Reinforcement (As Cast Composites)

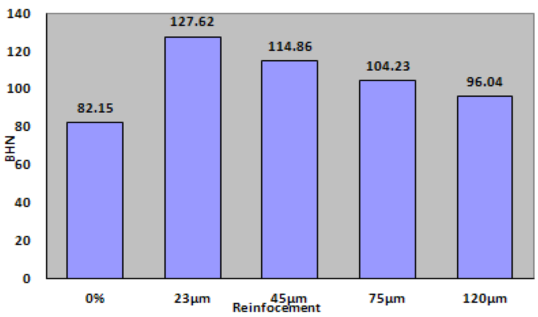

Fig 3.2 BHN V/S Size of Reinforcement (As Extruded Composites)

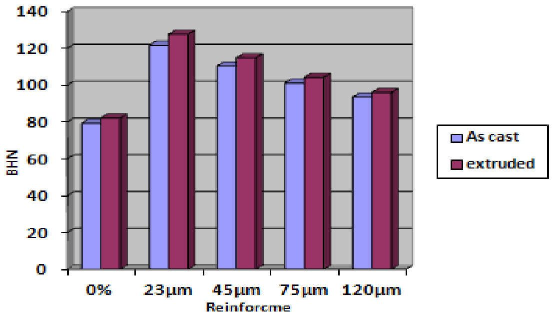

Fig 3.3 BHN V/S Size of Reinforcement (As Cast And Extruded Composites)

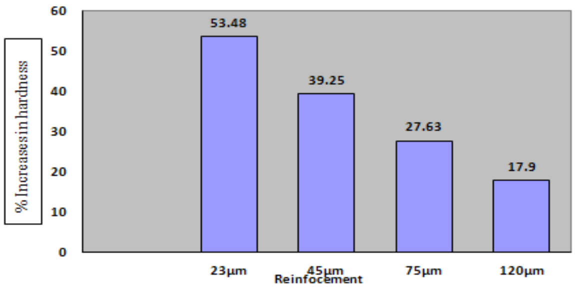

Fig 3.4 Percentage Change In Hardness of Casted Specimen

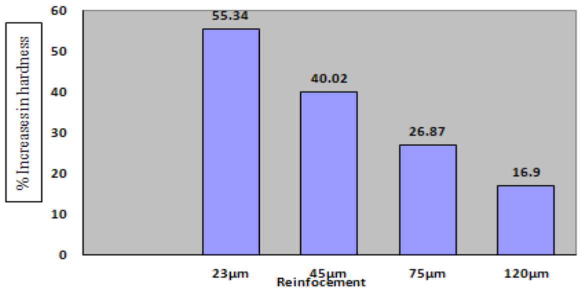

Fig 3.5 Percentage Change In Hardness of Extruded Specimen

3.2 Tensile Strength

Figure 3.6 - 3.10 illustrates the variation in tensile strength of composite test specimen of different size of particulate reinforcement. It can be observed from the results that there is a higher tensile strength of composites than the base alloy (A356) and also observed that there is in increasing trend in the tensile strength values of the composites with decreasing particle size of reinforcement. This increase strength can be attributed to the uniform distribution of the Al_2O_3 particulate reinforcement in the aluminum matrix alloy and better interfacial bonding between the matrix and reinforcement.

Table.5.2 Tensile Strength of as Cast and Extruded Composites

Specimen	Tensile strength of as cast composite in Mpa	Tensile strength of extruded composite in Mpa
A356+0% AL_2O_3	149.56	137.695
A356+10% AL_2O_3 (23µm)	218.12	200.040
A356+10% AL_2O_3 (45µm)	203.16	178.073
A356+10% AL_2O_3 (75 µm)	189.23	162.67
A356+10% AL_2O_3 (120 µm)	173.61	153.64

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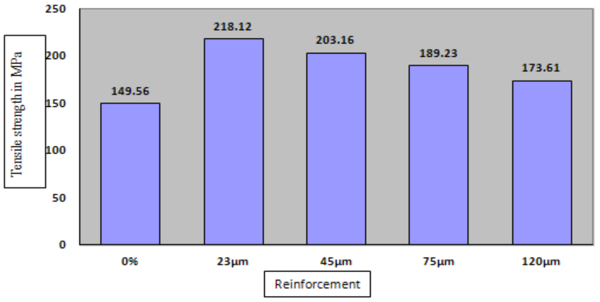

Fig 3.6 Tensile Strength of as Cast Composite V/S Size Reinforcement

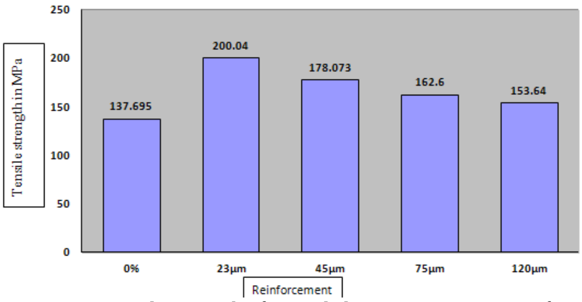

Fig 3.7 Tensile Strength of Extruded Composite V/S Size of Reinforcement

It can be observed that the, tensile strength of extruded composite specimens will decrease compared to base alloy extruded specimens due to increase in the hardness of extruded specimens.

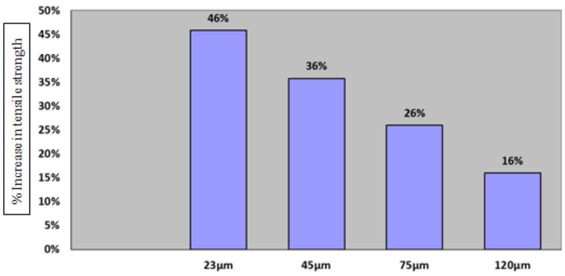

Fig 3.8 Percentage Change in Tensile Strength of Casted Specimen

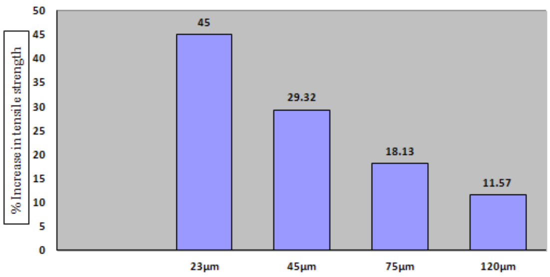

Fig 3.9 Percentage Change in Tensile Strength of Extruded Specimen

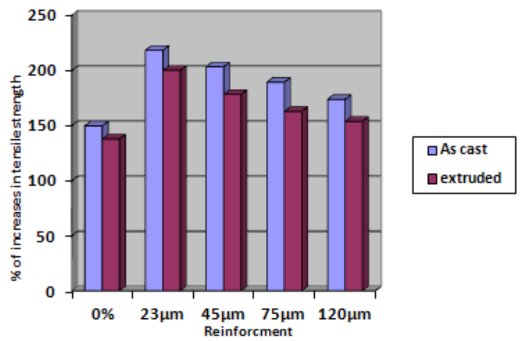

Fig 3.10 Tensile Strength V/S Reinforcement Size of Al_2o_3 (As Cast and Extruded Composite)

IV. CONCLUSION

The conclusions drawn from the present investigations are as follows:

1. The Liquid metallurgy route (stir casting technique) was successfully adopted in the preparation of A356– AL_2O_3 MMCs composites containing the reinforcement material 10% weight with particle size of 23µm, 45µm, 75µm, and 120µm.
2. The extrusion of casted A356– AL_2O_3 composite was successfully carried out with an extrusion ratio 12.6.
3. The hardness of the composite specimens is larger than base alloy and also hardness of the composites increases with decreases any particle size.
4. Extruded composite reveals that with extrusion the porosity level gets reduced and results in increased hardness.
5. The tensile strength of the composites are found to decrease due to grain modification at higher extrusion temperature.

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