Development and Evaluation of Mechanical Properties of Aluminium Based Alloy with Addition of 4% Alumina (Al_2O_3)

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Abstract—*In the recent years alumina is widely used as reinforcement in aluminium based composites (AMC) prepared by using stir casting method. In this study, aluminium 6063 was used as a matrix and fine particles of alumina was used as reinforcement. The stir casting method was used for producing AMC. In the previous studies, most of the researchers focus on the wt% of the reinforcement in the base metal. But the stirring parameters also play an important role to enhance the mechanical properties of the AMCs. So the aim of this work is to investigate the various process parameters of the stir casting method by addition of 4 wt% of the alumina. The effect of the stirring height, stirring speed and wt% of the reinforcement, were studied and analysed using charpy impact test, Vickers hardness test and FE-SEM/EDS analysis. The results, along with observations are discussed in detail in the present study.*

Keywords: *AMC, Stir Casting, Al-6063, Alumina*

INTRODUCTION

Composites play a vital role in modern science, particularly in all types of transportation, military and structural applications [1]. Composite material is amixture or combination of two or more micro or macro particles with an interface separating them that differ in form and chemical composition and are essentially insoluble in each other. In composites, materials are combined in such a way as to enable us to make better use of their parent material while minimising to some extent the effect of their deficiencies [2].

When the matrix is a metal, the composite is termed a **metal matrix composite (MMC)** [3]. The aims involved in designing metal matrix composite to combine the desirable attributes of metals and ceramics [3]. Metal matrix composite (MMC) focuses primarily on improved specific strength, high temperature and wear resistance application [4]. According to different demands for the properties of MMCs, the ingredients of MMCs are easily selected to optimize the mechanical characters of materials [5]. Mechanical properties of the composites are affected by the size, shape and volume fraction of the reinforcement, matrix material and reaction at the interface [6]. In general, according to reinforcement, the three types of metal matrix composites are; continuous-fiber, discontinuous-fiber and particulate reinforced. The advantages of particulate composites are improved strength, increased operating temperature, oxidation resistance, easy to produce, etc [7].

Aluminium is one of the most popular and commonly usedmatrix for MMC because it offers large variety of mechanical properties like good corrosion resistance, low density and high thermal and electrical conductivity. Aluminium matrix composites are progressively replacing conventional aluminium alloys in many applications due to superior properties [8]. Aluminium matrix composites are known as suitable material in most of the structural applications in which light weight is a priority [9]. Properties of aluminium matrix composites can be tailored to the demands of different industrial applications by suitable combination of matrix, reinforcement and processing routes [10]. The fabrication method of Aluminium Matrix Composites can be categorized into three processes: Solid-state method, Semi-solid-state method and Liquid-state method [11]. Compared to SiC particles, alumina has shown better stability at higher temperatures, since undesirable phases are not produced in such materials [9].Dispersion of Al_2O_3 particles in aluminium matrix improves the hardness of the matrix material [2,10,13,15,16]

The conventional and economic technique used to produce aluminium matrix composite is **stir casting** which involves stirring the filler in the molten metal. In the present a setup was prepared in the lab and metal matrix composite (MMC) with aluminium as base metal (Al 6063) was developed and alumina (Al_2O_3) was used as reinforcement and effect of the stirring height, stirring speed and wt% of the reinforcement, were studied and analysed.

PREPARATION OF SETUP

AMCs samples stir casting setup was prepared in the foundry lab as shown in figure 1. It was designed to vary two types of stirring parameters i.e. stirring speed and stirring height. The stirring speed was changed with the help of speed controller and stirring height was varied by changing the crucible stands. The stirring speed was taken as 250 rpm and 500 rpm and stirring heights were taken as 30 mm and 60mm.

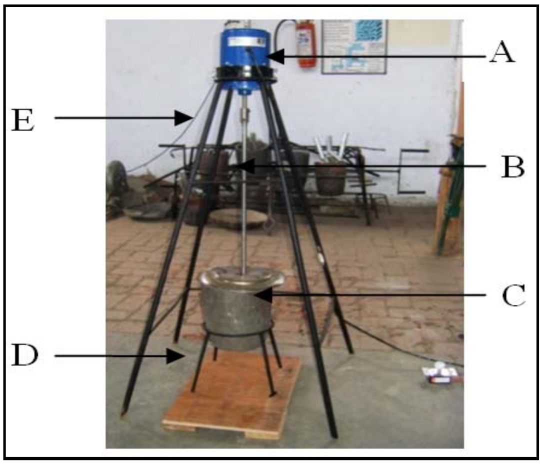

Fig. 1: Stir Casting Set up

A. Electric motor

B. Stirrer shaft

C. Crucible

D. Crucible stand

E. Frame

S1&S2-Stirring speed

H1&H2-Stirring height

Developments of Composites

Metal matrix composite (MMC) with aluminium as base metal (Al 6063) was developedand alumina(Al_2O_3) was used as reinforcement. The chemical composition of the aluminium 6063 was determined by using a spark spectrometric analyzer and the result is shown in Table 1.

Table 1: Chemical Composition of Al 6063

Al	Si	Mg	Fe	Cu	Mn	Zn
98.4	0.52	0.45	0.40	0.08	0.02	0.08

Alumina in powder form of 400 grit size was used. The chemical composition of alumina is given in the Table 2 [13].

Table 2: Chemical Composition of Alumina

α-alumina	Fe_2O_3	TiO_2	CaO	Other Materials
93	0.7	1.7	1.2	3.4

Experimentation

Pit furnace was used for melting the Al 6063. Alumina and magnesium were preheated in core baking oven at 300 ºC for a half hour to remove the moisture or any other gases present in the reinforcement. 1% magnesium powder along with required quantity of alumina was added into it. Magnesium was used as wetting agent and stirring was performed as illustrated in Fig. 2 and Fig. 3.

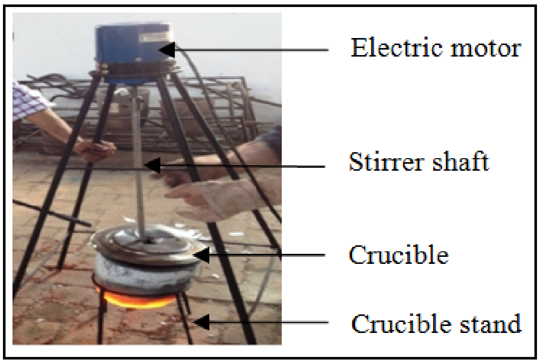

Fig. 2: Stirring

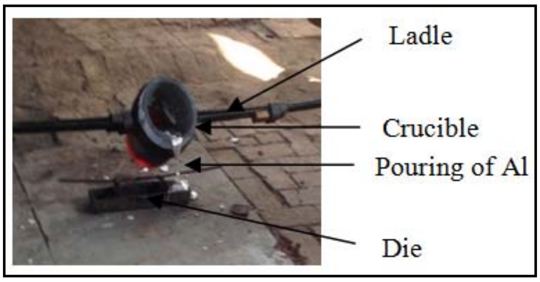

Fig. 3: Pouring of Molten Metal

After stirring, the molten metal was poured into the die. By using different process parameters four samples were prepared which are shown in table 3.

Table 3: Process Parameters of Samples

S. No.	Alumina wt.%	Alumina (grams)	Al-6063 (kg)	Height (mm)	Speed (rpm)
1	4	160	3.84	30	500
2	4	160	3.84	30	250
3	4	160	3.84	60	500
4	4	160	3.84	60	250

Results

Charpy Impact Test

The charpy V-notch testwas used to determine the amount of energy absorbed by material during fracture. This absorbed energy is a measure of a given material's toughness. The size of the specimens was according to the ASTM standards i.e.55×10×10.Fortesting the pendulum impact tester used.The impact strength of the samples is given below in the table 4.

Table 4: Variations of Impact Strength with Respect to Height and Speed

Sample no.	Alumina (%)	Speed (S)	Height (H)	Impact strength (Nm)
1	Pure Al	-	-	136
2	4	500	30	139
3	4	250	30	139
4	4	500	60	138.5
5	4	250	60	140

It was observed that as compared to pure Al with the addition of 4 % alumina impact strength increased. However at stirring height 30mm the stirring speed effect were negligible. Results were even better at stirring height 60mm at a stirring speed 250 rpm.

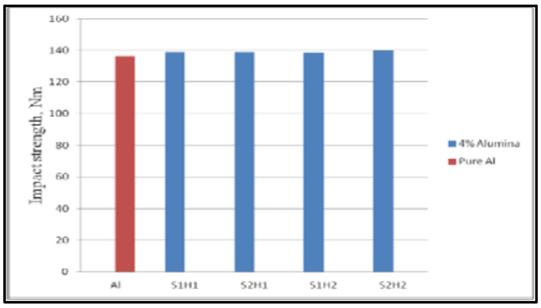

Fig. 4: Impact Test Result

Table 5: Value of Speeds and Heights

S1H1	Stirring speed 500 rpm and stirring height 30mm.
S2H1	Stirring speed 250 rpm and stirring height 30mm.
S1H2	Stirring speed 500 rpm and stirring height 60mm.
S2H2	Stirring speed 250 rpm and stirring height 60mm.

Considering the all parameters in the figure 4 clearly show that at Stirring speed 250 rpm and stirring height 60mm (S2H2)give the best result. This is due to proper distribution of alumina into the Al matrix and also strong interface bonding between the Al alloy and alumina interfaced.

FE-SEM/EDS Analysis

The micro structural characterization of the specimens was carried out by means of scanning electron microscopy (SEM) equipped with an energy dispersive spectroscopy (EDS). JEOL, model number JSM-6610 LV machine was used for the Characterization of the specimen. The test was performed at IIT, Roper (Punjab).The specimen surfaces were prepared by grinding through 150 to 2000 grit papers and then by polishing with 3μm diamond paste before performing tests.

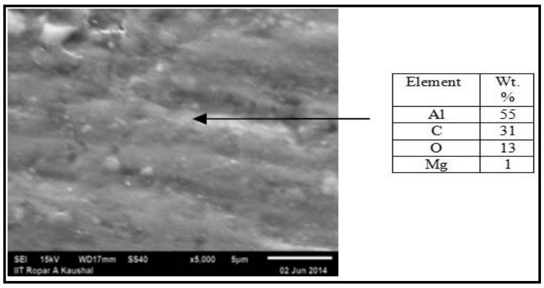

Fig. 5: FE-SEM/EDSanalysis at 5000X

Figure 5 shows the SEM-/EDS result at stirring speed 250 rpm and stirring height 60mm. The FE-SEM/EDS analysis of the samples show the mixing of alumina into matrix due to the presence of oxygen because Hitesh *et al.* [14] explain in their study that presence of mainly Al along with significant of carbon in the matrix and with small amount of oxygen which indicates the presence of alumina.

In Figure 5 amounts of O 13%, C 31% and Al 55% which indicate the higher concentration of the alumina at this point.

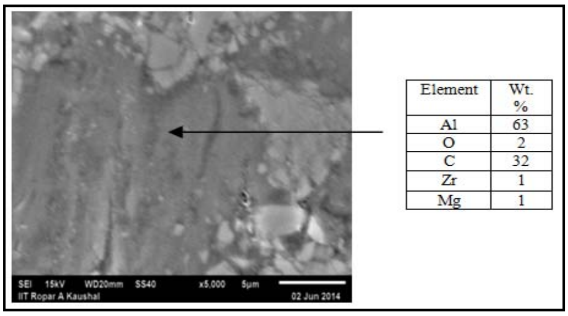

Fig. 6: FE-SEM/ED Sanalysis at 5000X

Figure 6shows the SEM-/EDS result at stirring speed 500 rpm and stirring height 60mm.In figure 6the presence of O is low and Al in higher wt% which show the uniform distribution of the alumina because in the MMC the major constituent is Al.

Hardness Test

The hardness test was performed on the Vickers hardness tester. The unit of hardness is known as Vickers pyramid number (HV). Vicker hardness tester of model number VM 50 and of maximum capacity of 50 kgf was used for testing the hardness of the specimens. The hardness of the samples is given below in the Table 6.

Table 6: Hardness Results at Variables Speeds and Heights

Sample no.	Alumina (%)	Speed (S)	Height (H)	Hardness (HV)
1	Pure Al	-	-	60
2	4	500	30	63
3	4	250	30	65
4	4	500	60	67
5	4	250	60	64

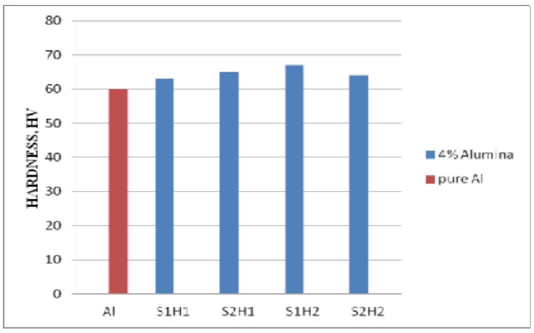

Fig. 7: Hardness Test Observations

As compared to pure Al, addition of 4 % alumina increased the hardness. This is due to increase in resistance to deformation by adding alumina as reinforcement in 6063 alloy similar to results obtained by Singh *et al.*, 2013 [10].

Considering the all parameters (figure 7) stirring speed 500and stirring height 60mm (S1H2) gave the best result. This may beattributed at higher speed and at stirring height of 60mm homogenous distribution of the reinforcement into the matrix was achieved.

CONCLUSION

- With the addition of reinforcement as compared to base metal mechanical properties improved.
- Stirring parameter [stirring speed 250 and stirring height 60mm](S2H2) showed maximum value for impact strength.
- The hardness value was maximum at[stirring speed 500 and stirring height 60mm](S1H2) and [stirring speed 250 and stirring height 60mm] (S2H2) process parameters.
- FE-SEM/EDS result showed that at a higher speed reinforcement was uniformly distributed into the matrix.

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