Fabrication and Machining of Al MMC and Evaluation of Surface Finish and Hardness Parameters

I. Sri Phani Sushma[1] and G.L.Samuel[2]

1 Department of Mechanical Engineering, University College of Engineering JNTUK Narasaraopet,

Narasaraopet-522 601,INDIA

2 Manufacturing Engineering Section, Department of Mechanical Engineering
Indian Institute of Technology, Chennai - 600 036, INDIA

Abstract

The present day industry focus on development of composites having superior properties in comparison with metals and the aluminium metal matrix composites (Al MCC) have wide scope for many applications. This paper presents the attempts carried out to explore the variation of surface characteristics generated while machining Al MMCs with various ratios of particulate reinforcement of fly ash and silicon carbide at high cutting speeds. Suitable machining operation on Al MMC and suitable machining parameters are investigated to achieve better surface characters. At higher machining speeds, aluminium alloys have excellent surface finish and they are useful for various industrial applications. It is also observed in this work that Al MMC shows a remarkable changes in properties as the percentage of fly ash increases and also it is observed that at certain ratios, the surface deterioration starts probably due reduction in material strength. This paper also presents the material characteristics and their effect on surface finish as the percentage of fly ash and silicon carbide are varied.

Key words: Al MMC, Reinforcement, Cutting speed, Feed, Depth of cut, Surface finish, Machinability etc.

1. INTRODUCTION

Metal Matrix Composites are composed of a metallic matrix (Al, Mg, Fe, Cu etc) and a dispersed ceramic (oxide, carbides) or metallic phase(Pb, Mo, W etc). MMCs are used for Space Shuttle, commercial airliners, electronic substrates, bicycles, automobiles, golf clubs and a variety of other applications. From a material point of view, when compared to polymer matrix composites, the advantages of MMCs lie in their retention of strength and stiffness at elevated temperature, good abrasion and creep resistance properties. . The primary constituent in a composite material is the matrix phase that provides load transfer and structural integrity, while the reinforcement to enhance mechanical properties. Important properties of composite materials are: improved strength & stiffness, excellent fatigue resistance, high heat resistant, high wear resistant, high corrosion resistant, low weight etc. From Review done by Pushpendra Kumar Jain [1],by suitable arrangement of metal matrix and reinforcement addition, it is possible to obtain desired properties for a particular application. The stir casting method is widely used among the different processing techniques available. Sachin [2] reported that the wear and hardness were enhanced on increasing the volume fraction of Sic They also reported that the tensile strength was high at 10 volume fraction of Sic and decreased as the volume fraction increased. Charles [3] studied the properties of aluminium alloy hybrid (Al-alloy/Silicon carbide (SiC)/fly ash) composites. Stir casting usually involves prolonged liquid-reinforcement contact, which can cause substantial interface reaction. Basavarajappa [4] investigated the mechanical properties of aluminium alloy (Al2024) reinforced with Sic and graphite particles. Their results revealed that the mechanical properties such as ultimate tensile strength, yield strength, hardness and compressive strength of the composite increased predominantly with the increase in volume fraction of reinforcement. Mahindra [5] investigated the properties of Al-.5% Cu alloy composite with fly ash as reinforcement. They reported the increase in hardness, tensile strength, compression strength and impact strength with increase in the fly ash content. Sudarshan [6] studied characterization of A356 Al - fly ash particle composites with fly ash particles of narrow range(53-106μm) and wide size range(0.5-400 μm) and reported that addition of fly ash lead to increase in hardness, elastic modulus and 0.2% proof stress. They also concluded that composites with narrow size range fly ash particle exhibit superior mechanical properties compared to composites with wide size range fly ash particles. Mahagundappa M.Benal [7] have studied the influence of reinforcement and thermal aging on the mechanical properties of Al 6061 based hybrid composites, and concluded that the ultimate tensile strength, compression strength, young's modulus and hardness increases with increasing the reinforcement content but the ductility decreases substantially. And all these things also increase with increase in the aging duration with the marginal improvement in the ductility which may be due to the formation of precipitate in matrix alloy. Hayrettin Ahlatci [8] investigated the mechanical properties of Aluminium Silicon with 60 volume % Sic composites and concluded that as amount of Si increased up to 1%, the strength of composites increased without significant loss in toughness after which the strength showed a decline with further increase in Si content. Hebbar [9] studied the mechanical properties of Silicon Carbide particle reinforced Aluminium alloy (AA2024) composites and found that tensile strength, tensile modulus, hardness, impact strength decreased with the reinforcement of Sic (1996) studied the mechanical properties of monolithic Aluminium with 12 weight % of silicon and found that ultimate tensile strength is improved considerably by the addition of low volume fraction (3-7%) of alumina silicate short fibres. Experiments were conducted at various cutting speeds and depth of cuts at constant feed rate and parameters, such as surface roughness and other mechanical properties and microstructures are examined. They found that higher weight percentage of Sic reinforcement produced a higher surface roughness and needs high cutting forces during machining operation of MMCs.

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From the above literature survey, we concluded that there were previous studies using reinforcement's fly ash and silicon carbide separately in aluminum matrix. In the present work, fly ash and silicon carbide are used as reinforcements and the properties were investigated with samples of fly ash alone as reinforcement in Al 6061 matrix and also silicon carbide along with fly ash in the matrix.

2. EXPERIMENTATION WORK

2.1 Specimen Preparation

The specimen is prepared with the different percentages of reinforcement of fly ash and silicon carbide of 10%, 15%, 20% and 5% respectively are prepared in mould. The mould consists of 6 fingers in which the hot liquid mixture of aluminum metal matrix is poured. The mould filled with the molten liquid of mixture, it is kept open in the surrounding atmosphere for some time. After the mixture is solidified, it is taken out from the mould and then the specimens are turned on the lathe to remove the extra material from the surface of the specimen.

2.2 Procedure

2.2.1 Processing of received fly ash

In the present study, aluminum based metal matrix composites containing 5% and 20% in weight of fly ash particulates were successfully synthesized by stir cast method the experimental set up is shown in Figure1. The matrix materials used in this study was commercial pure aluminum (99.5%). The reinforcement material was fly ash particulates, which were procured from Thermal power plant of RINL, Visakhapatnam Steel Plant, and Visakhapatnam, India. Fly ash has been dried at atmospheric conditions for 48 hrs, dried fly ash has been sieved for 15 minutes, using BSS meshes ranging in size from 100 to 350 by sieve shaker. The results show that more than 70% by weight retained in -200 +350 mesh with an average particle size of 150μm; hence this size was chosen as reinforcement for synthesis of Al- fly ash composites.
The synthesis of Al-fly ash composites (Al- 5% and 20% fly ash by wt.) were carried out by stir casting size was chosen as reinforcement for synthesis of Al- fly ash composites

a) Stir Casting furnace

Figure 1: Fabrication of Al-Fly Ash composite by Stir casting process

2.2.2 Synthesis of Al-Fly Ash composites

The synthesis of Al-fly ash composites (Al- 5% and 20% fly ash by wt.) were carried out by stir casting technique. Pure aluminum ingot of 240 gms is taken into a graphite crucible and melted in an electric furnace. The experimental set up used for making of these al composites after maintaining the temperature at 830 °C, a vortex was created using mechanical stirrer made of graphite. While stirring was in progress, the fly ash particulates in respective weight ratio were introduced, smooth flow of the particles addition is ensured while stirring. The molten metal was stirred at 400 rpm under argon gas cover; stirring was continued for about 5 minutes after addition of fly ash particles to get the uniform distribution in the melt. The molten mixture is poured into the die at that temperature and cooled for 1hr Figure 2 shows the casted samples.

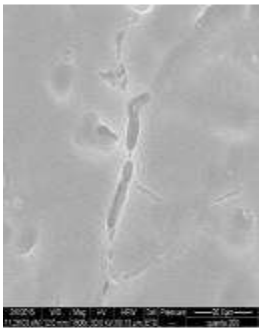
Figure 2: Casting of Al-MMC in stir casting process

By using stir casting samples of 30mm Diameter and 100mm length rods are casted at different weight ratios. Specimens were prepared from the castings to carry out microstructure and mechanical characterization. The specimens prepared from the cast AMCs were polished and etched as per the standard metallographic procedure. The microstructures of color etched specimens were observed using a scanning electron microscope (SEM).Figure 3 shows various SEM images at different resolutions to observe the dispersion rate of metal matrix composite in combinations of Fly ash and Sic

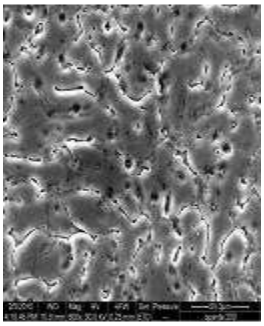
The samples obtained of various combinations are machined at various cutting speed from 150m/min to 250m/min in CNC orthogonal cutting. This cutting process is combined of rotational work piece and tool, tool assembly is composed of insert and tool holder. The machining of various samples are carried out using cemented carbide tools on Al MMC. Local coordinate system is calibrated in accordance with the work piece. During machining the feed is 0.1mm and depth of cut is 0.5mm keeping them as constants we vary speed of machining first 20mm the speed is 1000rpm then 1200rpm and so on. Second work piece is also installed and similar process is carried out a different speed. During machining, the cut chip is collected and the time for machining is noted for further analysis on machining.

3. RESULTS AND DISCUSSIONS

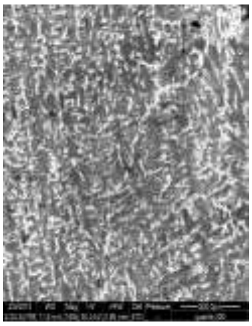
From the experiment, the machining is done at high speed. So that cutting speed is above 300m/s. And the feed and depth of cut is low. Feed is 0.1mm/rev and depth of cut 0. 5mm.The cutting speed is given by rotational speed i.e. in RPM. And the observations taken from the machine are tabulated in table 1. Surface roughness is measured using Mahrsurf and surface profile is shown in figure 4.

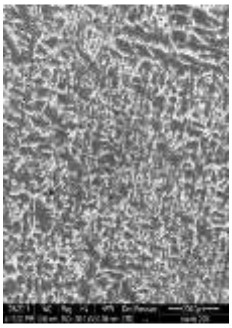


a). Al 6061

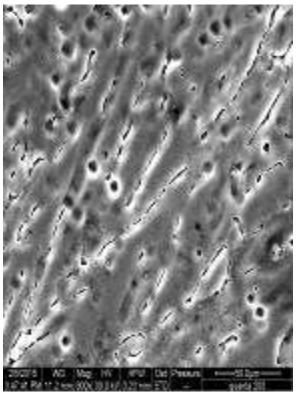


b). Al 6061 + 5%SiC





c). Al+5%Sic+10%flyash d). Al + 15% fly ash + Sic



e). 20% Fly ash and 5% Sic

Figure 3: Microstructure of different sample specifications

3.1. Mechanical properties testing on Al MMCs

The mechanical properties like Hardness, Density and Heat treatment are conducted on Al MMCs.

3.1.1 Hardness

Hardness is the measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. In the present work, Vickers hardness test is carried out. It is observed from Table 2 and Fig 5 (a) that as the percentage of fly ash is increased from 10% to 20% the hardness increased. The addition of silicon carbide further increased the hardness of the material from 70.336 to to 75.34 HV.

3.1.2 Density

Density also plays a vital role in the composite material study. As these materials having a scope in the automotive industry as well as in the space crafts, they must be of light weight. So the density should be reduced by adding some reinforced material like a fly ash of very low density. Variation of harness and density are tabulated in table 2. From Figure 5, it is observed that the hardness and density of the composite is varying than that of its cast matrix alloy and the hardness of composite increases with increased fly-ash content. The density of the composites found lower than that of the Al6061 matrix material. The increase in percentage of fly-ash in the matrix Al6061further decreases the density of its composites.

Table 1 Surface roughness values of various samples at different cutting speeds

Sample	Cutting Speed (m/min)	Surface roughness in R_a
Al6061	171	2.25
	198	3.10
	229	2.94
Al6061+10% Fly ash	176	0.68
	199	0.59
	229	0.86
Al 6061+15% Fly ash	185	1.06
	198	1.15
	229	1.13
Al6061 +5% Sic	171	0.56
	198	0.55
	229	0.76
Al6061 +5% Sic +10% Fly ash	188	0.45
	215	0.44
	230	0.34
Al6061 +5% Sic +15% Fly ash	190	0.42
	199	0.39
	229	0.36

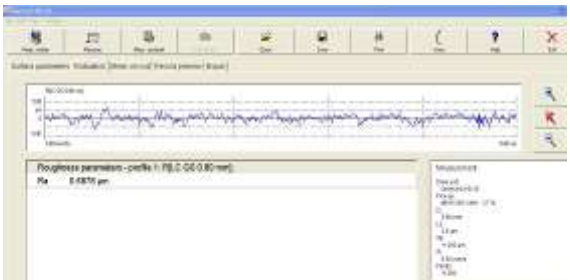
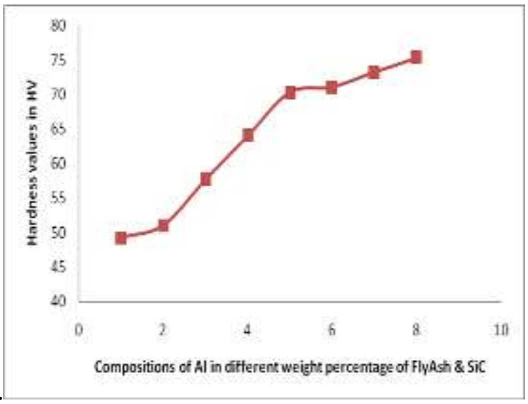


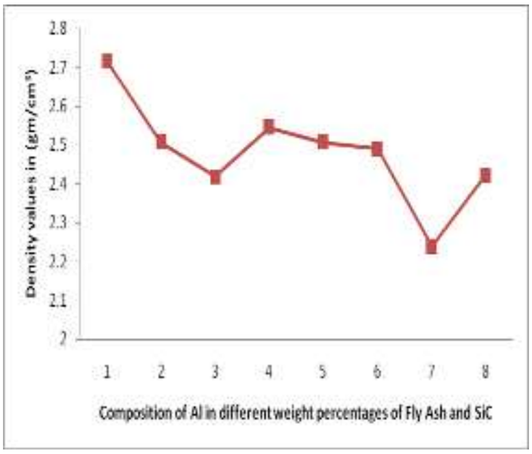
Figure 4: Surface roughness plots for Al+10% Fly ash machined at 2000 rpm

Table 2: Experimental results of Hardness and density of various samples

S.No	Composition	Hardness (HV)	Density (gm/cm3)
1	Al6061	49.25	2.716
2	Al6061+10% Fly ash	51.04	2.506
3	Al6061+15% Fly ash	57.68	2.419
4	Al6061+20% Fly ash	64.08	2.545
5	Al6061+5%Sic	70.336	2.506
6	Al6061+10% Flyash+5%Sic	71.096	2.49
7	Al6061+15% Flyash+5% Sic	73.272	2.239
8	Al6061+20% Flyash+5%Sic	75.34	2.4219



a) **Variation of hardness**



b) Variation of density

Figure 5: Variation of hardness and density at different weight percentages of Al, Fly Ash & Sic

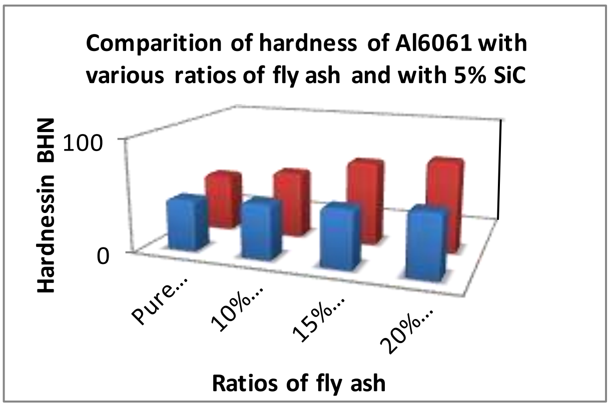


Figure 6: comparison of hardness at different weight percentages of Al, Fly Ash & Sic

From Figure 6, it is observed that the hardness of al with fly ash and Sic shows considerable increase than that of al with fly ash and the hardness of composite increases with increased fly-ash content. This property of hardness and density with MMC is unpredictable at high ratio increase of Sic.

4. CONCLUSIONS

While machining Aluminium fly ash composites, as the cutting speed increases the surface roughness decreases. This phenomenon is observed for composites with 20% of fly ash. As the percentage of fly ash is increased, it is observed that there is reduction in material strength and this is due to dispersion of fly ash and increase in porosity resulting in inferior mechanical properties. The hardness of the composite is greater than that of its cast matrix alloy and the hardness of composite increases with increased fly-ash content. The density of the composites found lower than that of the Al6061 matrix material. The increase in percent fly-ash in the matrix Al6061further decreases the density of its composites. It is also observed that as the cutting speed increased the surface finish also improved in spite of presence of fly ash and silicon carbide.

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