Scientific Journal Impact Factor (SJIF): 3.518
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745   ISSN (PRINT) : 2393 - 8161

INVESTIGATION ON EFFECT OF SIZE OF FLYASH ON SURFACE ROUGHNESS DURING MACHINING OF Al ALLOY BASED MMC

Ajit Kumar Senapati[1], Prabhat Kumar Nanda[2], Siddharth Satapathy[3], Remish Raman Patel[4]

[1,2,3,4] *Mechanical, G.I.E.T Gunupur*

Abstract-This paper presents an experimental investigation on the surface roughness of Metal matrix composites which conation different size of the fly ash. Al-Si Alloy based Metal matrix composites are prepared with two different sizes of the fly ash [Type-A (24μm) and Type-B (32μm)] by using stir casting method. The effect of reinforcements and machining parameters such as cutting speed, feed rate and depth of cut on surface roughness have been studied. The reinforcement greatly influences the performance of the machined surface which has been analyzed during turning operation. Results show that the presence of the carbon and smaller average size of fly ash particles reduces the surface roughness of composites compared with other fly ash reinforced metal matrix composite.

Key Words*:* MMC, Fly Ash, Stir Casting, Surface roughness.

I. INTRODUCTION

Aluminium and its alloys probably form the most widely used matrix materials for metal matrix composites. The Al-Si alloy was normally selected as matrix material due to high wear resistance, low thermal expansion coefficient, good corrosion resistance, and improved mechanical properties at a wide range of temperatures (Saheb et al 2001). Silicon imparts high fluidity and low shrinkage. MMCs reinforced with ceramic fibres or particles can offer improved strength, stiffness, hardness and damping capacity (Rohatgi 1994; Karayiannis and Moutsatsou 2006). The recent research has shown that aluminium-based composite exhibit many attractive material properties such as increased stiffness, wear resistance, specific strength and vibration damping and decreased coefficient of thermal expansion compared with the conventional aluminiumalloys [Donnell GO, Looney L (2001]. Al–Si alloys are widely used for various automobile applications owing to their good castability, high corrosion resistance and low density [Hemanth J (2005]. Most of the research has been carried out based on the conventional particulate reinforcement. Nowadays, focus must be given to an easily available and inexpensive reinforcement. Fly ash is one of the cheapest materials used as reinforcement in aluminium matrix composite. Millions of tons of fly ash powder are generated in coal based thermal power plants and only a small portion is being utilized. Various components, such as pistons, engine cover, connecting rods and other castings, have been made out of Al alloy/fly ash composite [Guo RQ, Rohatgi PK, Nath D (1996)].

Sudarshan et al. 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.Mehmet Alper et al. the relationship between cutting speed and surface roughness is inversely proportional. Generally, increasing the cutting speed decreases the surface roughness. The relationship between feed rate and surface roughness is proportional. Generally, increasing the feed rate increases the surface roughness. The relationship between depth of cut and surface roughness is proportional. Generally, increasing the depth of cut increases the surface roughness.Mohamed A.TahaNahed et al. realized the importance of the features of the machinability characteristics of lead free silicon during turning operation and found out that machinability property of metal varies with certain parameters such as feed , depth of cut and speed and variations in surface roughness where recorded .Most of the previous studies carried out on aluminium–fly ash composites to study the mechanical and tribiological properties. Machinability study of aluminium silicon alloy matrix with different size range of fly ash as reinforcement is a new area of investigation. However, to achieve enhanced properties of MMCs it is very important to have good selection of fly ash. Therefore, an attempt was made to use two different size range of flyash as reinforcement to fabricate the MMCs and a comparative analysis is presented interms of their machinability. The details of experimentation and results are discussed in subsequent sections below.

II. EXPERIMENT WORK

2.1. Matrix material

Al-Si master alloy is used as the matrix material, the composition (in wt %) of which is listed in Table 1.

Table 1:

Si	Co	Fe	Cu	Mn	Ti	Zn	Cr	Ca	Al
1 2.2491	0 .0174	0 .4353	0 .0800	0 .1601	0 .0672	0 .0944	0 .0199	0 .0082	8 6.7654

2.2 Reinforcement: Fly ash

Fly ash is collected from two different sources which are different in composition. Some of the result obtained in the laboratory for aluminium based composite has given some clue to select judiciously fly ash of suitable combination of size and chemical composition. Result obtained from aluminium based composite prepared with the two sources of fly ash have revelled the properties of the metal matrix composite (MMC) differ appreciably when prepared with the two sources of fly ash. From sieve and size analysis the fly ash type A is of 24 µm and fly ash type B is of 32 µm.

2.3 Preparation of MMC by stir casting.

After cleaning Al-Si ingot, it is cut to proper sizes, weighed in requisite quantities and are charged into a vertically aligned pit type bottom poured melting furnace. Fly ashes are preheated to $650^oC \pm 5^oC$ before pouring in to the melt of Al-Si Alloy. This is done to facilitate removal of any residual moisture as well as to improve wetability. The molten metal is stirred with a BN coated stainless steel rotor at speed of 600-650 rpm. A vortex is created in the melt because of stirring where preheated fly ash is poured centrally in to the vortex. The rotor is moved down slowly, from top to bottom by maintaining a clearance of 12mm from the bottom. The rotor is then pushed back slowly to its initial position. The pouring temperature of the liquid is kept around 700^0C. Casting is made in bar type metal mould (Ø25mmX290 mm). For comparison purpose two composites are prepared, one with fly ash type-A (24 µm) and the other with fly ash type-B (32 µm).

Fig-1 Stir Casting setup

2.4 Machinability test

The turning experiments were carried out using a CNC lathe (LT-16CNC) which has a maximum spindle speed of 4000 rpm and a maximum spindle power of 17 KW with Fanuc series Oi mate-TC controller. The experimental set up is shown in Fig. 3. In this experimental study, carbide inserts were used. The inserts were manufactured by SESCO with ISO designation of CNMG 120408, TM 4000 (diamond shapes inserts). The inserts were rigidly mounted on a right hand style tool holder designated by ISO as PCLNR2020 K 12 thus giving back rake angle of -6^0, clearance angle of- 5^0, negative cutting edge inclination angle of -6^0, major cutting edge or approach angle of 95^0 and nose radius of 0.8 mm respectively.

The work surface was characterized with roughness parameters as the arithmetic surface roughness average (Ra). The surface roughness parameters were measured by a surface roughness tester (Taylor Hobson, Surtronic 25) where cutoff length and assessment length was fixed as 0.8 mm and 4 mm respectively. The measurements were repeated five times at different locations and average values are reported

Fig 2. Machining setup

III. Result and Discussion

3.1 Preparation of Al-Si alloy based metal matrix composite.

Matrix used: Eutectic Al–Si (LM6) alloy.
Reinforcement used: As received fly ash type-A and B
The chemical compositions of the fly ashes are shown in table 2 and 3.

Table-2 Chemical Composition of Fly ash Type- A

Co mpound	S iO$_2$	l$_2$O$_3$	e$_2$O$_3$	aO	gO	a$_2$O	$_2$O
(Wt . %)	5 6.34	1.60	.97	.23	.56	.11	.64

Table-3 Chemical Composition of Fly ash Type- B

Co mpound	S iO$_2$	l$_2$O$_3$	e$_2$O$_3$	aO	gO		$_2$O
(Wt . %)	6 8.41	0.73	.97	.62	.46	.60	.97

The Al-Si alloy based metal matrix composites is prepared by using untreated and treated fly ash. In the present investigation, it is anticipated that both the composites i.e Al-Si with untreated fly

International Journal of Modern Trends in Engineering and Research (IJMTER)
Volume 03, Issue 03, [March – 2016] **ISSN (Online):2349–9745; ISSN (Print):2393-8161**

ash and treated fly ash will have the same vol% of the dispersed phases. However, within the experimental limitation, it was possible to have14.2 and 14.8 vol% of particulates in the untreated and treated composites respectively.

3.2 Microstructural studies.

Fig.3 (a and b) show optical micrographs of MMCs prepared with fly ash A and B. The Volume fractions of fly ash in MMCs prepared with A and B fly ash are measured to be 10.2% and 11% respectively. There is not much difference in volume % in the microstructure. The distribution of particles in the microstructure is seen to be uniform. On etching fine grain structures are observed.

(a) Fly ash Type-A **(b) Fly ash Type-B**

Fig-3. Optical Micrographs

3.3 Machinability Analysis in terms of Surface Roughness

3.3.1 Effect of cutting speed on surface roughness

Surface roughness values are plotted with different cutting speeds (Fig. 4), thus keeping the other two parameters, that is, feed rate (0.07 mm/rev) and depth of cut (0.2 mm), as constants at their optimum values to analyze the effect of cutting speed on surface roughness . (Table 4) Fig. 4 illustrates that an increase in cutting speed decreases the surface roughness of the machined surfaces of all tested materials. Surface roughness decreases from 2.851 μ m to 2.393 μ m when cutting speed increases from 1150 rev/min to 1910 rev/min at a constant feed rate (0.07 mm/rev) and depth of cut (0.2 mm) during the machining of the MMC reinforced with type A fly ash composite. The considerable reduction 16% in surface roughness is achieved by increasing the cutting speed by 66%. Similarly, the surface roughness of the MMC reinforced with type B fly ash composite decreases by 10% for the same percentage decrease in cutting speed.

Table 4:

SPEED in Rpm	**FEED in mm/rev**	**DEPTH OF CUT in mm**	**SURFACE ROUGHNESS [24µm]**	**SURFACE ROUGHNESS [32µm]**
1150	0.07	0.2	2.851	2.861
1530	0.07	0.2	2.622	2.665
1910	0.07	0.2	2.393	2.602

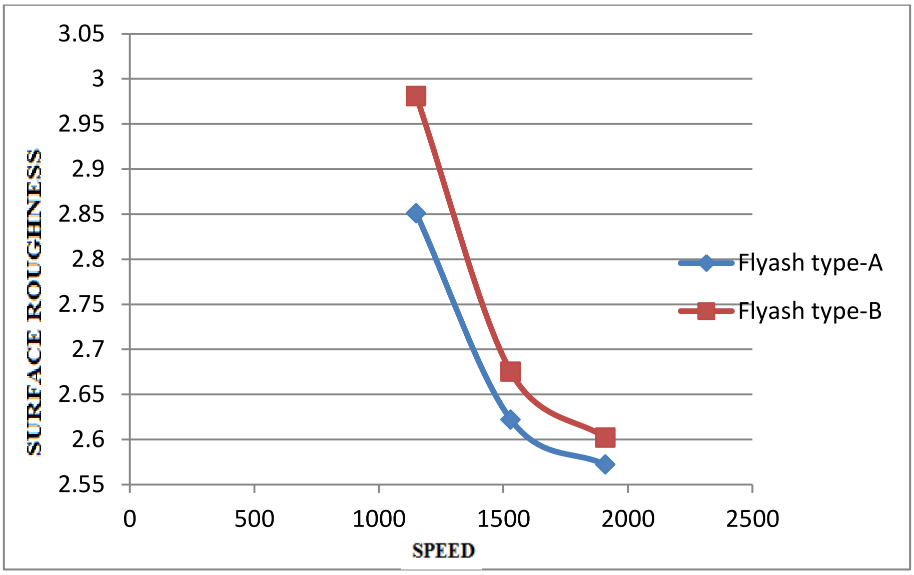

Fig.4 Graphical representation of effect of cutting speed on surface roughness

Type A fly ash reinforced MMC shows better surface roughness than Type B fly ash at all cutting speeds. The enhanced brittle nature of the composite surface and the subsequent vanishing of the BUE during machining can explain this finding. Fig. 1 also demonstrates that the surface roughness of the Type A fly ash reinforced MMC decreases by approximately 3% compared with the type B fly ash reinforced MMC when machined at a cutting speed of 1530 rev/min, feed rate of 0.07 mm/rev, and depth of cut of 0.2 mm. Fly ash with lower grain size (Type A) has greater reduction in surface roughness than higher grain size (Type B). The increased burnishing (or) honing effect of Carbon in fly ash type A particles act as a lubricant and reduce the coefficient of friction between the tool cutting edge and work piece. Carbon particles are dense and soft; they are easily spread on the work piece surface. The carbon particles tend to prevent the direct contact of the cutting edge of the tool and reduce the ploughing effect during machining.

3.3.2 Effect of feed rate on surface roughness

To analyze the effect of the feed rate on surface roughness, surface roughness values at different feed rates are plotted while keeping the optimum cutting speed at 1910 rev/min and depth of cut at 0.2 mm. (Table 5**)** Fig. 5 illustrates that the surface roughness of all tested materials apparently follows an increasing trend with increasing feed rate.

Table 5:

SPEED in Rpm	FEED in mm/rev	DEPTH OF CUT in mm	SURFACE ROUGHNESS [24μm]	SURFACE ROUGHNESS [32μm]
1910	0.07	0.2	2.393	2.951
1910	0.14	0.2	2.442	3.22
1910	0.21	0.2	3.11	3.552

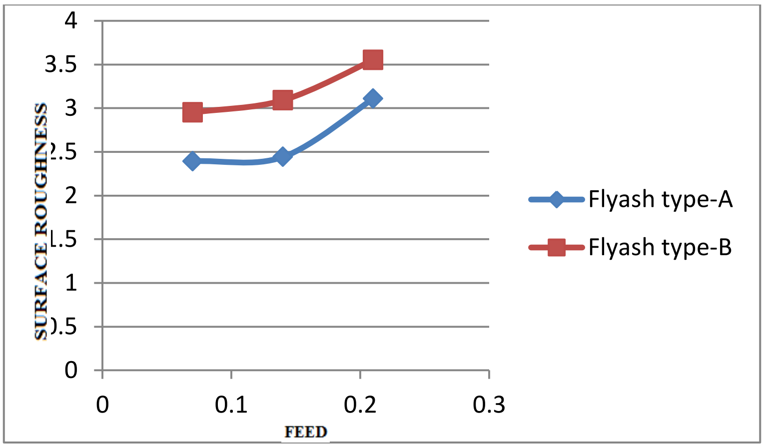

Fig.5 Graphical representation of effect of feed rate on surface roughness

The results show that the surface roughness of MMC reinforced with type A fly ash composite increases by 29%, when the feed rate increases by 200% i.e. from 0.07 mm/rev to 0.21 mm/rev (Table 5) at optimum cutting speed (1910 rev/min) and depth of cut (0.2mm) values whereas under the same condition for type B fly ash surface roughness increases by 32%. A higher feed rate induces higher friction at the interface between the tool and pure alloy, thus generating heat. This heat tends to soften the MMC, which then adheres onto the tool face to form the BUE and increases the surface roughness of the machined surface. The surface finish of MMC with type B fly ash composites deteriorates more rapidly than that of MMC with type A fly ash because at higher feed rate causes higher interfacial temperature and decreases the bonding effect between fly ash particles and the matrix. Some of the fly ash particles are partially is completely removed from the machined surface during machining, thus increasing surface roughness. Fine chips that break off also have a tendency to attach onto the cutting tool and weld themselves to the edge of the tool because of high temperatures, thus leading to the formation of BUE and increasing the roughness. The surface roughness of the MMC with type A fly ash increases only by 29% and for MMC with type B fly ash it increases by 32% when the feed rate increases from 0.07 mm/rev to 0.21mm/rev. Thus it states that MMC with type B reinforced fly ash possess more surface roughness as compared to MMC with type A reinforced fly ash with increase in feed rate because type A fly ash contains more percentage of alumina (Al_2O_3) which provides more hardness .It is also observed that type A fly ash contains irregular grains shape providing higher bonding strength as compared to type B fly ash in which the grains are regular in shape.

3.3.3 Effect of feed rate on surface roughness

Fig.6 shows that the surface roughness of the MMC with type A Fly ash increases by approximately 23% compared with that of MMC with type B with an increase of 25% when machined under optimum cutting parameters. The higher grain size particles can be inferred to increase the surface roughness of composites considerably with increase of depth of cut.

Table 6:

SPEED in Rpm	FEED in mm/rev	DEPTH OF CUT in mm	SURFACE ROUGHNESS [24µm]	SURFACE ROUGHNESS [32µm]
1910	0.7	0.2	2.393	2.951
1910	0.7	0.4	2.519	3.051
1910	0.7	0.6	3.11	3.552

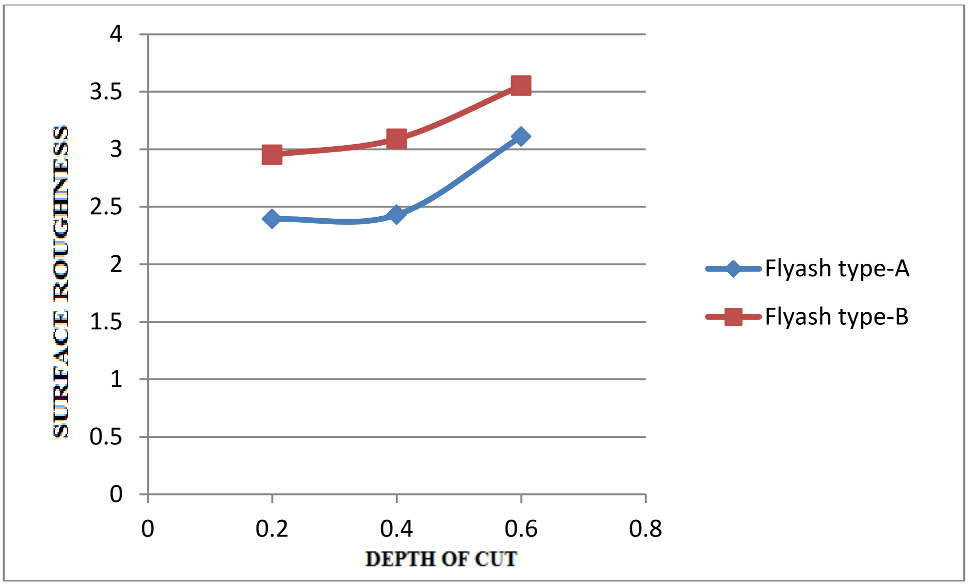

Fig.6 Graphical representation of effect of depth of cut on surface roughness

Fig. 6 indicates that the surface roughness of the tested materials increases with increasing depth of cut. The minimum surface roughness is achieved when the depth of cut is maintained at 0.2 mm irrespective of the materials machined. The surface roughness of the MMC with type A fly ash increases by 23% when the depth of cut increases from 0.2 mm to 0.6 mm (Table 6) under optimum cutting speed (1910 rev/min) and feed rate (0.7mm/rev) conditions. The surface roughness of the type B fly ash reinforced MMC by approximately 25%. At a constant cutting speed and feed rate, an increase in the depth of cut increases the chip cross-sectional area, thus causing more cutting force and increasing the surface roughness of the machined surfaces. A greater depth of cut results in high normal pressure and seizure on the cutting edge of the tool. Moreover, a greater depth of cut promotes BUE formation because of increased area of contact. In the case of MMC with type A fly ash, an increase in the depth of cut increases subsurface damage, which deteriorates the surface finish. However, the depth of cut has more substantial increase in surface roughness for type B fly ash MMC.

IV. CONCLUSION

The continuous stir casting method used to prepare the composites could produce uniform distribution of the reinforced fly ash particles. In the present investigation, it was anticipated that both the composites i.e Al-Si with fly ash Type A and Type B fly ash will have the same vol% of the dispersed phases. However, within the experimental limitation, it was possible to have 10.2 and 11 vol% of particulates in the MMC A and MMC B composites respectively. In this investigation it is concluded that MMC reinforced with type-A fly ash i.e. small average size shows better surface finish in comparison to MMC reinforced with type-B fly ahs which is bigger in average size so the presence of higher alumina, lower silica and higher carbon help to achieve better surface roughness for MMC reinforced with type-A fly ash.

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