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SYNTHESIS AND MACHINING CHARACTERISATION OF SiC REINFORCED ALUMINIUM COMPOSITES

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The aim of present work is to fabricate aluminium metal matrix composites by reinforcing silicon carbide of 40 micron size particles with 5 percentage of weight using stir casting technique. A356 alloy is well known material as a matrix material for composite due to its castability. Due to less density difference, silicon carbide is a popular reinforcing agent for A356 alloy. Hence these are selected for the preparation of composite in the present work. There are so many methods and techniques established by researchers for the past three decades for the synthesis of metal matrix composites. Out of all these stir casting is popular and mostly used for the same. Permanent mould i.e. Die is used for specimen preparation in this work. On successful synthesis of specimens, they are tested for machinability studies. Cutting forces have shown increasing trend up to a speed of 50mm/min due to work hardening of the composite, and then decreased at high speed due to softening of the material. MRR and surface roughness has shown increasing trend with respect to speed. Due to increase in depth of cut, the tool has to deal with higher volume of material which will ultimately result in an increase in the cutting force as well as power consumption. MRR has shown increasing trend with respect to depth of cut whereas surface roughness has decreased from 0.95 µm to 0.75 µm and then increased at high depth of cut.

***Keywords*:** Depth of cut, Feed, Material removal rate.

1. Introduction

Now a day's metal matrix composites (MMCs) are replacing conventional materials in many applications because of their superior properties such as high strength to weight ratio, hardness, stiffness and wear and corrosion resistances over conventional materials. Silicon carbide particle (SiC) reinforced aluminium-based MMCs are among the most common MMC and commercially available ones due to their economical production.[1] In addition, the development of stir casting route for synthesis has brought down their cost to an acceptable level compared to those processed by powder metallurgy and spray casting process Particulate metal matrix composites have produced economically by conventional casting techniques. However, the stiffness, hardness and strength to weight ratio of cast MMCs are increased, but a substantial decrease in ductility has obtained. There are various techniques for production of AMC, eg, solid state, liquid state, vapour deposition and in-situ. Processing in the liquid state is an easy proposition and is adopted widely for the production of AMC. In the present investigation, a novel in-situ composite is attempted to be developed from a waste (Colliary shale) produced during the mining of coal from underground mine in the colliary by treating in the plasma reactor/ vacuum furnace.[2]

2. Materials

2.1 . Matrix Material(A356):

A preformed A356 alloys with thixotropic structure (designated SSM-A356) was systematically studied on mechanical properties in order to establish the database for further investigations in forming and heat treatment. Because of the specific microstructure and characteristics, the heat treatment conditions of SSM-A356 were explored through the observations observations of microstructure and the measurement of micro-hardness. In the investigation of heat of heat treatment, it was observed that the eutectic silicon was refined and spheroided which is is unlikely for conventional processing. The mechanical testing results showed that the yield and ultimate tensile strength of SSM-A356 were respectively around 115% and 34% greater than those of conventional A356, and the elongation was also 2-3 times larger. According to the analysis of fracture mode via fatigue test, the crack propagation was in the way of trans- granular which a typical type of ductile fracture is. Thus, an excellent ductility for SSM-A356 was expected. From the experimental analysis results, it could be concluded that the superior mechanical behaviour of SSM-A356 are basically attributed to the refinement of microstructure and the periodization of eutectic silicon. This structure can be maintained during forming by further processing of die or squeeze casting.[3]

Fig.2.1 A356 Ingots

2.2 . Reinforcement material –SiC:

Silicon carbide also known as carborundum has been mass-produced since 1893 for use as an abrasive. Silicon Carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of silicon and carbon. The chemical formula of silicon carbide is SiC.[4] It is a simple compound with the carbon atom attached to silicon through a triple bond, leaving both atoms with a positive and negative charge. Silicon carbide is prepared industrially by the Acheson method, in which pure silica sand (SiO_2) and finely ground coke (carbon) are mixed together and heated to very high temperatures in an electric furnace.

$$SiO_2 + 3\,C \rightarrow SiC + 2\,CO \quad (1)$$

Pure SiC is obtained as colorless crystals, with a density of 3.21 g/ml and an extremely high melting point of 2,730 °C. It is more commonly found as a bluish-black, iridescent crystalline solid, due to small amounts of iron or other impurities from the industrial production. Silicon carbide (SiC) particles exhibit characteristics like high thermal conductivity, high stability, high purity, good wear resistance and a small thermal expansion co-efficient. These particles are also resistant to oxidation at high temperatures. An important point to be noted about their storage is that they must be kept away from moisture, heat and stress. The material has been developed into a high quality technical grade ceramic with very good mechanical properties.[5]

3. Stir casting Process

A Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional metal forming technologies.[6]

. Fig.3.2Mould Fig.3.3 A356+SiCComposite

4. Experimental method

The turning experiments were carried out by using HSS tool bits in a automatic lathe machine. The machining trials were performed with three cutting speeds (Vc) 202, 303, and 455 m/min with a constant feed (f) of 0.2 mm/rev and a depth of cut of (t)1 mm under dry environment. Cutting forces were measured on lathe tool dynamometer facility at NEC college. At the same time temperature and surface roughness values are also taken at different feed and depth of cut conditions.

Fig.4.1 Lathe tool dynamometer setup

5. Experimental conditions:

5.1 Input parameters:

We are giving different cutting speed, depth of cut and feed as input parameters to calculate various machining characteristics.

- Cutting speed(m.,/min.,)
- Depth of cut(mm.,)
- Feed(mm.,/rev)

Table.5.1 Experimental condition of machine

S. no	Speed (m/min.,)	Depth of cut (mm)	Feed (mm/rev)
1	30	0.5	Constant (0.4)
2	50	0.75	Constant (0.4)
3	70	1	Constant (0.4)

5.2 Responses measured:

During machining, cutting forces and temperatures are taken from lathe tool dynamometer and by using these values power and material removal rate are calculated.

Axial force (F_x) in(N)

Cutting force (F_y) in(N)

Radial force (F_z) in(N)
Temperature (Tt) in(^{O}C)
Metal removal rate (MRR) in(mm^3/min.,)
Power in(kw)
Surface roughness in (µm)

6. Results and discussion

After loading the component on the lathe machine plane turning operation has performed and specimen is divided into six divisions to perform six operations by varying speed and depth of cut parameters. Feed is kept constant in every time.

6.1 Effect of speed:

Under this situation turning operation is carried out at different cutting speeds like 202, 303 and 455 rpms at the same time feed and depth of cut are kept constant. Cutting forces values are taken from lathe tool dynamometer.

Table.6.1 Cutting forces values at different cutting speeds

Cutting speed (m/min)	F_x(N)	F_y(N)	F_z(N)
30	39.24	147.15	176.58
50	78.48	235.44	225.63
70	78.48	196.2	206.01

By noticing the above values we can find that by gradually increasing the speed, cutting forces induced between the tool and work piece are increased.

6.2 Effect of depth of cut:

Under this situation turning operation is carried out by giving different depth of cuts like 0.5, 0.75 and 1 mm. while cutting speed and feed are constant. Again cutting forces values are taken from lathe tool dynamometer.

Table.6.2 Cutting forces values at different depth of cuts

Depth of cut (mm)	F_x(N)	F_y(N)	F_z(N)
0.5	88.29	206.01	215.82
0.75	88.29	196.2	196.2
1.0	147.15	294.3	274.68

6.3 Machining results

By using the values collected from lathe tool dynamometer we calculated power and material removal rate and by using surf test instrument we checked surface roughness of machining specimen.

6.3.1 Effect of speed

Power, material removal rate and surface roughness values under different cutting speeds are as follows

Table.6.3 Power, MRR and surface roughness values at different cutting speeds

Cutting speed	Power (kw)	MRR(mm^3/min)	Surface

(m/min)			roughness(µm)
30	4.29	8.75	17.02
50	10.3	13.92	19.01
70	12.9	18.19	29.09

6.3.2 Effect of depth of cut

Power, material removal rate and surface roughness values under different depth of cut are as follows

Table.6.4 Power, MRR and surface roughness values at different depth of cuts

Depth of cut (mm)	Power (kw)	MRR(mm^3/min)	Surface roughness(µm)
0.5	6.01	8.75	14.08
0.75	8.58	13.92	13.67
1.0	19.35	16.15	20.40

7 CONCLUSION

- A356-SiC composite has successfully prepared by using stir casting technique.
- Cutting forces have shown increasing trend up to a speed of 50m/min due to work hardening of the composite, and then decreased at high speed due to softening of the material.
- MRR and surface roughness has shown increasing trend with respect to speed.
- Due to increase in depth of cut, the tool has to deal with higher volume of material which will ultimately result in an increase in the force as well as power consumption.
- MRR has shown increasing trend with respect to depth of cut whereas surface roughness has decreased up to 0.75 mm and then increased at high depth of cut.

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