

Effect of cutting parameters on surface finish and machinability of graphite reinforced Al-8011 matrix composite

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Abstract. Many materials such as alloys, composites find their applications on the basis of machinability, cost and availability. In the present work, graphite (Grp) reinforced Aluminium 8011 is synthesized by convention stir casting process and Surface finish & machinability of prepared composite is examined by using lathe tool dynamometer attached with BANKA Lathe by varying the machining parameters like spindle speed, Depth of cut and Feed rate in 3 levels. Also, Roughness Average (Ra) of machined surfaces is measured by using Surface Roughness Tester (Mitutoyo SJ201). From the studies it is cleared that mechanical properties of a composites increases with addition of Grp and The cutting force were decreased with the reinforcement percentage and thus increases the machinability of composites and also results in increased surface finish.

1. Introduction

Composite materials play an important role in the field of science and engineering as well as advance manufacturing in response to unprecedented demands from technology due to rapidly advancing activities in aircrafts, aerospace, sporting goods, marine and automotive industries[1]. MMCs have higher strength-to-density ratios, better fatigue resistance, better elevated temperature properties (such as high strength and low creep rate), lower coefficients of thermal expansion, high thermal conductivity, good damping characteristics, excellent wear properties and flexibility in design attributes[2]. Some of the typical applications of these MMCs are bearings, automobile pistons, cylinder liners, piston rings, connecting rods, sliding electrical contacts, turbo charger impellers, space structures, etc. [3]. Several researches done experiments on machining of MMCs.[4] have investigated the effect of machining parameters on the surface roughness and tool wear when turning 10% SiCp/Al composites. Results indicated that higher cutting speeds result in relatively better surface finish, but resulting in increased flank wear. [5] Developed the analytical model extending the classical Merchant's theory, Slip line theory and Griffith's theory of brittle fracture to the machining of ceramic particle reinforced MMCs. This model predicted the cutting forces and was validated experimentally. They have concluded that the size of reinforcements in the composite material influences roughness of the machined surfaces significantly when its magnitude is comparable to that of the feed rate and tool nose radius employed during machining of the composite. [3] have studied tool wear and surface roughness in machining of particulate aluminum metal matrix composite .it is revealed that the formation of BUE significantly affects the tool wear at low speeds whereas thermal softening plays



important role at higher speeds and feed rates. However, no work addresses the machinability of Al-8011–Grp composite produced by stir casting. Hence, the main objective of the present work is to study the effect of reinforcement (2, 4, 6, and 8%) and machining parameters such as cutting speed, feed rate, and depth of cut on surface roughness, and cutting force were analyzed during turning operations.

2. Preparation and characterization composite material

Apart from iron, aluminium / aluminum is currently the next most widely used metal in the world. This is due to the fact that aluminium / aluminum has a unique combination of attractive properties. Properties such as its low weight, corrosion resistance, and easy maintenance of final product, have ensured that this metal and its alloys will be in use for a very long time. In this work aluminum 8011 a wrought alloy is used a matrix alloy Weighed quantity of Al-8011 was melted in electrical resistance furnace to desired superheat temperature of $750 \pm 200\text{C}$ in graphite crucible. After attaining the required temperature degassing agent (C_2Cl_6 – solid hexachloro ethane) was added in order to degas the entrapped gases in the melt. Then the molten metal was stirred manually at an average speed of 300 rpm for 200 Sec to form a vortex in the melt. Once the vortex is achieved the preheated ($300 \pm 200\text{C}$) Grp was added by varying weight percentage of 2, 4, 6, 8 respectively. Prepared molten metal then poured in preheated cast iron mould and allowed to solidify. The cast specimens were machined as per the mentioned ASTM standards for measuring tensile and compression test in universal testing machine having 0-20 tons of capacity as per the ASTM-E8M and ASTM-E09 respectively and cylinder samples are polished as per the metallographic procedure to get fine surface before testing their hardness. The hardness of prepared composite is measured by Rockwell hardness test.



Figure 1. Lathe Tool Dynamometer



Figure 2. Surface roughness tester

Table 1. Machining parameters

Sl. No	Speed (rpm)	Feed (mm/sec)	Depth of Cut (mm)
1	175	0.067	0.2
2	263	0.111	0.4
3	395	0.167	0.6

The experiments were employed to study the effects of cutting parameters on surface roughness of the materials when machining MMCs work piece. The lathe tool dynamometer which is attached to BANKA-Lathe is used for measuring the cutting forces during the machining are shown in Figure 1. The HSS Cutting tool which is used for machining has following geometry: Rake angle: 0° and clearance angle: 7° , cutting edge angle: 85° and Nose radius: 0.8 mm. The machining parameters which are used for experiments are listed in the table 1. ULI-15 model lathe tool dynamometer having a capacity of 500kg in the X, Y & Z directions with 12mm tool holder and Strain gauge based 350Ω bridge sensor is used for experiment

Cutting forces are measured in each co-ordinate and collectively taken as multi-component forces. The average surface finish (Ra) in the direction of the tool movement was measured in five different places of the machined surface using a surface roughness tester- Mitutoyo SJ201, surface mean roughness (Ra) in microns value of the five locations was considered for the particular trial. A Inductive type Diamond cone Surface roughness tester (Mitutoyo SJ201) having a measuring speed of 0.25mm/s, 0.55 mm/s in forward direction and 0.8 mm/s in returning with a total gauge length of 12.5mm is used for measuring a roughness value of a machined surface.

3. Results and discussions

3.1. Mechanical properties

Machined composite materials are then tested for their mechanical properties as per the ASTM standards. The average results of 5 specimens are tabulated in the table 2. From the results we can say the capacity of withstanding applied tensile load is increased with the addition of weight percentage of reinforcement, this is because of increased bonding between the matrix and the reinforcement. The compression strength of a base alloy Al-8011 is 38.06 KN. The load bearing capacity of matrix material will increased with the addition of reinforcement and the strength of the composite are also implies in hardness test, the indentation resistance of the composite with 8% of Grp is increased to 52.1%.

Table 2. Mechanical properties of composite with different weight percentage of Grp

Composition	Tensile strength (MPa)	Compression Strength (KN)	Hardness (BHN)
Al-8011	91.405	38.06	21.3
Al+2% Grp	105.08	50.87	22.06
Al+4% Grp	122.28	62.96	24.35
Al+6% Grp	145.58	69.16	32.41
Al+8% Grp	160.09	78.50	34.87

3.2. Surface roughness

The surface roughness (Ra) decreases as the cutting speed increases. At low cutting speed, the temperature between the machining interfaces is more enough to create the unstable larger BUE (Built up edge) and also the chips fracture readily producing the rough surface this may cause adhesive wear on tool. As the cutting speed increases, the machining time will reduces and the BUE vanishes, chip fracture decreases, and hence the roughness. Though these phenomena of improved surface finish at higher cutting speeds can be observed in machining conventional materials also, the effect is more pronounced here because removal of hard strengthen particles from the Aluminum matrix becomes easier at higher cutting speeds. Figure 3 shows the effect of cutting speed and reinforcement on surface roughness keeping feed rate and depth of cut constant. The influence of feed rate on the surface roughness is shown in Figure 4. At same level of feed rate the surface roughness value increased when increasing reinforcement wt. percentage. Figure 4 also shows that the increase in feed rate increases the surface roughness (Ra). At the lower feed rates, the BUE forms readily and is accompanied by feed marks resulting in increased roughness. With the increase in feed rate beyond 0.11 mm/rev, the rate of increase in surface roughness (Ra) is less due to the reduced effect of BUE.

The best surface finish was achieved at the lowest feed rate and highest cutting speed combination. Figure 5 shows the effect of depth of cut and reinforcement on the surface roughness (Ra). It shows that when higher depth of cut given its results in poor surface finish. As we known the shear angle and HAZ (Heat affected zone) is depend on the depth of cut, has the depth of cut increases the HAZ and shear angle, thus increase in Cutting force, friction and rise in temperature and causes deposition of removed material on rake face of a tool. Hence, the surface roughness (Ra) increases along with increase in depth of cut.

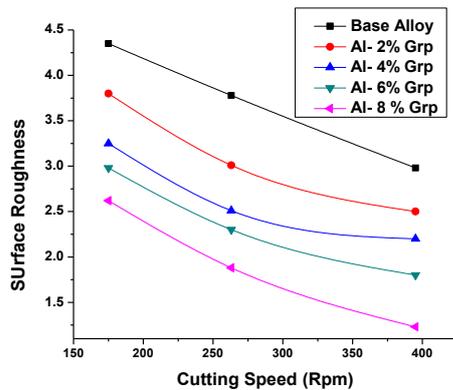


Figure 3. Effect of cutting speed and reinforcement on surface roughness (Feed-0.11 mm/Rev and Depth of cut-0.4 mm)

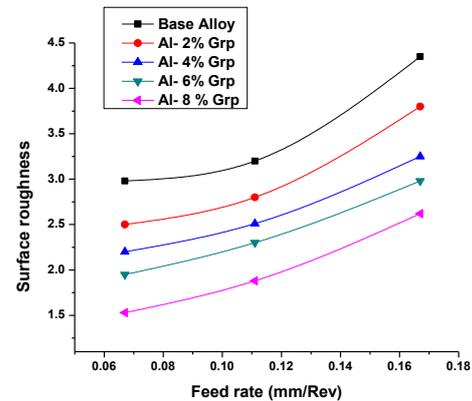


Figure 4. Effect of feed rate and reinforcement on surface roughness (Speed-263 Rpm and Depth of cut-0.4 mm)

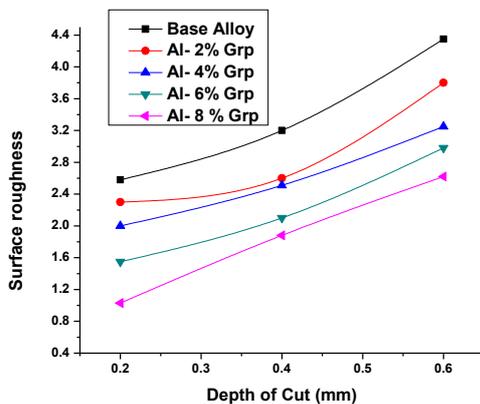


Figure 5. Effect of Depth of cut and reinforcement on surface roughness (Speed-263 Rpm and feed-0.11 mm/Rev)

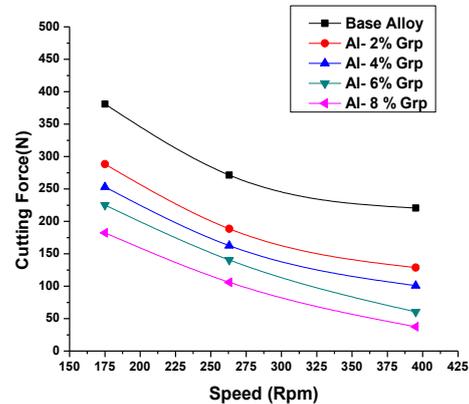


Figure 6. Effect of cutting speed and reinforcement on cutting force (Feed-0.11 mm/Rev and Depth of cut-0.4 mm)

3.3. Cutting force

The effect of an increase in reinforcement is evaluated under different speeds, at a constant feed rate of 0.11 mm/rev, a depth of cut of 0.4 mm, and a length of turning of 80 mm. When constant cutting speed was considered, the cutting force is decreased as the reinforcement added. The presence of reinforcement will minimize the build-up edge formation, which reduce the cutting force. It can be observed that the increase in cutting speed will reduce the chip tool contact length therefore cutting force is reduced. Figure 7 shows the trend of cutting force by considering constant Speed-263 Rpm and Depth of cut-0.4 mm for length of 80 mm turning operation. When machining of Al-8011 alloy with higher feed rates the friction in the machining interface will be high this requires high pressure to shear the material thus the cutting force will be more. Figure 7 also reveals that addition of Grp in the matrix material will decrease the cutting force this is because the Grp itself acts as a lubricant to avoid the friction in cutting tool and work piece interface. The same trend is followed when machine the alloy and composite material by varying depth of cuts which is shown in figure 8. The contact area of tool – work material interface will directly depend on the cutting force.

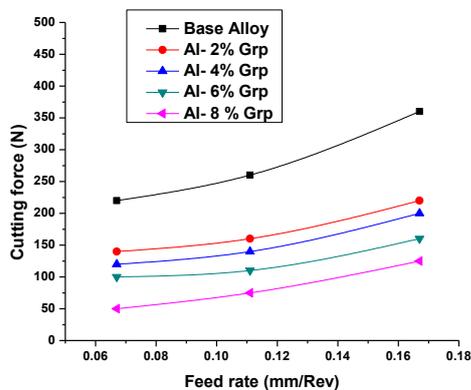


Figure 7. Effect of feed rate and reinforcement on Cutting force (Speed-263 Rpm and Depth of cut-0.4 mm)

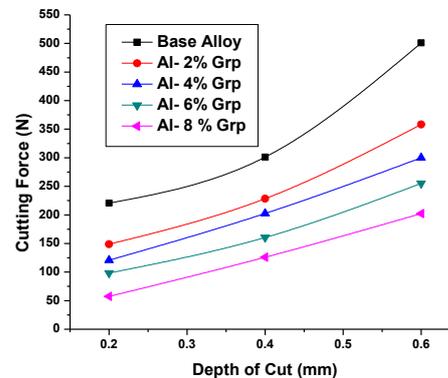


Figure 8. Effect of Depth of cut and reinforcement on Cutting force (Speed-263 Rpm and feed-0.11 mm/Rev)

4. Conclusions

The results of plain turning studies of Al-8011 alloy and Al reinforced Grp composites using HSS-tool by varying machining parameters at three different levels were presented. From the results obtained following conclusions can be drawn:

- Mechanical properties like tensile, compression strengths of Al alloy can be tailored with the addition of Grp by conventional stir casting route
- Higher cutting speed with lower depth of cut and lower feed rates gives good surface finish when compare to lower speed
- Addition of Grp to alloy will gives more surface finish because of its lubricant property
- Increased federates and depth of cuts produces more cutting force and poor surface quality.

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