Optimization of the machining parameters for surface roughness during turning of Al/SiC/Gr Hybrid MMC.

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Abstract

In this experimental work, hybrid Al/SiC/Gr MMC samples were prepared with by stir casting method. Aluminium alloy reinforced with 10% wt of SiC and 5% wt of Graphite. The effect of cutting speeds, feed rates and depth of cut on surface roughness was investigated in the turning operation of hybrid Al/SiC/Gr MMC. Taguchi L9 orthogonal array was used for the experiment plan. Machining operations were conducted using uncoated tungsten carbide tool. Surface roughness (Ra) was measured for at three different cutting speeds (100, 150 and 200 rev/min), three different feed rates (0.2, 0.4, 0.6 mm/rev) and three depth of cut (0.2, 0.6, 1 mm). The result of experimental work shows that surface roughness increased with increasing feed rate and depth of cut.

1. Introduction

A composite material is a 'material system' composed of a combination of two or more micro or macro constituents that differ in form, chemical composition and which are essentially insoluble in each other. Aluminum-matrix composites are not a single material but a family of materials whose stiffness, strength, density, thermal and electrical properties can be tailored. The matrix alloy, reinforcement material, volume and shape of the reinforcement, location of the reinforcement and fabrication method can all be varied to achieve required properties. The aim involved in designing metal matrix composite materials is to combine the desirable attributes of metals and ceramics.

Metal matrix composites (MMCs) are one of the important innovations in the development of advanced materials. Among the various matrix materials available, aluminum and its alloys are widely used in the fabrication of MMCs and have reached the industrial production stage. The emphasis has been given on developing affordable Al-based MMCs with various hard and soft reinforcements (SiC, Al_2O_3, zircon, graphite, and mica) because of the likely possibilities of these combinations in forming highly desirable composites. Graphite, in the form of fibers or particulates, has long been recognized as a high-strength, low-density material. When at least three materials are present, it is called a hybrid composite. Al/SiC/Gr-MMC is one of the important hybrids composite among MMCs, which have SiC & Gr particles with Aluminum matrix.

A combination of soft lubricant like graphite and hard reinforcements like SiC can improve the tribological properties of the composite and strength more than the properties of composites containing either SiC or graphite particles by themselves. Composites containing more than one type of reinforcements are called hybrid composites. Such composites by using two or more types of reinforcements extend the idea of tailor-making a composite material to meet specific property requirement. In addition, since graphite particles are lighter than the matrix metallic alloys, the hybrid composite can be used to reduce the weight more than the Al-SiC composite. Aluminum graphite particulate MMCs produced by solidification techniques represent a class of inexpensive tailor-made materials for a variety of engineering applications such as automotive components, bushes, and bearings. Their uses are being explored in view of their superior technological properties such as the low coefficient of friction, low wear rate, superior gall resistance. This has led to increases research interest on evaluating the effect of type and weight fraction of reinforcement in the matrix and procedure that used to produce of MMCs.

Since MMCs contain certain amount of hard and abrasive ceramic reinforcements, they are considered to be one of the most difficult materials to machine. The addition of hard reinforcements makes machining of MMCs significantly more difficult and leads to severe tool wear and workpiece damage. Improving the machinability of MMCs and developing machining data are the most promising ways to convince designers and manufacturers to use MMCs in their applications. The prominent quality indicator for machined products is Surface roughness. In many critical applications, achieving the desired surface quality is of great importance for the effective use of the product.

Looney et al (1992) significant research has been conducted on the machining of fiber, particulate, and whisker MMCs. performed a series of turning tests in which different tool materials (other than diamond) were used to machine an aluminum/SiC MMC. The best overall performance was achieved using cubic boron nitride inserts.

Manna, A. and Bhattacharayya, B. (2004) presented an experimental investigation of the influence of cutting conditions on surface finish during turning of Al/SiC-MMC. In this study, the Taguchi method, a powerful tool for experiment design, is used to optimize cutting parameters for effective turning of Al/SiC-MMC The influence of the interaction of cutting speed/feed on the surface roughness height Ra and Rt The cutting speed, feed and depth of cut are having effect on the surface roughness characteristics. High speed, low feed rate and low depth of cut are recommended for achieving better surface finish during turning of Al/SiC MMC.

Manna, A. and Bhattacharayya, B. (2005**)** were presented the result of an experimental investigation on the machinability of silicon carbide particulate aluminium metal matrix composite during turning using a rhombic uncoated carbide tool. The influence of the length of machining and cutting time on the tool wear and the influence of various machining parameters, e.g. cutting speed, feed, depth of cut on the surface finish criteria has been analyzed through the various graphical representations. The job surface condition and wear of the cutting tool edge for the different sets of experiments have been examined and compared for searching out the suitable cutting condition for effective machining performance during turning of Al/SiC-MMC. Test results show that no built-up edge is formed during machining of Al/SiC MMC at high speed and low depth of cut. From the test results and different SEM micrographs, suitable range of cutting speed, feed and depth of cut can be selected for proper machining of Al/SiC-MMC.

Muthukrishnan, N. (2010) studied on the effect of work piece reinforcing percentage on the machinability of Al-SiC metal matrix composites and concluded that increase in percentage of reinforcing SiC has no improvement in their mechanical properties rather than increase in the tool wear. It is observed that the best surface finish is obtained at higher cutting speeds.

Sasimurugan, T. and Palanikuma, K. (2011) studied on Analysis of the Machining Characteristics on Surface Roughness of a Hybrid Aluminium Metal Matrix Composite (Al6061-SiC-Al2O3) and the result indicates that the increase of cutting speed, depth of cut and feed rate speed reduces the surface roughness. In order to obtain reduced average surface roughness it is recommended to use medium cutting speed, minimum feed rate and lower depth of cut.

Kathirvel, M. and Purushothaman, S. (2011) studied on the machining of hybrid metal matrix composite (MMC) work piece using polycrystalline diamond (PCD) tool tip in a CNC lathe at various machining conditions. The results indicated that % volume fraction of SiC shows more effect on forces, whereas spindle speed and feed are highly influential parameters for flank wear and surface roughness in machining of hybrid Al-SiC metal matrix composites.

Yakup, Turgut (2011) Studied on cutting force and surface roughness in milling of Al/Sic metal matrix composites. In this study, cutting forces and surface roughness in the milling of reinforced aluminum composites containing SiC particle are investigated. The result shows that increasing the feed rate, cutting speed and depth of cut leads to increase in the cutting force for all cutting conditions. Surface roughness in the uncoated tools is increased with feed rate whereas; the Ra in coated tools is decreased by feed rate. The best surface roughness is obtained with increasing cutting speed whereas; the worst surface roughness is measured by increasing feed rate.

Ramanujam, Radhakrishnan et al. (2011) presented the detailed experimental investigation on turning Aluminium Silicon Carbide particulate Metal Matrix Composite (Al/SiC MMC) using polycrystalline diamond (PCD) 1600 grade insert. The objective was to establish a correlation between cutting speed, feed and depth of cut to the specific power and surface finish on the work piece. The optimum machining parameters were obtained by Grey relational analysis. Finally, confirmation test was performed to make a comparison between the experimental results and developed model and also tool wear analysis is studied.

Babu, T.S. Mahesh and Muthu, Krishnan N. (2012) studied on turning of Al/SiC/B4C Hybrid Metal Matrix Composites using ANOVA analysis. The results shows that the optimization of the complicated multiple performance characteristics can be greatly simplified through this approach. It is shown that the performance characteristics of the turning process of Al-SiC (10p) - B4C (5p) Hybrid Composites such as surface roughness (5.85 to 2.10 um), power consumed (1.15 to 0.35 KW) and cutting force (236.54N to 39.53N) are improved together by using the proposed method in this study.

2. Experimental Procedure

Al/SiC/Gr Metal Matrix Composite materials are to be used as work-piece materials. It is essential to select proper machining parameters for effective machining of Al/SiC/Gr-MMC's. Stir casting technique will be used to prepare the work-piece samples.

Experiments will be conduct based on Taguchi's method and as per $L_9(3^3)$ orthogonal array with considering three controllable factors (i.e. parameters). Each factor has three levels. The levels of parameters will be deciding through detailed study of literature and based on the preliminary experimentation. The values take by factor are termed to be levels. The factors will be study and their levels chosen are detailed in the Table1 format for L_9 (3^3) orthogonal array i.e. matrix which will be used for conducting experiment.

Table 1: Cutting Parameters And Their Levels

Levels	Speed(N) (RPM)	Feed (f) (mm/rev)	Depth of cut (d) (mm)
1	100	0.2	0.2
2	150	0.4	0.6
3	200	0.6	1.0

2.1 Design of Experiment

Experiments have been carried out using Taguchi's L9 Orthogonal Array (OA) experimental design which consists of 9 combinations of spindle speed, longitudinal feed rate and depth of cut. Taguchi's L9 Orthogonal Array design of experiment has been found suitable in the present work. It considers three process parameters to be varied in three discrete levels. The experimental design has been shown in Table 2.

Table 2: Taguchi's L9 Orthogonal Array

Levels	Speed(N) (RPM)	Feed (f) (mm/rev)	Depth of cut (d) (mm)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	2
9	3	3	1

3. Results and Discussions

After all the experimentations and measurements, it is required to study the effect of different machining parameters during turning of hybrid Al/SiC/Gr MMC. The surface roughness has been measured for each experiment to study the effects of the spindle speed, feed rate and depth of cut during machining. The brief experimental results obtained during turning of hybrid Al/SiC/Gr MMC have been explained through various graphs. The following table shows the value of surface roughness at different speeds, feed rates and depth of cut.

Table 3: Results of Surface Roughness (Ra)

S.No.	Speed (N)	Feed (f)	Depth of cut(d)	Surface roughness (Ra)	S/N Ratio	Mean
1	100	0.2	0.2	3.89	-11.79	3.89
2	100	0.4	0.6	5.57	-14.91	5.57
3	100	0.6	1.0	7.18	-17.12	7.18
4	150	0.2	0.6	4.53	-13.12	4.53
5	150	0.4	1.0	6.33	-16.02	6.33
6	150	0.6	0.2	5.82	-15.29	5.82
7	200	0.2	1.0	4.96	-13.90	4.96
8	200	0.4	0.2	4.20	-12.46	4.20
9	200	0.6	0.6	5.03	-14.03	5.03

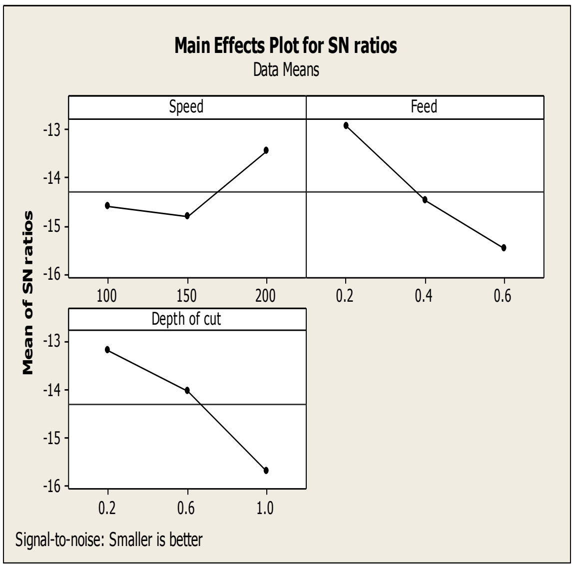

Figure 1: Graph of S/N Ratio For Surface Roughness

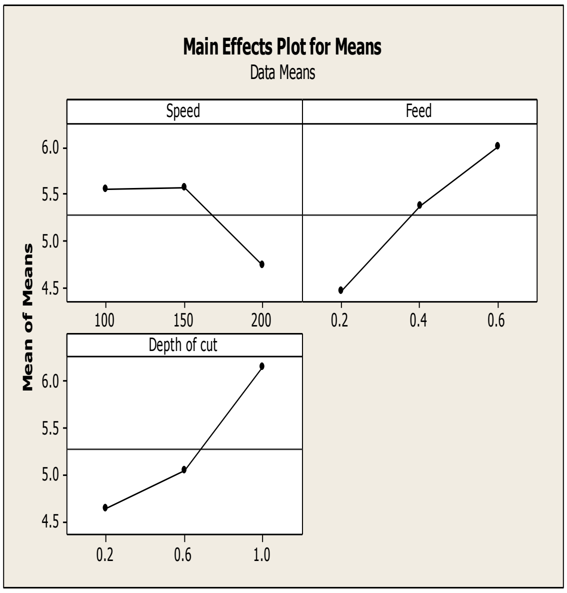

Figure 2: Graph of Mean For Surface Roughness

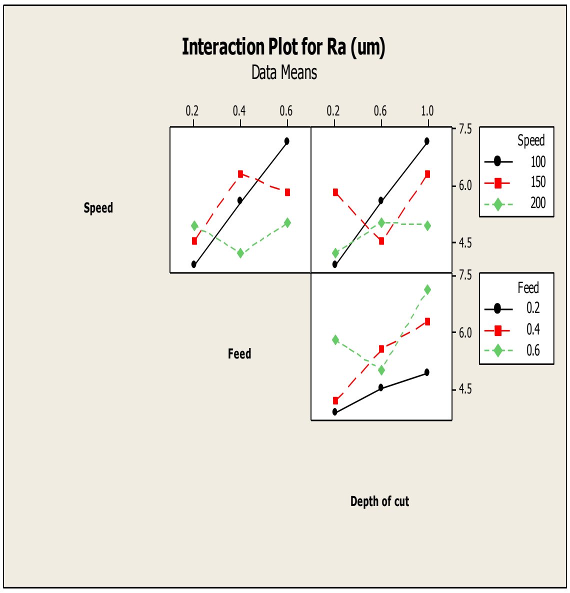

Figure 3: Interaction Plot For Means (Ra)

Table 4: Response Table for Signal to Noise Ratios-Smaller is better (Ra)

Level	Speed (N)	Feed (f)	Depth of cut (d)
1	-14.61	-12.94	-13.19
2	-14.82	-14.47	-14.02
3	-13.47	-15.48	-15.69
Delta	1.35	2.54	2.50
Rank	3	1	2

Table 5: Response Table for Means (Ra)

Level	Speed (N)	Feed (f)	Depth of cut (d)
1	5.547	4.460	4.637
2	5.560	5.367	5.043
3	4.730	6.010	6.157
Delta	0.830	1.550	1.520
Rank	3	1	2

1st interaction plot shows the minimum value of surface roughness is obtained at speed=100 rev/min and feed=0.2 mm/rev.
2nd interaction plot shows the minimum value of surface roughness is obtained at speed=100 rev/min and depth of cut=0.2 mm.
3rd interaction plot shows the minimum value of surface roughness is obtained at feed=0.2 mm/rev and depth of cut=0.2 mm.

From the interaction observed that minimum surface roughness obtained at speed=100 rev/min, feed=0.2 mm/rev and depth of cut=0.2 mm.

4. Conclusions

In present work, experimental investigation of turning of Al/SiC/Gr MMC components was carried to optimized machining parameters to minimize surface roughness. The main results of this study are summarized below.

1. Surface roughness is increasing with the increase in feed rate and depth of cut. The best surface roughness is obtained with depth of cut=0.2 mm/rev.
2. The minimum surface roughness is also obtained at lower speed=100 rev/min and lower feed rate=0.2 mm/rev.
3. The optimum machining parameters for minimum surface roughness =3.89 micron is obtained at speed=100 rev/min, feed=0.2 mm/rev and depth of cut=0.2 mm.

4. It can be concluded that lower speed=100 rev/min, lower feed rate=0.2 mm/rev and lower depth of cut=0.2 mm are the suitable parameters for minimum surface roughness.
5. The depth of cut and feed rates had greater effect on surface roughness.

6. References

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