Optimization of Cutting Forces During Turning of Al/SiC/Gr Hybrid Metal Matrix Composite

[1]Gurpreet Singh, [2]Bineet Pal Singh, [3]Kulwinder Singh
[1]Assistant Professor, Chandigarh University, Gharuan, India
[2,3]Assistant Professor, CSME, Chitkara University, Punjab, India

Abstract

In this experimentation, 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 cutting forces were investigated in the turning operation of hybrid Al/SiC/Gr MMC. Taguchi L9 orthogonal array plan was used for conducting the experiments, Machining operations were conducted using uncoated tungsten carbide tool. Cutting forces (F_X ,F_Y, F_Z) were 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 experimentation shows that change in depth of cut have the maximum effect on the cutting forces than feed rate and speed. The optimum parameters for minimizing the cutting forces are 100rpm ,0.2mm/rev,0.2mm

Keywords

Hybrid MMC, Stir Casting, Turning, M/C Parameters Optimize, Cutting Forces

I. 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. Aluminium-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, aluminium 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.. 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. 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-Si-C composite. Aluminium 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 work piece 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 [4] 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 Aluminium/SiC MMC. The best overall performance was achieved using cubic boron nitride inserts.

Manna et al [5] 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 et al [7] 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. [6] 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.

Arokiadass, R. et al.[7] studied on Tool flank wear model and parametric optimization in end milling of metal matrix composite using carbide tool. A minimum tool flank wears of 0.211 mm attained under the process parameters: 3000 RPM of speed, 0.04 mm/rev of feed, 1.5 mm of depth of cut. Spindle speed and %wt. of SiCp were found to have greater influence on tool flank wear in end milling of Al/SiCp MMC, followed by feed rate. Depth of cut has minimum influence on the tool flank wear.

Sasimurugan, T. et al [10] 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 et al [3] , 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 various effects are analyzed by using analysis of variance (ANOVA) for Ra, Vb, Fx, Fy, Fz with given speed, feed and depth of cut. 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.

Ramanujam, et al. [9] 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.

Mahesh et al. [8] 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.

Gurpreet Singh [2] has optimized the machining parameters for surface roughness during turning of Al/SiC/Gr hybrid metal matrix composite. In this study, the Taguchi method, a powerful tool for experiment design, is used to optimize cutting parameters for effective turning of hybrid MMC. The results shows that the minimum surface roughness obtained at lower speed, lower feed rate and lower depth of cut.

II. 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 L9 (33) 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

A. Design of Experiment

Experiments are carried out using Taguchi L9 Orthogonal array , 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 L_9 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	1
9	3	3	2

III. 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 cutting forces have 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 3 shows the value of cutting forces at different speeds, feed rates and depth of cut.

Table 3: Results of Cutting Forces

Level	Speed (N)	Feed (f)	Depth of cut (d)
1	21.58	21.58	21.58
2	24.08	26.84	26.84
3	22.92	24.08	28.94
Delta	2.5	5.2	7.36
Rank	3	2	1

Table 1: Response Table for Signal to Noise Ratios-Smaller is better (Cutting forces)

S. No	Speed (N)	Feed (f)	Depth of cut (d)	F_x	S/N Ratio	F_y	S/N Ratio	F_z	S/N Ratio
1	100	0.2	0.2	12	21.58	14	22.92	24	27.60
2	100	0.4	0.6	22	26.84	18	25.10	40	32.04
3	100	0.6	1.0	40	32.04	30	29.54	75	37.50
4	150	0.2	0.6	31	29.82	14	22.92	56	34.96
5	150	0.4	1.0	36	31.12	23	27.23	64	36.12
6	150	0.6	0.2	16	24.08	21	26.44	29	29.24
7	200	0.2	1.0	28	28.94	22	26.84	45	33.06
8	200	0.4	0.2	14	22.92	22	26.84	25	27.95
9	200	0.6	0.6	29	29.24	20	26.02	43	32.66

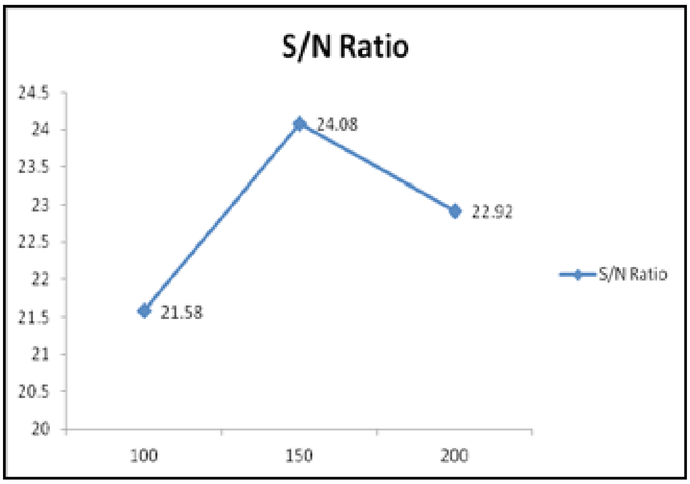

Fig. 1: Graph of S/N ratio for Speed (Smaller is better)

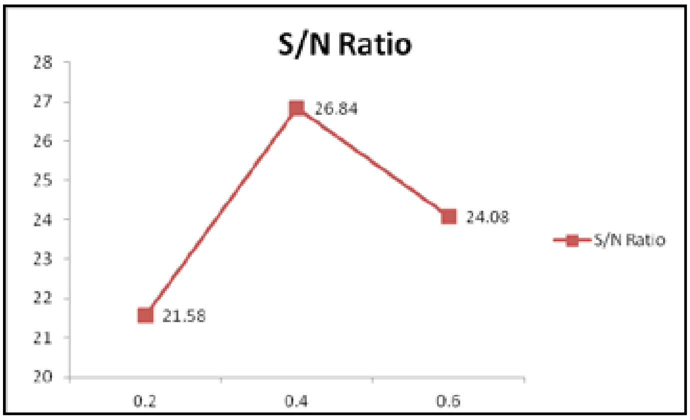

Fig. 2:Graph of S/N ratio for feed rate (Smaller is better)

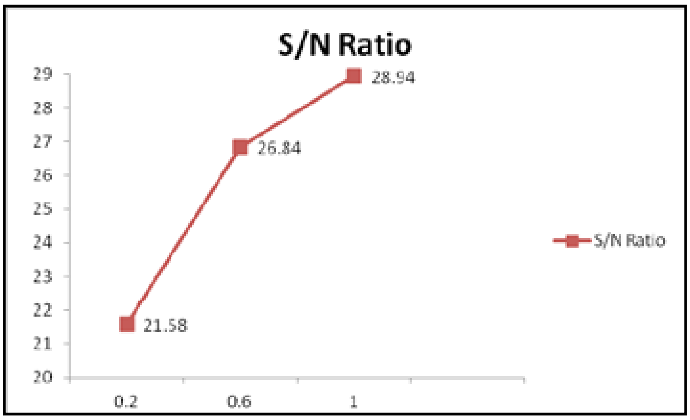

Fig. 3: Graph of S/N ratio for depth of cut(Smaller is better)

From the S/N ratio table1 it is shown that depth of cut is having the maximum difference in the highest and lowest ratio indicating it is having the maximum impact on the cutting forces ,with depth of cut being rank 1.
Using the above tables we plot the S/N ratio graph for 3 levels of speed, feed and depth of cut. As we have to minimize the cutting forces the level at which ratio is the lowest is the desired machining parameter . In the Fig 1 the S/N ratio is minimum at 100 rpm. Similarly for Fig 2 and 3 the S/N ratio is minimum at 0.2 feed rate and 0.2 depth of cut.

IV. Conclusion

In present work, experimental investigation of turning of Al/SiC/Gr MMC components was carried to study the effect of machining parameters on cutting forces. The main results of this study are summarized below.

1. The cutting forces are affected the most with increase in depth of cut. The minimum cutting forces obtained with depth of cut=0.2 mm.
2. The minimum cutting forces are also obtained with speed=100 rev/min and feed rate=0.2 mm/rev.
3. The optimum machining parameters for minimum cutting forces (F_x=12N, F_y=14N and F_z=24N) are obtained at speed=100 rev/min, feed=0.2 mm/rev. and depth of cut=0.2 mm.

References

[1] Arokiadass, R., Palaniradja, K., Alagumoorthi, N.,"Tool flank wear model and parametric optimization in end milling of metal matrix composite using carbide tool", International Journal of Industrial Engineering Computations, Vol. 3, 2011.
[2] Gurpreet Singh,"Optimization of the machining parameters for surface roughness during turning of Al/SiC/Gr Hybrid MMC" International Journal of Engineering Research & Technology (IJERT), Vol. 2 Issue 11, November - 2013.
[3] Kathirvel, M., Purushothaman, S.,"Applications of ANOVA in validating hybrid MMC machinability data", ARPN Journal of Engineering, Vol. 6, No. 10, 2011.
[4] Looney, Monaghan, J.M., Taplin, D.M.R., "The turning of an al/sic metal matrix composite", J. mater. process. technol., Vol. 33, No. 4, pp. 453-468, 1992.
[5] Manna, A., Bhattacharyya, B.,"Investigation for optimal parametric combination for achieving better surface finish during turning of Al /SiC-MMC", International Journal Advance Manufacturing Technology, Vol. 23, pp. 658–665, 2004.
[6] Muthukrishnan, N.,"Effect of work piece reinforcing percentage on the machinability of Al-SiC MMC", Journal of Mechanical Engineering Research", Vol. 3, No.1, pp. 15-24, 2010.
[7] Manna, A., Bhattacharayya, B.,"Influence of machining parameters on the machinability of particulate reinforced Al/SiC–MMC", International Journal Advance Manufacturing Technology, Vol. 25, pp. 850–856, 2005.
[8] Mahesh, Babu T.S., Muthu, Krishnan N.,"An Experimental investigation of turning Al/SiC/B4C Hybrid Metal Matrix Composites using ANOVA analysis", Scholarly Journal of Engineering Research Vol. 1, No. 2, pp. 25-31, 2012.
[9] Ramanujam, Radhakrishnan, Muthukrishnan, Nambi, Ramasamy, Raju,"Optimization of Cutting Parameters for Turning Al-SiC(10p) MMC Using ANOVA and Grey

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Relational Analysis", International Journal of Precision Engineering and Manufacturing, pp. 651-656, 2011.

[10] Sasimurugan, T., Palanikuma, K.,"Analysis of the Machining Characteristics on Surface Roughness of a Hybrid Aluminium Metal Matrix Composite (Al6061-SiC-Al_2O_3)", Journal of Minerals & Materials Characterization & Engineering", Vol. 10, No. 13, pp. 1213-1224, 2011.

[11] Yakup, Turgut,"Study of cutting force and surface roughness in milling of Al/Sic metal matrix composites", Scientific Research and Essays, Vol. 6, No. 10, pp. 2056-2062, 2011.

Mr Gurpreet Singh is working as Assistant Professor in Chandigarh university ,Gahrauan with 6 yrs of teaching experience. He has 6 yrs of teaching experience with research in machining of composites.

Mr. Bineet Pal Singh is working as Assistant Professsor in Chitkara college of engineering and technology. He has 6 yrs of Industry experience with 3 yrs of teaching exp. The areas of his research are composites and manufacturing management.

Mr. Kulwinder Singh is working as Assistant Professsor in Chitkara college of engineering and technology.He has 6 yrs of industry experience with 6 yrs of teaching expererience.The areas of research are materials and manufacturing management.