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Optimization of Machining Parameters of Al-SiC alloy by Using Taguchi Method

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Abstract: *Productivity and the quality of the machined parts are the main challenges of metal cutting industry during turning process. Therefore cutting parameters must be chosen and optimize in such a way that the required surface quality can be controlled.*
Quality and productivity play significant role in today's manufacturing market. From customers' viewpoint quality is very important because the extent of quality of the procured item (or product) influences the degree of satisfaction of the consumers during usage of the procured goods. Therefore, every manufacturing or production unit should concern about the quality of the product. Most of the resource done based by taking the conventional material like steel, brass, al etc. where crack initiation and propagation will take place with less time interval. In order to overcome this problem now –a-days most of the research is done by taking the composite material mostly by taking the Al alloy due to it's high strength to weight ratio , high wear resistance, high temperature stability etc. Therefore in order to find a good result of surface roughness we carried out an experiment by taking the composite material Al-SiC alloy. The main objective of the paper is to minimize the surface roughness using taguchi method. From our paper we conclude that the surface roughness is minimized by taking Al-SiC alloy as compared to other conventional material.
Keywords*: Al-SiC alloy, Lathe tool dynamometer, Taguchi method, SN ratio, ANOVA, Surface roughness;*

1. INTRODUCTION

Mechanical and physical properties of light metal matrix composites such as high specific strength, stiffness and wear resistance indicate that these materials play important role in application for engineering components. Aluminum reinforced composite particles is one of the combinations of MMC's, which has more significance in the areas of aerospace and automotive engineering components and other diverse industries. Al particulate composites are increasingly being used for varieties of engineering applications from automotive to aircraft components. The common applications are bearings, automobile pistons, cylinder liners, piston rings, connecting rods, sliding electrical contacts, turbo charger impellers, space structures, etc. There are manufacturing techniques with which it is possible to produce high quality MMC components to near-net shape.

The composite materials with low density and high strength are mostly preferable for most applications in the industry world. The unique properties such as the high specific stiffness and strength, high mechanical strength, high damping, good corrosive resistance and low thermal expansion of the fibre-reinforced composite materials have enabled their use in automotive, machine tool industries, aerospace, sporting equipment industries . However, composite materials could be very difficult to machine because of their non-homogeneous, anisotropic and reinforced by very abrasive materials. So, the machined composite work piece may experience a significant damage and high wear rate of cutting tools. After all, the machining of composite materials is depending on several conditions such as the material properties, relative content of the reinforcement and the matrix materials, and the response to the machining process.

1.1 IMPORTANCE OF OPTIMIZATION:

This study helpful in evaluating optimum machining parameter like tool geometry, tool material, cutting speed, feed and depth of cut for forces for machining in Lathe machine. Taguchi's parameter optimization method is used to evaluate best possible combination for minimum cutting force during machinability. The literature survey reveals that the machining of Al composite materials are one of the most important and most demanded area. The objective of this case study is to obtain minimization of surface roughness while machining Al-SiC composite material with HSS tools. Taguchi method is adopted in order to find the optimum value for material.

2. EQUIPMENTS USED

2.1 High speed lathe machine

It consists of 8 spindle speeds ranging from 50 rpm to 1250 rpm with 4 different feed values.

Fig 1: High Speed Lathe Machine

2.2 CUTTING TOOL

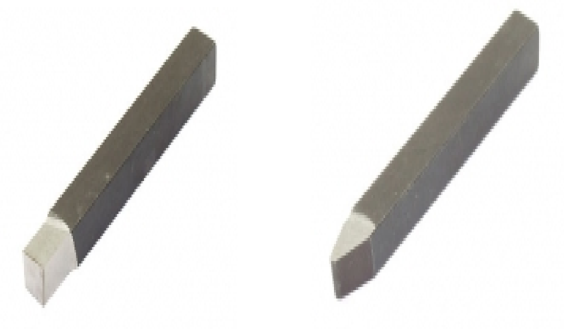

Fig. 2: HSS Cutting Tool

2.3 WORK PIECE USED

We have taken the Al-SiC composite material of length 40cm and the 20mm.

Fig 3: Al-SiC alloy MMC workpiece

2.4 SURFACE ROUGHNESS TESTER

Roughness measurement has been done using a portable surface roughness tester, shown in Fig. 4. The surface roughness tester is a portable, self-contained instrument for the measurement of surface texture. The parameter evaluations are microprocessor based.

The measurement results are displayed on an LCD screen and can be output to an optional printer or another computer for further evaluation. The instrument is powered by non-rechargeable alkaline battery (9V). It is equipped with a diamond stylus having a tip radius 3.16μm. The measuring stroke always starts from the extreme outward position. At the end of the measurement the pickup returns to the position ready for the next measurement. The selection of cut-off length determines the traverse length.

Usually as a default, the traverse length is five times the cut-off length though the magnification factor can be changed. Roughness measurements, in the transverse direction, on the work pieces have been repeated four times and average of four measurements of surface roughness parameter values has been recorded.

The measured profile has been digitized and processed through the dedicated advanced surface finish analysis software Taguchi for evaluation of the roughness parameters. Surface roughness measurement with the help of surface roughness tester has been shown in Figure 4.

Fig.4 Surface Roughness tester

3. EXPERIMENTAL PROCEDURE

In order to optimize the surface roughness of the material we adopted the following procedure.
a) Checking and preparing the Centre Lathe ready for performing the machining operation.
b) Cutting Al-Sic performing initial turning operation in Lathe to get desired dimension of the work pieces.
c) Calculating weight of each specimen by the high precision digital balance meter before machining.
d) Performing straight turning operation on specimens in various cutting environments involving various combinations of process control parameters like: spindle speed, feed and depth of cut.
e) Calculating weight of each machined plate again by the digital balance meter.
f) Calculating the Fx, Fy, Fz by using lathe tool dynamometer.
g) Measuring surface roughness and surface profile with the help of a portable Surface roughness tester.
h) After getting the different parameter to optimize the surface roughness by using taguchi method.

4. RESULT AND DISCUSSION

Table 4.1 indicates the surface roughness of Al-SiC composite material by taking the input speed, feed and depth of cut. To calculate the output parameters like surface roughness and cutting force in different cutting speed, feed and depth of cut.

First 3 experiment we carried out by taking the same speed and by varying the depth of cut and feed. Next 3 experiment is calculated by increasing the speed and taking the same speed for next 3 experiment and varying the feed and depth of cut.

Table 4.1: Obtaining various surface roughness by varying the input parameters.

	Input Parameters			Response Parameters	
Serial No.	Cutting Speed (m/min)	Feed rate (mm / rev)	Depth of Cut (mm)	Surface roughness (µm.)	Cutting force (N)
1	100	.05	.5	2.71	83
2	100	.1	1	2.91	97
3	100	.2	1.5	2.98	121
4	125	.05	1	2.67	86
5	125	.1	1.5	2.89	105
6	125	.2	.5	2.76	94
7	150	.05	1.5	2.43	88
8	150	.1	1	2.1	79
9	150	.2	.5	2.45	88

4.2 MAIN EFFECTS PLOT FOR MEANS

From fig. 5 main effect plot for means, it has been observed that the minimum surface roughness can be achieved with the optimal parameter level of speed at 100 rpm, feed 0.125 mm and depth of cut 1.5 mm respectively.

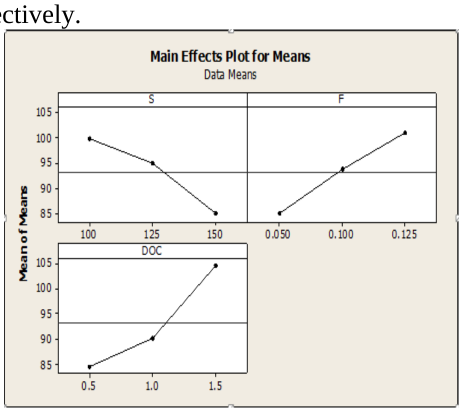

Fig. 5: Main Effects Plot for Means

4.3 MAIN EFFECTS PLOT FOR SN RATIOS

From the figure 6 for main effects plot for SN ratios, the Signal to Noise ratio of surface roughness is measured on the basis of smaller the better method. Here the optimal value of surface roughness is found at a cutting speed of 100 rpm, 0.125 mm feed and 1.5mm depth of cut, which is relatively same as the value obtained from main effects plot for means.

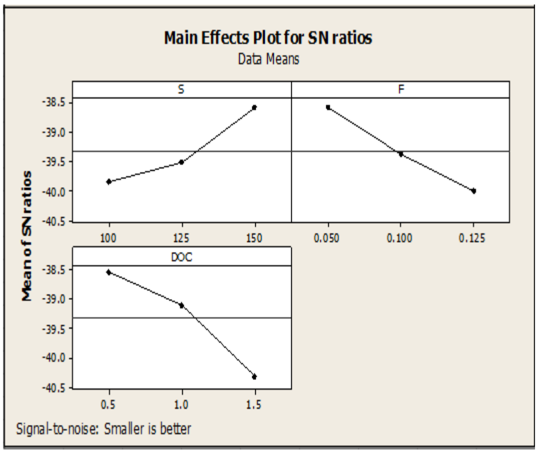

Fig. 6: Main Effects Plot for SN Ratios

4.4 RESIDUAL PLOTS FOR SN RATIOS

From the residual plot Fig. 7, it is observed that the factors are on the linear line that indicate the residual error is very less.

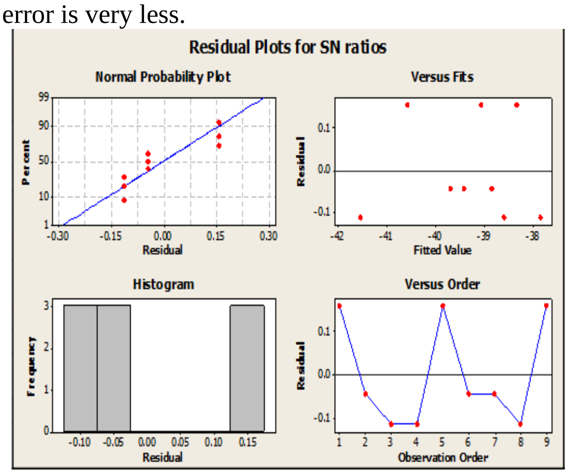

Fig. 7: Residual Plots for SN Ratio

4.5 LINEAR MODEL ANALYSIS: SN RATIO vs. SPEED, FEED & DEPTH OF CUT

The model coefficients are need to be estimated for different input variables like speed, feed and depth of cut in order to find out the signal to noise ratio. The table below helps to find out the model co-efficient.

Table 2: Estimated Model Co-efficient for SN ratios

Term	Coeff SE	Coeff	T	P
Constant	-39.3188	0.08143	-482.871	0.0000
S 100	-0.5348	0.11516	-4.644	0.043
S 125	-0.2067	0.11516	-1.795	0.215
F 0.050	0.7357	0.11516	6.389	0.024
F 0.100	-0.0518	0.11516	-0.450	0.697
DOC 0.5	0.7905	0.11516	6.865	0.021
DOC 1.0	0.2138	0.11516	1.856	0.205

S= 0.2443	R-Sq = 98.9%	R-Sq (adj) = 95.6%

Here the value of R- square is 98.9% and adjusted R-square value is 95.6%. The error is found because of the loss due to the vibration and heat caused during turning operation.

4.6 ANALYSIS OF SIGNAL TO NOISE RATIO

Smaller-the-better performance characteristic is selected to obtain better surface finish because smaller the surface roughness better the surface finish.

Table 3: Response table for surface roughness

Level	Speed	Feed Rate	Depth of Cut
1	-39.85	-38.58	-38.53
2	-39.53	.39.37	-39.11
3	-38.58	-40	-40.32
Δ	1.28	1.42	1.79
Rank	3	2	1

4.7 ANALYSIS OF VARIANCE

ANOVA is a statistical technique that is very useful in determining the level of significance of influencing factors. It separates the total variability of the response into contributions rendered by each of parameters. ANOVA was performed to identify the significant factors tabulated in Table 4. It is observed that the depth of cut (46.52%) is most significant factor followed by feed rate (28.03%) and cutting speed (24.34%). From tables below it can be noted that in order of importance, the factors are in same sequence, which reveals the accuracy of the Taguchi method.

Table 4. Analysis of Variance Table

Source	DF	Seq SS	Adj. SS	Adj. MS	F-value	Percentage of contribution
Cutting speed (m/min)	2	2.6357	2.6357	1.31786	22.08	24.34%
Feed rate (mm/rev)	2	3.0347	3.0347	1.51734	25.43	28.03%
Depth of cut (mm)	2	5.0375	5.0357	2.51874	42.21	46.52%
Error	2	0.1193	0.1193	0.05967		
Total	8	10.8272				

5. CONCLUSION

In this paper the optimal machining parameters determined for single response characteristics namely surface roughness in the turning of Al-SiC alloy composite material. It is observed that there is a good agreement between the estimated value and experimental value.

Taguchi method of experimental design has been applied for optimizing the process parameters for turning Al-SiC alloy. Results obtained from Taguchi method closely matched with ANOVA. Best parameters found for lesser tool force are: Cutting Speed (100 RPM), Feed (0.125 mm/rev) and Depth of Cut (0.5mm) for machining on a high speed lathe and the result indicated by prediction model of regression equation was found to be almost confirming with the actual values obtained from experimental analysis. When optimization technique is applied to cutting parameters of Alloy following conclusion were drawn:

• Depth of cut has less influence on cutting force rather than feed and depth of cut according to our model.
• Speed having lesser influence on surface roughness, Depth of cut and feed has more influence on surface roughness.
• Speed has a very high impact on power consumption, more effect caused from depth of cut and feed.
• From the analysis of ANOVA for cutting force speed having more contribution towards cutting force.
• Similarly Depth of cut has influence to surface roughness.
• Speed having more contribution towards power consumption.
• From the model summary R-SQ (Predicted) is 98.9% for cutting force, surface roughness, and Power consumption.
• As MMC is somewhat harder than alloy the cutting force is more compared to alloy.
• Surface roughness is also more influence by speed, depth of cut and then feed.
• Power consumption for cutting of MMC is more compared to Alloy.

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