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A Study on Process Parameters in Milling of Al-MMC

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Abstract-Metal Matrix Composites have become a leading material among composite materials. In particular, particle reinforced Aluminum Metal Matrix Composite (AMMC) have received considerable attention due to their excellent engineering properties. Aluminum metal matrix refers to the class of light weight high performance aluminum centric material systems. The reinforcement in AMC's could be in the form of continuous/ discontinuous fibers, whiskers or Particulates in volume fractions ranging in percentages. Properties of AMC's can be tailored to the demands of different industrial applications by suitable combinations of matrix reinforcement and processing routes.

In this study an attempt has been made to manufacture the AMC through a liquid metallurgical route. The matrix used in the study is Aluminum alloy and reinforcement particles selected are Silicon Carbide (SiC) particles ranging its size from 50-70 microns. The study also focuses to establish a mathematical relationship between process parameters like Cutting speed, Feed Rate, Depth of cut and surface roughness (Ra) in End Milling operation. A CNC machining center with 8 mm diameter HSS end milling cutter with 30° helix angle is used for machining by employing a L_{16} (4^4) Taguchi's orthogonal array for the experiment plan. A linear and multiple regression analysis using analysis of variance is conducted to determine the performance of experimental measurements and to show the effect of four cutting parameters on the surface roughness.RSM methodology was selected to optimize the surface roughness resulting minimum values of surface roughness and their respective optimal condition.

Key words : Orthogonal Array, CNC End milling, Multiple regression, RSM.

I. INTRODUCTION

Surface roughness plays an important role in the performance and economic aspects of machine components. Surface roughness has impact on mechanical properties like fatigue strength, corrosion resistance etc., a large number of various parameters influence the surface finish. Proper selection of process parameters is desired for better finish. Many parts are designed such that they must be processed on milling machines in at least one stage of their fabrication. In modern industries CNC milling is most widely used operation because it is versatile and accurate machining process that allows manufacture of products with high quality and good finish. Aluminum Metal Matrix Composites are good substitute for Aluminum alloys with their greater strength, improved stiffness, improved abrasion, wear resistance and damping capabilities. As less research work is done in machining of AMC's and from the available data it is understood that the hard and abrasive reinforcements pose problem while machining AMC and effects surface finish.

Several studies have been done on different materials with different cutting tool materials in order to study the influence of various machining parameters on surface roughness. H. oktem develop an integrated study of surface roughness to model and optimize the cutting parameters when end milling of AISI 1040 steel material with TiAlN solid carbide tools under wet condition. Nafis Ahmed, Tomohisa Tanaka and Yoshio Saito find optimum feed rate and cutting speed for a specific depth of cut of end milling operation by minimising the machining time in end milling operation of Aluminium alloy with HSS 4 flute end milling using SOAP based Genetic algorithms. Sanjit Moshat,Saurav Datta,Asish Bandyo Padhyay and Pradeep Kumar Pal highlights optimization of CNC end milling process parameters to provide good surface finish as well as high material removal rate while machining Aluminium with CVD coated carbide tools using PCA based Taguchi Method. K.Kadirgama explores on the optimization of the surface roughness of milling mould aluminium alloy with carbide coated inserts using statistical method. Kantheti Venkata Murali Krishnam Raju, Gink Ranga Janardhana , Podaralla Nanda Kumar and Vanapalli Durga Prasada Rao develop an integrated study of surface roughness to model and optimize the cutting parameters when end milling of 6061 aluminium alloy with HSS and carbide tools under dry and wet conditions using GA. Seeman.M & G. Ganesan & R. Karthikeyan & A. Velayudham model the machinability evaluation considering cutting speed, feedrate, depth of cut and machining time on surface roughness and flank wear through the RSM in machining of 20% SiCp LM25 Al MMC manufactured through stir cast route. Suresh K. Reddy.N ,Venkateswara Rao.P asses the performance of end milling and effect of tool geometry (radial rake angle and nose radius) and cutting conditions (cutting speed and feed rate) on the end milling of Medium carbon steel with solid coated carbide tools using GA.

In this study, an effective multiple regression model was used to build mathematical relation between response and process parameters. This multiple regression model obtained using statistical software MINITAB. The work material selected for study are Aluminum Metal Matrix Composite with 5% Sic reinforcement. The best combinations of cutting parameters leading to the lower surface roughness when end milling of AMC with 5% SiC reinforcement was studied. Taguchi based orthogonal array L_{16} (4^5) , with 4 factor 5 level design has been used to conduct the experiments.

II. METHODOLOGY

In this work mathematical model have been developed using experimental results with the help of multiple regression model. The combinations of process parameters for minimum surface roughness are studied. Taguchi's orthogonal array for 4 level 5 factor design being used for conducting experiments.

A. Taguchi's Method

Taguchi's approach was built on traditional concepts of design of experiments (DOE) such as factorial and fractional factorial designs and orthogonal arrays; he created and promoted some new DOE techniques such as signal-to-noise ratios, robust designs ,parameter and tolerance designs. Taguchi's Orthogonal Array (OA) analysis is used to produce the best parameters for the optimum design process, with the least number of experiments.

Orthogonal arrays are a special set of Latin squares , constructed by Taguchi to layout the product design experiments. An orthogonal array is a type of experiment where the columns for the independent variables are "orthogonal" to one another. OA are employed to study the effect of several control factors. OA are used to investigate quality. OA are not unique to Taguchi. However Taguchi have simplified their use by providing tabulated sets of standard orthogonal arrays and corresponding linear graphs to fit specific projects. Table 1 shows L_{16} array for 4 level 5 factor design.

TABLE-1 TAGUCHI'S L_{16}ORTHOGONAL ARRAY

1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	1	4	4	4
5	2	1	2	3
6	2	2	1	4
7	2	3	4	1
8	2	4	3	2
9	3	1	3	4
10	3	3	1	2
11	3	3	1	2
12	3	4	2	1
13	4	1	4	2
14	4	2	3	1
15	4	3	2	4
16	4	4	1	3

B. Mathematical Model

In statistics, regression analysis helps us understand how the typical value of dependent variable changes when any one of the independent variable is varied, while the other independent variables are held fixed. Regression analysis is widely used for prediction.

In linear regression, the model specification is that the independent variable Yi is a linear combination of the parameters. For example, in simple linear regression for modeling n data points there is one independent variable xi and two parameters β0 and β1.

Straight line : $Yi = \beta_0 + \beta_1 xi + \varepsilon i$, i = 1 . . . . n (1)

In multiple linear regression, there are several independent variables or functions of independent variables. For example, adding a term in xi^2 to the preceeding regression gives :

Parabola: $Yi = \beta_0 + \beta_1 xi + \beta_2 xi2 + \varepsilon i$, i = 1, ... , n (2)

Where εi : measurement error

III. PURPOSE AND SCOPE

The specific purposes of the study were as follows:

- An attempt has been made to manufacture the AMC through a liquid metallurgical route.
- To assess the machinability criteria of AMC and to establish a set of conditions at which favorable surface roughness is attained for each of the material.

- To analyze the main effects of cutting speed, feed rate, depth of cut, cutter diameter on surface roughness in end milling operation.
- To determine the interacting effect of these variables on R_a in end milling operation.

The surface finish prediction strategy has been developed for correlating the machining parameters with surface roughness, using regression technique, and studies the mechanical characteristics of AMC.

IV. EXPERIMENTATION

The material selected were Aluminum 7075 alloy and Metal matrix composite of aluminum. The test specimens are cast into 174*15*15 sizes, to accommodate 16 samples machining in each piece. Specimen are rough machined all faces to get flat surface. The thickness is maintained 15mm to ensure rigidity of mounted piece on the machine table.

The experiments were conducted as per the standard orthogonal array L_{16} (4^5) as shown in table.1 with 4 level 5 factor design. The process parameters selected were cutting speed, feed rate, depth of cut, and cutter diameter. HAAS-VF2 CNC machining centre with 10,000 rpm spindle speed, 1000 IPM vector dual drive being used for experimentation. Fig-1 shows the machine set up for conducting experiments. Table-2 indicates the factors and their values. The cutting tools used for experiment were HSS end mills with required number of cutting edges. Aluminum metal matrix composite was selected as a material for present study. The response to be studied was surface roughness (Ra). Talysurf was used to measure Ra values of work surfaces in random order at 3 places and average of these values was recorded. Fig.2 shows the measurement of surface roughness using Talysurf.

Fig-1 Machine set up

Fig-2 Measurement of surface roughness

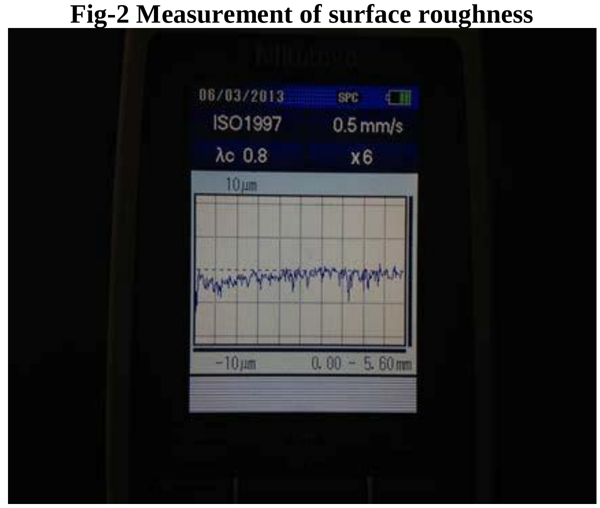

Fig-3: Surface Roughness Illustration

The mathematical relationship between responses and machining parameters was established using the multiple regression analysis. In the present study, the correlation between the process parameters cutting speed, feed rate, depth of cut, number of cutting edges, step over distance and surface roughness are established.

C. Aluminium Metal Matrix Composite (AMC)

Regression analysis shows 87.9% of closeness with experimental data as shown in table-2. Fig-4 shows the variation of roughness values obtained from experiments with predicted values using regression equation of Aluminium Composite. Fig-5 shows the main effects of various factors on surface roughness of Aluminium Composite.

Referring to Fig. 6 of AMC, the surface roughness increases with increase of cutting diameter and depth of cut and surface roughness decreases with increase of cutting speed and feed rate.

TABLE -2: Summary of Regression Analysis AMC

S value	R-Sq (%)	R-Sq(adj)
2913	98.4	87.9

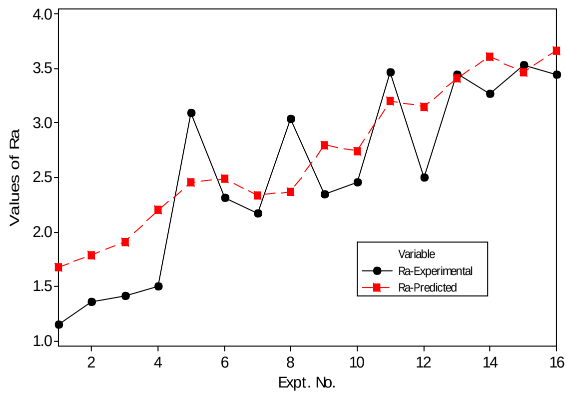

Fig-4: Roughness values of AMC Experimental Vs Calculated

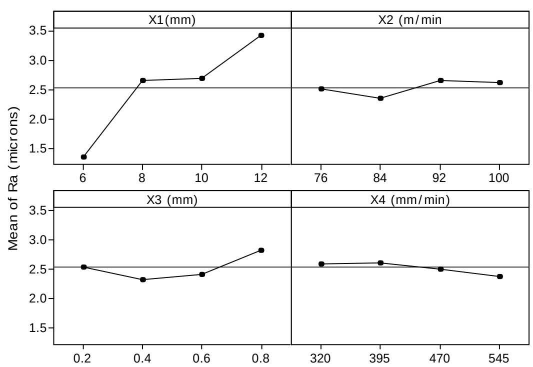

Fig-5: Main effects plot for surface roughness of AMC

V. CONCLUSIONS

In the present study, the best combinations of cutting parameters have been found to provide the lowest surface roughness for end milling of AMC using HSS tooling. The regression analysis were conducted to develop mathematical model.

The minimum surface roughness for AMC is 1.108420 microns at cutter diameter of 6mm ,cutting speed of 76 m/min, depth of cut of 0.4 mm, feed rate of 545 mm/min. Regression analysis shows closeness of 87.9% (for AMC) with experimental data.

From graph it is concluded that:

The surface roughness increases with the increase in cutting diameter up to a certain value, then further increases at high cutting diameter.

The surface roughness decreases with increase in cutting speed and further increases as cutting speed increases.

The surface roughness decreases up to a certain value and then increases with increase in depth of cut.

The surface roughness value decreases with increase in feed rate.

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