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Research Paper

OPTIMIZATION OF MICRO MILLING PARAMETERS OF AL-6082 BY ANOVA METHODOLOGY

M Saravana Kumar[1]*, T T M Kannan[1], S Giridharan[1] and P Vijaya Kumar[1]

*Corresponding Author: M Saravana Kumar, ✉ msrbemech@gmail.com

Micro-machining is the basic technology of micro-engineering for the production of micro-sized parts and components. Miniaturization of machine tools to size compatible to target products without compromising machining tolerance lead to enormous saving in energy, space and resources. The paper deals with optimization of micro milling parameters of AL-6082. Generally micro milling processused inBio-medical, Aeronautical, Microelectronic industries. Recentlymicro milling widely used for the manufacturing industries due to its capability of producing tedious geometric surfaces with good accuracy and surface finish. In this experimental work micro milling experiments are conducted in Micro milling machine using 0.5 mm diameter end mill at spindle speeds up to 10,000 rpm on machining of AL-6082. The analysis of the result shows that the optimal combination for higher Metal Removal Rate (MRR) is medium cutting speed, high feed rate and high depth of cut. Using Design Of Experiment (DOE) concept, other significant effects such as the interaction among micromilling parameters are also investigated by using ANOVA method.

Keywords: Micro-milling, End mill, DOE concept, MRR, ANOVA

INTRODUCTION

Micro milling machines arewidely used to machine micro components in ferrous and non ferrous materials. Miniature of milling machine can also be used for cutting keyways, racks and slots. It is characterized by mechanical interaction of a sharp tool with the work piece material, causing breakage inside the material along defined paths, and eventually leading to removal of the useless part of the work piece in the form of chips. The study of metal cutting focuses the work material, tools, machining parameters and cutting fluid which influencing process efficiency and output quality characteristics. AL-6082 is a popular grade which readily machinable in any condition which best suitable for high tensile strength and wear resistance components. It is available in heat treated forms posses good homogeneous metallurgical structure and

[1] Department of Mechanical Engineering, Prist University, Thanjavur 613403, India.

gives consistent machining and mechanical properties. There are relatively few researches releasing to surface roughness with using side and face milling cutter in hardened steel. Zhang *et al.* (2007) used Taguchi design of optimization to predict surface roughness CNC milling operation. El-Sonbaty *et al.* (2008) used artificial neural networks and traced geometry approach to predict the material removal rate of profile milling operations. Palanisamy *et al.* (2008) using regression the end milling operation. Routara *et al.* (2009) by using RSM the surface modeling and optimization in milling process. Baek *et al.* (2001) by RSM optimized the feed rate in face milling operation. Ghani *et al.* (2004) explain high cutting speed, feed and depth of cut were adopted for low surface roughness is obtained for high hardened steel. Vivancos *et al.* (2004) analyze mathematical model of surface roughness were established by means of design of experiments. Ding *et al.* experimentally investigated at the effect of cutting parameters on cutting forces and surface roughness in hard milling. Previous study provides much valuable information for under studying of material removal rate in milling process, very few researches were conducted to investigate in material removal rate in aluminium alloy. It is necessary to determine the optimal milling conditions based on reliable experimental results to improve the productivity in the micro milling processes. The number of steps per one milling, the cutting speed, and the spindle rpm are used as process parameters to determine the optimum milling conditions. For this purpose, experimental works are carried out based on DOE (Design of Experiments), and the obtained experimental data are analyzed using ANOVA (Analysis of variance).

EXPERIMENTAL SETUP

Specification of Micro Milling Machine

Power of motor	:	220 V
Spindle speed	:	9000 rpm
Spindle capacity	:	0.2 to 10 mm
Accuracy	:	1 micron
Diameter and height	:	26 × 309 mm
Supporting column	:	97 × 116 mm
Net weight	:	3.25 kg
Space required	:	150 × 150 mm
Manufacturer	:	PABIIT (R&D)

Figure 1: Micro Milling Machine (PABIIT R&D)

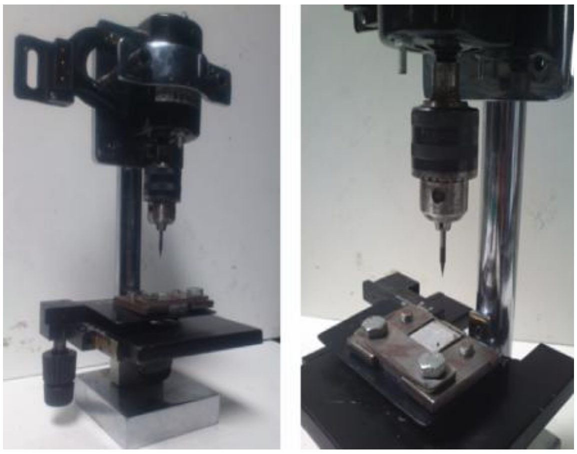


Figure 2: End Mill (Carbide 0.5 mm)

DESIGN OF EXPERIMENTS

L_9 orthogonal Array: To demonstrate the data analysis procedure, the following L_9 orthogonal Array will be used for predicting best level and best parameters. This Orthogonal array can be used to covers all combinations of parameters at three levels each.

Micro Milling Parameters

Table 1: L_9 Orthogonal Array

A	B	C
1	1	1
1	2	2
1	3	3
2	1	2
2	2	3
2	3	1
3	1	3
3	2	1
3	3	2

Note: A-cutting speed in m/min; B-feed rate in mm/rev; C-Depth of cut inmm.

ANOVA

The ANOVA procedure performs analysis of variance (ANOVA) for balanced data from a wide variety of experimental designs. Analysis of variance on the collected data from the Taguchi design of experiments can be used to select new parameter values to optimize the performance characteristic. In analysis of variance, a continuous response variable, known as a dependent variable, is measured under experimentalconditions identified by classification variables, known as independent variables.

The F-test: The F-test is used for comparisons of the components of the total deviation. For example, in one-way, or single-factor ANOVA, statistical significance is tested for by comparing the F-test statistic

$$F = \frac{\text{Variance between treatments}}{\text{Variance within treatments}}$$

RESULTS AND DISCUSSION

The cutting speed, feedrate and depth of cut are input micro milling parameters which is analyzed the response parameter like material removal rate of AL-6082.

MRR = (®*DN*/1000) × *f* × Depth of cut

where,

MRR = Metal removal rate

D = Diameter of end mill (mm)

N = Rotational speed of end mill (rpm)

F = Feed (mm/rev)

After conducting experiments on AL-6082 Material the following results were obtained.

- Milling parameters on AL-6082 cutting speed is the dominating parameter for MRR in micro milling process.
- During micro milling process we observe AL-6082 having good machinability property and produce good surface finish.

Table 2: Micro Milling Parameters of MRR

Cutting Speed	Feed Rate	Depth of Cut	MRR
1	1		0.0163
1	2	2	0.0228
1	3	3	0.0293
2	1	2	0.0218
2	2	3	0.0280
2	3	1	0.0156
3	1	3	0.0216
3	2	1	0.0120
3	3	2	0.0168

Figure 3: Main Effect Plots for Micro Milling Parameters on AL-6082

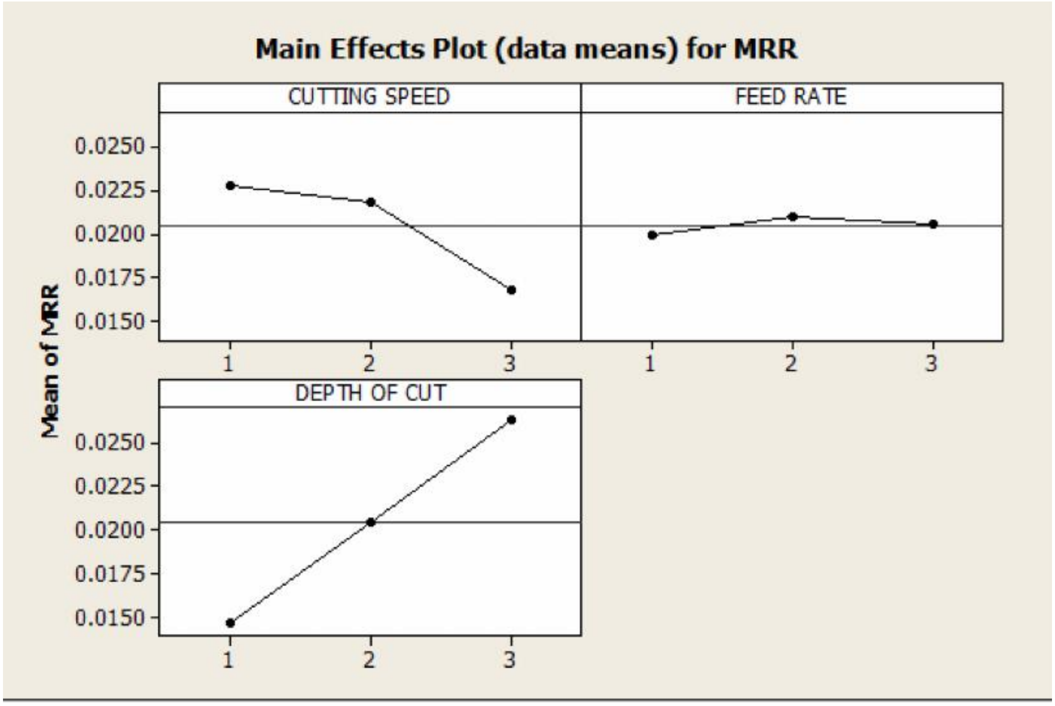
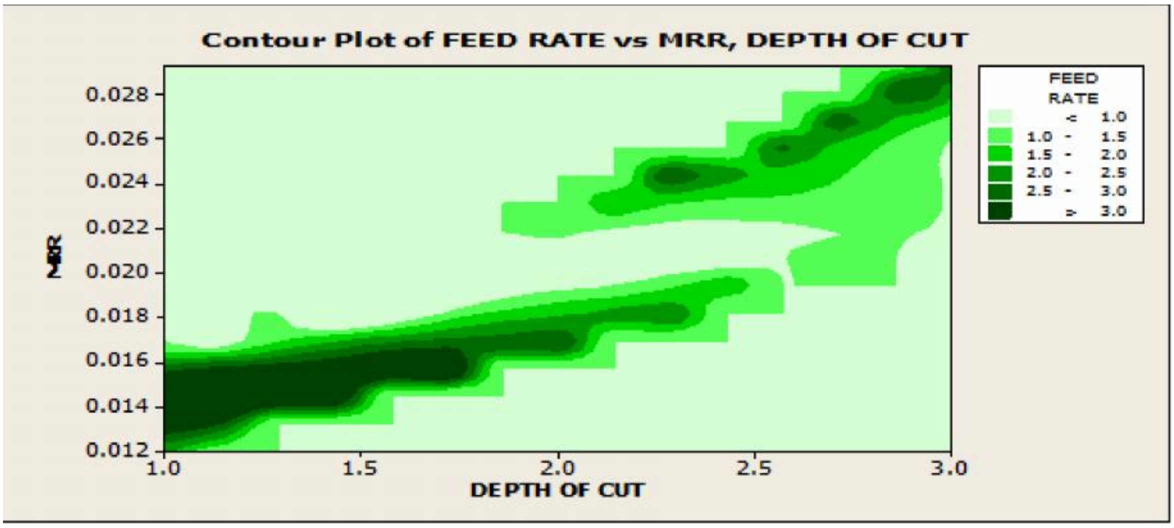


Figure 4: Contour Plot for Micro Milling Parameters AL-6082

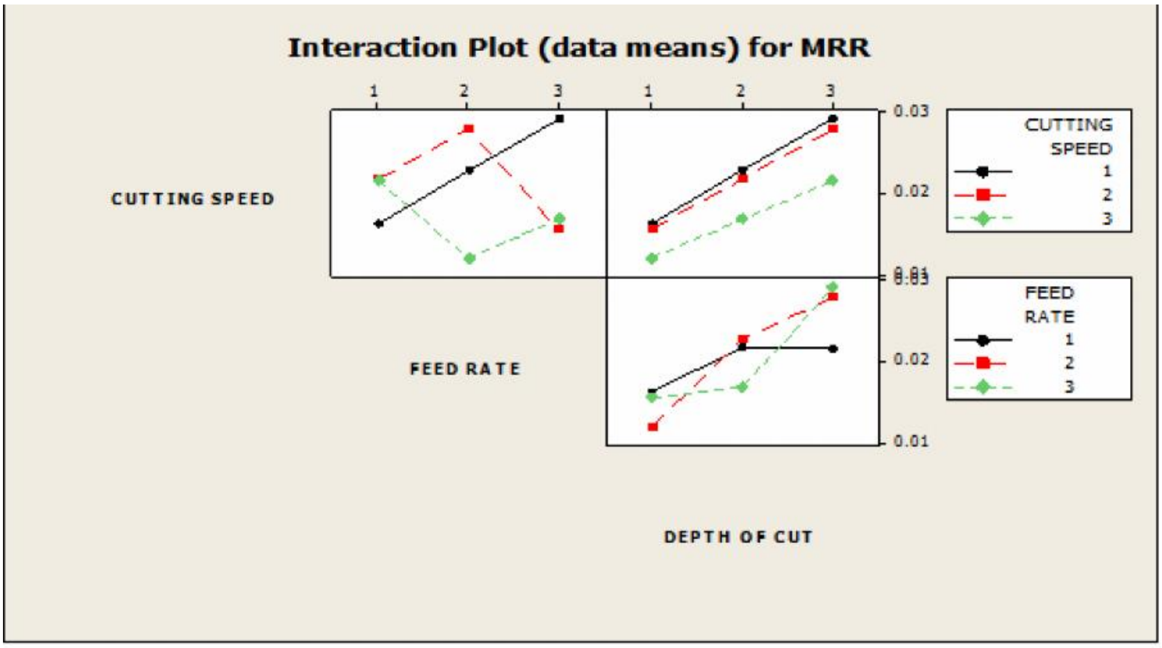


- However micro milling is possible in conventional small size milling machine.

Table 2 represents MRR of AL-6082 on optimum parameters are level 2 (3000 rpm) speed, level 2 (0.0033 mm/rev) and level 3 (0.7 mm) depth of cut.

Contour plot is a 3 dimensional representation of milling parameters which

Figure 5: Interaction Plot for MRR of Micro Milling Parameters



indicate the larger material removal rate in 1st level of depth of cut during machining of AL-6082.

The Figure 4 represents Metal Removal Rate of AL-6082 indicates cutting speed and Depth of cut are dependent parameters and feed rate is independent parameter.

CONCLUSION

This study was performed to find the effect of MRR of AL-6082. After data collection, analysis and discussion on the experiment, the optimum range of cutting parameter for micro mill with diameter 0.5 mm was 3000 to 9000 rpm for spindle speed and for respective feed rate. Based on the main objective of the study and the result from the experiment, several conclusions have been made;

- The value of MRR is decreases when the tool diameter, spindle speed and feed rate are decreases.
- The optimal parameters of AL-6082 plates are level 2 (3000 rpm) speed, level 2 (0.0033 mm/rev) feed rate and level 3 (0.7 mm) depth of cut are produced MRR of 0.0280 mm^3/sec.
- The end mill carbide type (0.5 mm) is suitable for manufacturing AL-6082 plates.
- The tool breakage does not occur due to the increase in point angle.
- In a logical sense, if the feed rate is increases, the time taken to finish the micro milling operation is faster and machine time is reduced and productivity is increase.
- Micro milling is possible in conventional micro milling machine are proved.

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