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Effect of Machining Parameters on Surface Roughness During Milling Operation

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Abstract. Aluminum is one of the most extensively used metal in aerospace industry and other applications due to its corrosion resistance, good machineability excellent mechanical properties and high strength to weight ratio. Machining parameters like number of inserts, depth of cut, cutting speed, feed rate, and cutting tool diameter have considerable impact on production rate, surface finish, energy consumption and sustainable machining. Suitable process parameters during machining and specifically milling process not only leads towards better surface finish but also towards sustainable machining. Aim of machining has always been to produce parts with better surface quality and lower energy consumption. To study the effect of milling parameters on the surface finish, Taguchi L9 array was employed for experimentation. The outcome of each parameter on surface finish has been examined using ANOVA and the most considerable parameters were identified. It has also been observed that the number of inserts significantly influence the surface finish.

Keywords. Surface Roughness, ANOVA, Milling Machine.

1. Introduction

To obtain the desired geometry and shape most widely used machining operations are milling, drilling, and turning. Possibility of creating diversity of shapes and better production yield makes milling one of the most frequently utilized machining process [1]–[3]. Milling is interrupted cutting operation as the cutting tool can have one or more than one cutting edge which engages the work piece [2]. Machining parameters that can be varied during the milling operation includes width of cut, depth of cut, number of inserts, feed, cutting speed, type of lubricant, tool material, inserts geometry and tool diameter [4]–[6].
Surface roughness has most important role in surface topography and other mechanical properties of a part like fatigue life and tensile strength [7]–[11]. Beside influencing the properties and functioning of the machined components surface roughness is additionally one of the major parameter of dimensional accuracy [3]. Geometric factors, machine tool factors and work piece material are the three factors affecting the surface roughness of

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any part or component. Geometric factors affecting the surface roughness includes type of machining operation, feed rate and cutting tool geometry [12].

By using appropriate machining parameters, required surface finish can be attained. However, surface finish can be adjusted, improved and predicted depending upon the selection of geometric factors which includes width of cut, depth of cut, cutting velocity, feed per tooth, and type of machining operation [13]–[22]. In comparison to wet machining MQL shows better surface finish [23]. In the published literature feed rate and depth of cut performs the most significant part in generating surface roughness [24], [25]. Improved surface finish can be attained by increasing cutting velocity and by decreasing feed [25]–[28].

2. Experiment Design and Material Selection

This experimental study is performed on MV-1060 YDPM milling machine using Sandvik end mill cutter of 25mm diameter and surface roughness (µm) is measured using TIME® 3110 roughness tester. As recommended by past research, key process variables can be established using Taguchi's methodology by designing experiments using orthogonal arrays to reduce production costs and improve quality [29]. Taguchi L9 array is employed for design of experiments. Number of inserts, cutting velocity, depth of cut and feed/tooth are varied in 3 intervals. Unified milling experiments using the same workpiece material supplied from the same stock and using the same cutting inserts supplied by Sandvik were used as recommended by past researchers [30, 31].The machining parameters are shown in table III. Workpiece material is aluminium 6061-T6. Inserts and cutting tool is selected using Sandvik catalogue. Chemical and mechanical properties of aluminium 6061-T6 are shown in table I and cutting tool and inserts specifications are displayed in table II.

Table I: Chemical and mechanical properties of aluminium 6061-T6 [30]

	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
%	0.62	0.22	0.29	0.07	1.1	0.18	0.01	0.01	~Bal
Mechanical properties									
Tensile Strength (MPa)		Yield Strength (MPa)			Elongation %		Hardness (HV)		
280-300		250-260			12.0-14.0		101-108		

Table II: Tool Holder, End mill cutter and inserts specifications.

Specifications	Descriptions
Tool holder	WALTER A170M.063.080.25
End mill cutter	R390-0.25B25-11M & R390-028B25-11L
Insert	R390-11 T3 02E-KM H13A
Tool diameter	25mm
Maximum cutting velocity (m/min) of insert	1000
Feed per tooth (mm/tooth)	0.08-0.18

Machining parameters are varied and their effect on surface roughness is analysed using ANOVA at 95% confidence level (significance level for $\alpha=0.05$). Factor whose P-value is below 0.05 was considered significant.

Table III: Levels of machining parameters used in this study.

Depth of Cut (mm)	Cutting Speed (m/min)	Feed per Tooth (mm/tooth)	Number of Inserts
1	325	0.1	1
1.5	350	1.4	2
2	375	1.8	3

3. Results and Discussion

Main effect plots for average surface roughness are presented in figure I and results of ANOVA are shown table IV. Figure I show that average surface roughness increase with the decrease in depth of cut and average surface roughness increases with the increase in the cutting speed, feed per tooth and number of flutes (inserts).

P-value for all the factors is less than 0.05 which means that these machining parameters are significant for average surface roughness.

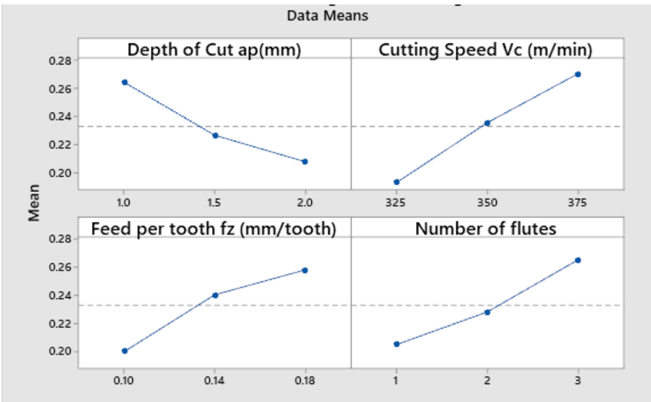

Figure I: Main Effect Plots for Average Surface Roughness

Table IV. ANOVA results for this study

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Depth of Cut ap(mm)	2	0.009990	0.004995	7.14	0.014
Cutting Speed Vc (m/min)	2	0.018209	0.009104	13.01	0.002
Feed per tooth fz (mm/tooth)	2	0.010727	0.005364	7.66	0.011
Number of flutes	2	0.011194	0.005597	8.00	0.010
Error	9	0.006300	0.000700		
Total	17	0.056420			

Conclusion

From this experimental analysis it is concluded that surface finish is highly dependent on machining parameters which are number of inserts, feed per tooth, cutting speed and depth of cut.

- With a decrease in depth of cut average surface roughness (*Ra*) increases. So, to obtain better surface finish, higher values of depth of cut should be selected.
- Average surface roughness rises with the greater number of inserts, feed per tooth and cutting velocity/speed. So, greater values of above said parameters should be used for better surface finish.
- Results of ANOVA shows that all machining parameters which are cutting velocity/speed, depth of cut, feed/tooth and number of inserts plays significant role in generation of surface roughness.
- By using suitable machining parameters, better surface finish can be achieved.

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