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STUDY THE EFFECT OF CNC MILLING PARAMETER ON SURFACE ROUGHNESS OF POM MATERIAL

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ABSTRACT

Polyoxymethylene (POM) belongs to a group of high-performance thermoplastic polymers, which has high specific properties as compared to conventional metallic materials. Due to its own properties and potential applications in various fields of structural components, it is necessary to investigate the machining of POM. This paper present the relationships between the cutting conditions (depth of cut, feed rate and cutting speed). The researcher focuses on interaction effects between the controllable factors and responses during machining of POM material under dry machining condition. An experiment and analysis was conducted by using design of experiment method (DOE). The optimum parameter was determined by measuring the surface roughness (Ra) of each workpiece and anlyse the result via an interaction of main effect by ANOVA. The researcher were successfully record the optimum parameters which is 4000 RPM of cutting speed, 0.25 mm/tooth for feed rate, 4 mm of depth of cut. By using this parameter, the smallest value of surface roughness is measured -0.0286µm.

Keywords: polyoxymethylene, CNC milling, surface roughness.

INTRODUCTION

Polyoxymethylene occupies an important in industry as well as in society. It is expected that the development of high value added materials will result in the requirement to distinguish them from existing POM materials. Injection molding is the most commonly used manufacturing process for the fabrication of plastic parts. A wide variety of products are manufactured using injection molding, which vary greatly in their size, complexity, and application.

Although injection molding is arguably the most common way to form plastics, in some cases milling plastic parts is more cost effective or is simply necessary. According to Wright and Dunk (1988) when using injection moulding for plastic part the plastic burning onto the cylinder walls and then flaking off into the melt. Air trapped in mold causing the burning. Mold also too cold causing a premature freezing and higher resistance to flow is typically due to the fact that there is moisture on the plastic granules.

The challenge of modern machining industries is mainly focused on the achievement of high quality, in term of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and increase of the performance of the product with reduced environmental impact. End milling is a very commonly used machining process in industry. The ability to control the process for better quality of the final product is paramount importance.

End milling is the most important milling operation, widely used in most of the manufacturing industries due to its capability of producing complex geometric surfaces with reasonable accuracy and surface finish. However, with the inventions of CNC milling machine, the flexibility has been adopted along with versatility in end milling process. In order to build up a bridge between quality and productivity and to achieve the same in an economic way, the present study highlights optimization of CNC end milling process parameters to provide good surface finish and high material removal rate
(MRR).

Bouzakis *et al*., (2008) reported that material proved to be the toughest from both the cutting force and the specific cutting resistance point of view. The specific cutting force decreases substantially by increasing the cutting parameters (feeding, depth of cut). Taking into account the chip type formed it can be said that it is a hardly machineable material. Using the lower feeding (0.2 mm/tooth) is recommended. Its value with the increasing of feed and depth of cut does not decrease such amount as in case of reinforced plastic. At cutting the small feeding (0.2 mm/tooth) and the greater depth of cut (4 to 8 mm) is suggested.

The earliest literatures on machining polymer by R. Izamshah *et al*., (2013) which studies the surface roughness on milling unfilled PEEK engineering plastic under dry condition. The three significant independent variables considered were spindle speed, feed rate and depth of cut. R. Izamshah *et al*., (2013) were also reported that the feed exerts the strong effect on the roughness value, whilst cutting speed has a secondary influence followed by depth of cut. The result of surface roughness of PEEK material not smooth surface finish and expand because of heat from dry mill processing. The statistical result shown that the feed rate is the main factor that influence the surface roughness followed by milling speed and depth of cut which shown that there is some

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form of polymeric softening taking place when cutting speed exceeded a critical cutting speed.

According to Xioa and Zhang (2002) suppliers and end users agree that it is crucial to keep the plastic milling operation as cool as possible, but they don't always agree on how to do it. Researcher acknowledged that there is divergence of opinion on the use of coolant. Some people say never use coolant, while some say have to use coolant. As far as the cutting tool end of it, should always use coolant. But those promoting dry machining of plastics using air-jet cooling point out that some plastics are hydroscopic, plastic material absorb water.

EXPERIMENT

Design of experiment

Design of experiments (DOE) is a systematic, rigorous approach for engineering problem solving that applies principles and techniques at the data collection stage so as to ensure the generation of valid, defensible, and supportable engineering conclusions. In addition, all of this is carried out under the constraint of a minimal expenditure of engineering runs, time, and money. In this paper, the researcher will run the experiment by using full factorial design with three factor and two level as shown in Table-1 and 2.

Table-1. Process parameter.

Parameter	Unit	Low (-1)	High (1)
Cutting speed	rpm	4000	8000
Feed rate	Mm/tooth	0.2	0.3
Depth of cut	mm	4	8

Table-2. Metric model.

Run	Cutting speed	Feed rate	Depth of cut
1	-1	-1	-1
2	1	-1	-1
3	-1	1	-1
4	1	1	-1
5	-1	-1	1
6	1	-1	1
7	-1	1	1
8	1	1	1

The experiments were conduct with eight numbers of trial run under appropriate parameters that were designed based on DOE full factorial. All of this workpiece were undergo CNC milling machine with end-mill type cutting tool to identify the surface roughness. Hence, the measurement of surface roughness will be analyse by using Anova: General linear model in order to obtain the optimum parameters design.

RESULT AND ANALYSIS

Data collection

The experiment was conducted by using full factorial design with two level and three factor. The surface roughness was inspecting by using MAHR SURF in order to check the surface roughness of workpiece. Hence the result of surface roughness measurement was recorded and tabulated in the Table-3 and Figure-1. Based on the result of normality test graph, the p-value show the data is normal. The p-value is 0.294. Since the p-value is greater than 0.05, the result obtain from this experiment is normal. Hence the analysis of significant factor and interaction between the parameter has been conduct by using main effect and interaction graph.

Table-3. Result of measurement log transformation.

StdOrder	cutting speed	feed rate	depth of cut	log result Ra (μm)
1	4000	0.20	4	-0.5124
2	6000	0.20	4	-0.0057
3	4000	0.25	4	-0.0286
4	6000	0.25	4	-0.1539
5	4000	0.20	6	-0.3262
6	6000	0.20	6	0.6316
7	4000	0.25	6	-0.2684
8	6000	0.25	6	0.0404

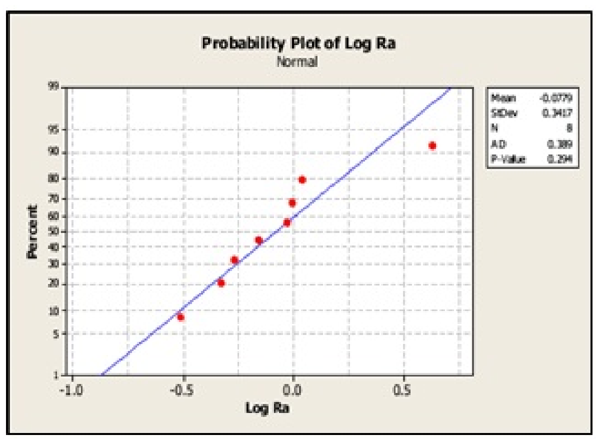

Figure-1. Normality test log.

Main effect analysis

The main effect plot is used to determine which level of the factor would effect the response output and to define the strong positive (+ ve) and strong negative (-ve) main effect that effect the milling process workpiece. Main effect plot analysis in Figure-2 shown that only 2 parameters which is cutting speed and depth of cut shown the strongest effect. It means that the higher the cutting speed and depth of cut the higher potential of milling process in increasing roughness value. For the other parameter which is feed rate has recnegative low main effect if the parameters applied is adjusted.

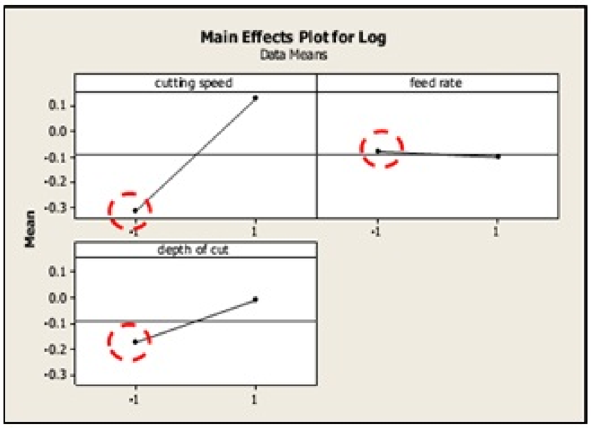

Figure-2. Main effects plot.

Analysis of variance (ANOVA)

ANOVA is an analysis of the variation present in an experiment. It is a test of the hypothesis that the variation in an experiment is no greater than that due to normal variation of individual characteristics and error in their measurement. The purpose of the ANOVA is to investigate which of the process parameters significantly affect the performance characteristics. In this experiment, the operator is analyzed based on the normality plot, main effects plot, and interaction plot.

From the analysis, the significant factor which is p-value is taken for every factor. Degrees of freedom (DF) are used to then determine whether a particular null hypothesis can be rejected based on the number of variables and samples of in the experiment. The number of DF of sum of squares is equal to the number of independent elements in the sum of square. Sum of square (SS) is used to partition the total variation in the experiment. Mean square (MS) is SS divided by DF. F statistic is the value of MS divided by mean square error (MSE). The basis for every statistical test is to phrase the question in terms of a null hypothesis, essentially that everything is equal, and then to test whether that can be accepted within a certain probability.

By referring to the result (Figure-3), it shows that every factor is not significant because the p-value is more than 0.05. For the cutting speed conclusion it shows the value that nearly to be significant with p-value 0.138, that make the main effect of the factor is the most significant. It can be observed that, cutting speed the strongest effect on the roughness value, whilst depth of cut has a secondary influence followed by feed rate. Although by controlling the cutting speed to a minimum value could control the surface roughness, however the machining productivity is low. Thus, the optimal combination between parameters is necessary to ensure the machining performance can be achieved.

Interaction effect analysis

Interaction plot (Figure-4) is used to determine whether the setting of interaction effects between the same level factors or the interaction between two different factors would be the same as main effect setting. If the two straight lines are parallel, then the interaction between two factors are relative to each other. However, all of these parameters or factors have high possibility to respond or give impact in this experiment thus to identify the significant interaction based on means, two w ay interaction was carried out for each factor to determine the significant of the factors intersection.

We can say that there have interactions between the parameter cutting speed with feed rate and cutting speed with depth of cut but they are not too strong. Then analysis in Figure-5 shows there is significant interaction between these parameters. The statistically significant effects are shown in red. The stronger the effect, the nearest from the blue line it is.

Factor	Type	Levels	Values
cutting speed	fixed	2	-1, 1
feed rate	fixed	2	-1, 1
depth of cut	fixed	2	-1, 1

Analysis of Variance for Log Ra, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
cutting speed	1	0.33949	0.33949	0.33949	3.42	0.138
feed rate	1	0.00489	0.00489	0.00489	0.05	0.835
depth of cut	1	0.07566	0.07566	0.07566	0.76	0.432
Error	4	0.39750	0.39750	0.09937		
Total	7	0.81754				

S = 0.315238 R-Sq = 51.38% R-Sq(adj) = 14.91%

Figure-3. Ra versus cutting speed, feed rate, depth of cut.

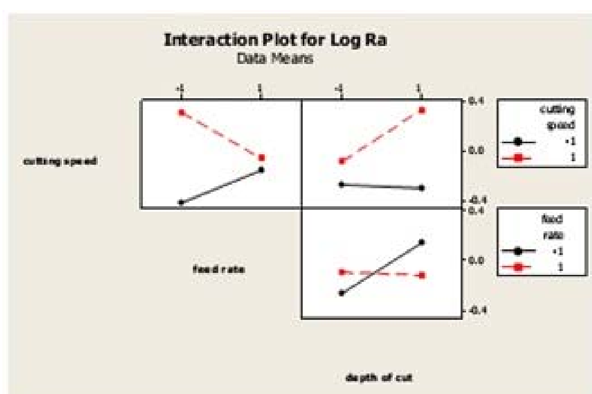

Figure-4. Interaction plot.

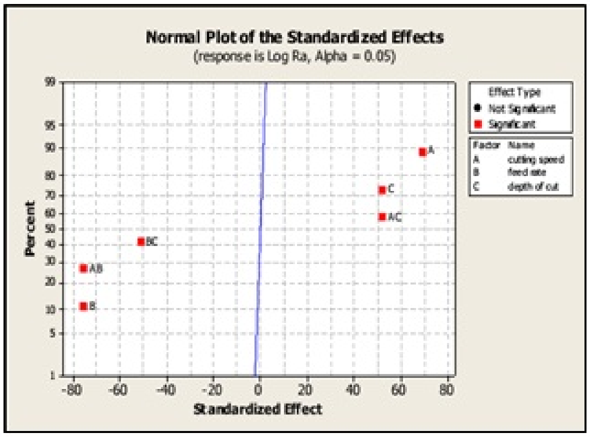

Figure-5. Normal plot of standardized effects.

CONCLUSIONS

As a conclusion, the cutting speed was found as the most effective parameter on the surface roughness. At the main effect and interaction of feed rate has shown that the value did not significant to the cutting process. The influence of the most significant cutting speed (-1), depth of cut (-1) and the parameter of the feed rate (-1) in the experiment were give the smooth surface and the lowest value which is -0.0286µm.

In the future work, the researcher should tackle the variation of dry and wet milling condition on POM material under milling in order to get the real condition of milling process for this engineering plastic.

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