ISSN: 2454-9940

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

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www.ijasem.org

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

ISSN2454-9940www.ijasem.org

Vol 8, Issuse.3 Sep 2020

A Study on Surface Roughness when Milling C45 Steel

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ABSTRACT

C45 steel is put through its paces with a research on face milling cutters in this article. The Box-Behnken approach was used to generate an experimental matrix for an experiment. Cutting speed, feed rate, and depth of cut were all altered in each trial. To assess the milling process, surface roughness has been used as a metric. Cutting parameters and their interactions on surface roughness have been studied experimentally and shown to have a significant impact. There have been two suggested regression models for surface roughness. The Johnson transformation is used in this case. Models for surface roughness prediction were utilised in conjunction with the experimental data. Johnson's transformation offers a better degree of accuracy than other data transformation methods. Surface Roughness, Johnson Transformation, P6M5 Insert, C45 Steel Milling

INTRODUCTION

It is widely accepted that milling is the most efficient way of cutting [1]. There are several criteria that may be used to assess the machining process while using the milling technique, much as with other cutting and machining procedures. As a result, the workpiece's surface roughness is often used as an indicator of milling quality. Because surface roughness directly influences the product's workability and durability, it's clear to see why this is important. On the other hand, measuring surface roughness is a straightforward process that may be used in a variety of manufacturing and research settings. In milling, adjusting the cutting parameters is the easiest way to evaluate surface roughness since the operator of the machine may readily change the cutting parameters. The cheap cost and superior machinability of C45 steel make it a popular choice in the industrial sector. A wide range of items, including shafts, forks, and gears, may be made from it. Because of its cheap cost, thermal resistance, and high hardness, P6M5 (the Russian standard) is often used to create cutting tools in mechanical processing. Turning, milling, and drilling bits are all made using this sort of cutting tool in the cast iron and steel industries, respectively.

Milling C45 steel with a P6M5 cutting tool was used in this research to examine the effect of cutting parameters on surface roughness. Among the variables studied in this research include cutting speed, feed rate, and depth of cut, among others. Additionally, a surface roughness regression model has been presented. Additionally, the Johnson transformation approach has been used to enhance the accuracy of the regression model. A C45 steel milling test was conducted. The investigation made use of C45 steel samples. The steel sample has dimensions of 200 mm in length, 60 mm in width, and 20 mm in height. Machine 6H82 (Russian Federation) was utilised in this experiment. An electronic frequency changer, also known as a frequency converter, is attached to the machine's main shaft motor to allow it to be set to the required cutting speed. An alloy of grade P6M5 was employed in the experiment's cutting inserts. For mounting, they use two symmetrical cutting components installed on the face milling cutter's main frame. To mill the whole surface of the steel sample, a diameter of 80 millimetres is required for the tool body. Each cutting component is used just once to minimise the impact of tool wear on surface roughness.

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The Box-Benken approach was used to build an eighteen-item experimental matrix. Cutting speed, feed rate, and depth of cut will all be altered with each trial. Three levels of each cutting parameter were chosen. corresponding to the coding levels -1, 0, and 1. The values of these parameters were selected according to a published study [3] (Table 1). The experimental matrix is presented in

Table 1. Cutting parameters

Parameter	Unit	Code value	Symbol	Value at the level		
				-1	0	1
Cutting speed	m/min	x1	v	140	200	260
Feed rate9	mm/tooth	x2	f	0.1	0.2	0.3
Depth of cut	mm	x3	t	0.28	0.4	0.52

Table 2. Experimental matrix and results

Trial	Code value			Real value			Ra, μm
	x1	x2	x3	v, m/min	f, mm/tooth	t, mm	
1	0	0	0	200	0.2	0.4	1.056
2	-1	0	1	140	0.2	0.52	1.224
3	1	0	-1	260	0.2	0.28	0.804
4	0	0	0	200	0.2	0.4	1.032
5	1	1	0	260	0.3	0.4	1.464
6	-1	0	-1	140	0.2	0.28	0.984
7	0	1	-1	200	0.3	0.28	2.256
8	1	-1	0	260	0.1	0.4	0.864
9	-1	1	0	140	0.3	0.4	1.428
10	0	0	0	200	0.2	0.4	1.044
11	0	0	0	200	0.2	0.4	0.984
12	-1	-1	0	140	0.1	0.4	0.996
13	0	-1	1	200	0.1	0.52	0.864
14	1	0	1	260	0.2	0.52	0.744
15	0	-1	-1	200	0.1	0.28	0.828
16	0	0	0	200	0.2	0.4	0.984
17	0	0	0	200	0.2	0.4	1.116
18	0	1	1	200	0.3	0.52	2.424

Experimental results and discussion

Ordered according to Table 2, the tests were performed in that sequence. Three steel samples were used for each test. To determine the surface roughness, the steel samples were cleaned with alcohol and allowed to dry after testing. It was used to test the surface roughness of Japan's SJ-301 (Japan). At least three measurements were made on each piece of steel. The average of at least nine measurements is used to calculate the roughness value for each experiment. Table 2 includes the surface roughness measurement findings from each trial. The findings were analysed using Minitab statistical software. The graphs in Figure 1 and Figure 2 indicate the effects of cutting parameters and the interaction effect between cutting parameters on surface roughness. Figure 1 shows the feed rate, which has the biggest impact on the surface roughness of the finished product. Surface roughness rises fast as feed rate increases. Surface roughness is unaffected by cutting speed or depth of cut. Nonetheless, it has been proven that the cutting speed has a greater impact on the surface roughness than the depth of cut does.

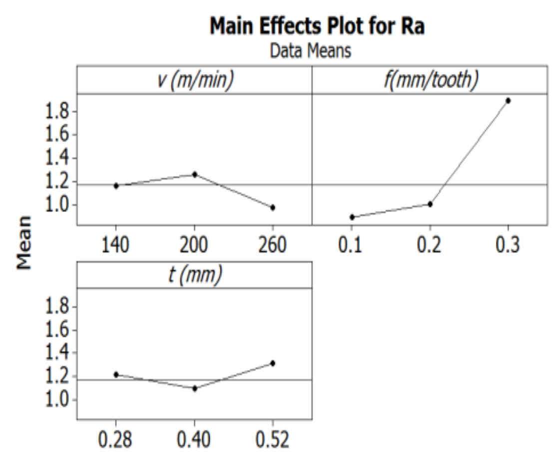

Figure 1. Effect of cutting parameters on surface roughness

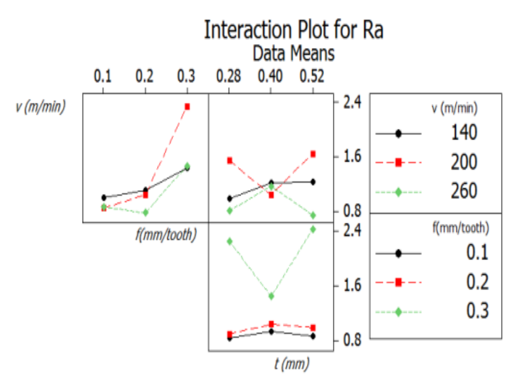

Figure 2. Interaction effects of cutting parameters on surface roughness

Surface roughness may be affected by a variety of factors, including cutting settings. Figure 2's chart reveals the following: Increasing the feed rate increases surface roughness for all three cutting speeds (140 m/min, 200 m/min, and 260 m/min). Consistent with Figure 1, this finding is also shown to be true. - If the cutting depth is increased from 0.28 mm to 0.40 mm when cutting at 140 m/min, the surface roughness will rise. A further increase of 0.52 mm in cutting depth has no effect on the surface roughness. surface roughness decreases fast when the cutting speed is 200 metres per minute and the cutting depth rises from 0.28 millimetre to 0.40 millimetre. A rise in cutting depth of more than 0.40 mm will cause the surface roughness to rise fast. — The surface roughness rises from 0.28 mm to 0.40 mm while cutting at 260 metres per minute, yet the surface roughness decreases as cutting depth rises. Both feed rates (0.1 mm/tooth and 0.2 mm/tooth) have essentially little effect on roughness as the cutting depth varies. Surface roughness decreases fast if cutting depth rises from 0.28 mm to 0.40 mm at a feed rate of 0.3 mm/tooth. When cutting depth is raised from 0.40 mm to 0.52 mm, the roughness of the surface rises dramatically. Software for data analysis The surface roughness regression model was built using Minitab once again. The regression model has been established as a consequence of the data.

$$R_a = 1.0360 - 0.0945x_1 + 0.5025x_2 + 0.0480x_3 - 0.0750\,x_1x_2 + 0.0330x_1x_3 - 0.2510x_1^2 + 0.4030x_2^2 + 0.1540x_3^2$$

The R-Square coefficient is 0.8552 in this equation, while the modified R-Square(adj) coefficient of determination is 0.6154. These coefficients have been studied extensively in various sources, and the closer these coefficients are to 1, the more accurate the regression model is [4] A change in cutting parameters is only represented by 61.54 percent of the change in surface roughness, as shown by an R-Square(adj) of 0.6154. The remaining variance in surface roughness is the result of unknown sources (confounding factors). Therefore, the following section of this work focuses on enhancing the accuracy of the surface roughness regression model.

Improve the accuracy of the surface roughness model

Using the Box-Cox and Johnson metric transformations [5, 6] and others is a well-known way to enhance the precision of the regression model. Neither of these modifications can be applied if the starting data set is not non-normal. A 0.05 threshold of significance was used to calculate the surface roughness data distribution rule shown in Figure 3. Figure 3 shows that the surface roughness data set is quite a distance away from the standard line on the graph (the middle line). The significance level is substantially less than P-value 0.005. Surface roughness datasets are not distributed according to normal distribution criteria. There is no need to do anything else.

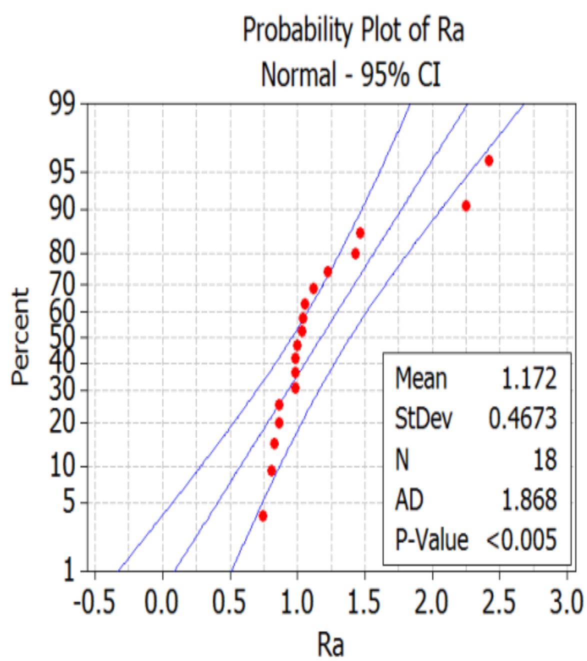

Figure 3. The surface roughness distribution rule

Use of Johnson transformation was used in this investigation. The data transformation graph is shown in Figure 4. Surface roughness distribution rule without conversion is seen in the upper-left image (above analyzed). The distribution of data after conversion is shown in the image to the right. A bell-shaped distribution of data may be seen. A typical distribution like that. The figure below indicates that the converted data are quite near to the standard line, and specifically the P-value = 0.594 is very big. Following the Johnson transformation, the data set shows that it has a normal distribution. Mathematical relationships between the data before and after modification are shown in Figure 4.

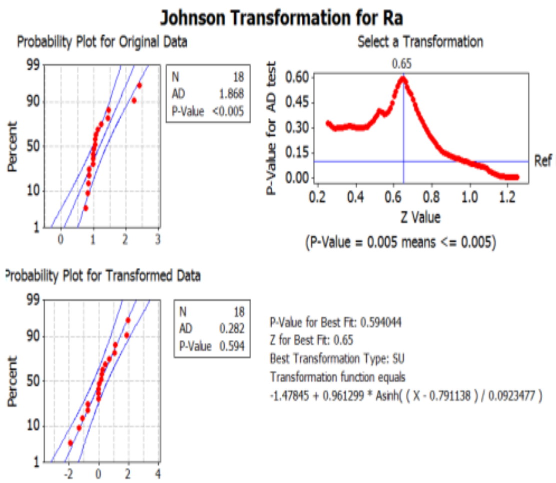

Figure 4. Jouhnson plot for power transformation

From there, we can determine the surface roughness model according to the converted data as in formula (2).

$$-1.47845+0.961229*Asinh\left(\frac{R_a-0.791138}{0.0923477}\right)=0.1446$$
$$-0.5818x_1+1.0770x_2+0.0698x_3-0.3355x_1x_2-0.0544x_1x_3 \quad (2)$$
$$-0.4731x_1^2+0.6704x_2^2-0.3377x_3^2$$

Or:

$$R_a=0.791138+0.0923477*Sinh(X) \quad (3)$$

With:

$$X=1.6885-0.6053x_1+1.1204x_2+0.0726x_3-0.3490x_1x_2$$
$$-0.0566x_1x_3-0.4922x_1^2+0.6974x_2^2-0.3513x_3^2$$

This model has an R-Square coefficient of determination and an adjusted R-Square(adj) coefficient of determination of 0.8591 and 0.6227, respectively.

Using formulas (1) and (3) to calculate the roughness, then compared with the roughness value when testing, the results are presented in Table 3

R-Square and R-Square(adj) coefficients of determination are 0.8591 and 0.6227, respectively for this model's R-Square coefficient. Table 3 shows the results of calculating the roughness and comparing it to the roughness value that was measured.

TT	x_1	x_2	x_3	Ra (measured)	Ra (calculated – without transformation	Ra (calculated – Johnson transformation
1	0	0	0	1.056	1.036	1.032
2	-1	0	1	1.224	1.049	1.004
3	1	0	-1	0.804	0.764	0.811
4	0	0	0	1.032	1.036	1.032
5	1	1	0	1.464	1.521	1.145
6	-1	0	-1	0.984	1.019	0.951
7	0	1	-1	2.256	2.048	1.796
8	1	-1	0	0.864	0.666	0.840
9	-1	1	0	1.428	1.860	3.216
10	0	0	0	1.044	1.036	1.032
11	0	0	0	0.984	1.036	1.032
12	-1	-1	0	0.996	0.705	0.903
13	0	-1	1	0.864	1.139	0.898
14	1	0	1	0.744	0.926	0.814
15	0	-1	-1	0.828	1.043	0.878
16	0	0	0	0.984	1.036	1.032
17	0	0	0	1.116	1.036	1.032
18	0	1	1	2.424	2.144	1.954

Table 3's data may be used to compute the mean difference between the predicted outcomes and the experimental findings. It is 14.51 percent in the roughness model without data transformation, and 12.93 percent in the Johnson transformation. For two surface roughness models, one that doesn't use data processing and the other that does, certain comparison features are presented in Table 4..

Comparison of some parameters of two roughness roughness models

Model	*R-Square*	*R-Square(adj)*	*F*
Without transformation	0.8552	0.6154	14.51%,
Johnson transformation	0.8591	0.6227	12.93%

Table 4 reveals that the R Square and R-Square(adj) parameters of the model employing Johnson transformation are greater than those of the model that does not use data transformation, as shown by the data. To make matters worse for models without Johnson data transformations, the F parameter in models with them is lower. This is enough evidence to show that the model utilising Johnson transformation has a better degree of accuracy than the one that does not.

CONCLUTION

In this investigation, certain results were reached after the experimental milling of C45 steel using the P6M5 tool. It is the feed rate that has the most impact on the roughness of the surface. Surface roughness rises fast as feed rate increases. Surface roughness is unaffected by cutting speed or depth of cut. Cutting parameters and surface roughness have a complicated relationship. Johnson transformation and data transformation have been used to build two regression models for surface roughness. Models with Johnson transformations are more accurate than models without data transformations, according to the findings of this study.

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