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Research Article

# Effect of Tool Diameter and Feeding Speed on Surface Roughness in the AISI 1045 Steel Milling Process

*Iswanto[a*], Prantasi H. Tjahjanti[a], Mulyadi[a] and Edi Widodo[a]*

[a]*Department of Mechanical Engineering, Universitas Muhammadiyah Sidoarjo, Jl. Mojopahit 666 B Sidoarjo 61215, Indonesia*

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E-mail: iswanto@umsida.ac.id

**A B S T R A C T**

This paper discusses the influence of the tool diameter and feeding speed on the surface roughness in the milling process of AISI 1045 steel. Accordingly, the cutting tool diameter varied, ranging from 6 to 10 mm. Meanwhile, the feeding speed was set at 33.5 mm/min, 59.4 mm/min and 111.9 mm/min. Furthermore, the milling process was performed, and the surface roughness of the products was measured. Eventually, it can be concluded that both tool diameter and feeding speed contribute significantly to the magnitude of surface roughness of AISI 1045 milled products.

## 1. INTRODUCTION

In the manufacturing industry, metal-cutting processes, also known as machining processes, are the most widely used in small workshops and large industries [1–3]. The metal cutting process can be defined as the process of transforming the shape of a workpiece material into a product by removing its unwanted parts by cutting, peeling, or separating [4–6].

One machining process often used in the manufacturing industry is the milling process [7,8]. The milling process removes part of the workpiece material to form a new shape by means of a rotating tool that travels as the machine table moves left or right to create new machined surfaces [9–11].

The product's surface finish is crucial in the milling process to ensure its quality [12,13]. This is because the machine components' surface will rub against the surface of other components during its operation [14,15], Besides, a better surface finish will also affect the cost of production [16,17].

Surface finish is normally determined from the magnitude of surface roughness [12,18,19]. The achievable surface roughness level resulting from the milling process is influenced by many factors, including the spindle speed, depth of cut, and other input variables [20–22]. Korkut et al. investigated the influence of feed rate and cutting speed on the cutting forces, surface roughness, and tool–chip contact length during face milling [23]. It was found that special attention had to be paid before deciding

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the proper selection of machining parameters. Furthermore, Bhardwaj et al. studied the effect of cutting parameters on surface roughness in end milling of AISI 1019 steel [21]. They conclude that the surface roughness value would significantly depend on cutting variables and the appropriate design of cutting tool geometry. Meanwhile, by coupling the Response Surface Methodology (RSM) and Annual Neural Network (ANN) algorithm, Soleymani et al. obtained the surface roughness model for milling operation that is attributable to the contribution of speed and feed rates [24].

From the previous research, the magnitude of surface roughness seems to be observed based on the main cutting parameters. Whereas, the effect of cutting tool geometry tends to be ruled out. Meanwhile, the rotational speed is normally affected by one its macro geometry such as cutting tool diameter. Therefore, the current research is going to observe the effect of the tool diameter as well as feed rates on attainable the surface roughness value of the AISI 1045 product that is undergoing milling process.

## 2. MATERIALS AND METHODS

The initial step undertaken in this research is to prepare tools and materials for research. The tools and materials used in this research are;

- A mount and knee type of vertical milling machine.
- The end mill cutting tools that have variations in diameter of 6 mm, 8mm and 10 mm.
- The AISI 1045 steel was a workpiece material that has dimension of 25 mm x 50 mm.
- A Mitutoyo Surftes-301 is utilized to determine the surface roughness magnitude

After preparing the tools and materials needed in the study, the milling processes were conducted with spindle rotation of 310 RPM and 0.4 mm of depth of cut for each combination of feed rates and cutting tool diameter. All the milling operations were performed without the presence of cutting fluids. The milling process of making the specimen can be seen as shown in Fig. 1.

After the specimens had been machined per experimental plans, each specimen's surface roughness was measured as shown in Fig. 2.

Figure 1. The milling process of making a specimen.

Further, all the observed data were analyzed by using two-way ANOVA with the help of computer software.

Figure 2. The surface roughness measuring of a specimen

## 3. RESULTS AND DISCUSSION

The surface roughness data obtained in this study is presented in Table 1.

Tabel 1. Surface roughness value as varying tool diameter and feed rates

| Tool Diameter (mm) | Deep of cut (mm) | Spindle Speed (rpm) | Feed Rates (mm/min) | Surface Roughness (μm) |
|---|---|---|---|---|
| 6 | 0.4 | 310 | 111.9 | 4.41 |
| | | | 59.4 | 3.42 |
| | | | 33.5 | 2.76 |
| 8 | | | 111.9 | 7.07 |
| | | | 59.4 | 4.29 |
| | | | 33.5 | 4.25 |
| 10 | | | 111.9 | 6.10 |
| | | | 59.4 | 3.39 |
| | | | 33.5 | 3.02 |

### 3.1. *Effect of Tool Diameter on the Surface Roughness of the AISI 1045 Workpiece.*

From the data depicted in Table 1, the relationship between the different tool diameters and the surface roughness is developed based on the graph provided in Figure. 3. From Figure 3, it can be seen that the

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diameter of the tool affects the surface roughness of milled products. The highest surface roughness is obtained at the milling process with a cutting tool with a diameter of 8 mm. the lowest surface roughness is determined at a tool diameter of 6 mm.

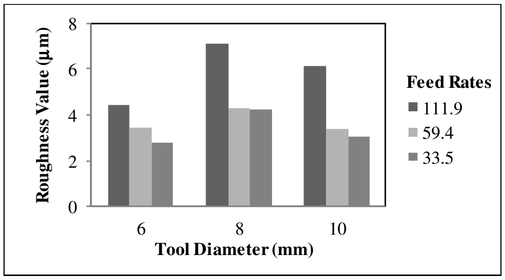


Figure 3. Influence of tool diameter on the surface roughness value

Thus, the selection of small tool diameters would reduce the magnitude of surface roughness of the milled products. This is due to the use of small tool tends to keep a stable rotation of the tool.

### *3.2. Effect of Feed Rates on the Surface Roughness of the AISI 1045 Workpiece.*

The data revealed from Table 1 were processed and plotted into the graph as shown in Figure 4 to establish the correlation between feed rates on the achievable surface roughness. Figure 4 shows that the worst surface finish would be caused by the selection of feed rates at 59.4 mm/min. In contrast, the lowest feed rates would guarantee a better surface finish.

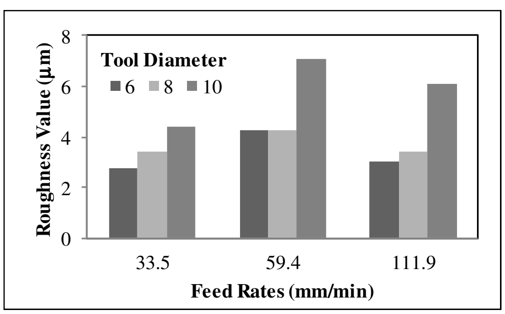


Figure 4. Graph of Relationship Between Feeding Speed and Surface Roughness.

This is attributable to low cutting forces applied when low feed rates are selected, resulting in a low surface roughness of the workpiece.

### *3.3. Multiple Linear Regression Analysis*

Multiple linear regression analysis functions is useful to determine the effect of two independent variables (e.g. feed rates and tool diameter) against the dependent variable (surface roughness). Then, it is determined that there are two independent variables, namely tool diameter ($X_1$) and feed rates ($X_2$), and one dependent variable, which is surface roughness (Y). After the data from Table 1 were analyzed using a computer software, the result is given in Tables 2, Table 3 and Table 4.

Table 2. Linear regression output (Summary)

Model Summary[b]

| Model | R | $R^2$ | Adj.$R^2$ | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | 0.792[a] | 0.627 | 0.503 | 1.00122 | 2.287 |

a. Predictors (Constant): tool diameter, feed rates
b. Dependent Variable: surface roughness

Table 3. Linear regression output (ANOVA)

ANOVA[a]

| Model | | Sum of square | df | Mean square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 10.122 | 2 | 5.061 | 5.049 | .052[b] |
| | Residual | 6.015 | 6 | 1.002 | | |
| | Total | 16.137 | 8 | | | |

a. Dependent Variable: surface roughness
b. Predictors (Constant): tool diameter, feeding speed

Table 4. Linear regression output (Coefficients)

Coefficients[a]

| Model | | Unstandardized Coefficients B | Unstandardized Coefficients Std. Err | Standardized Coefficients Beta | t | Sig. |
|---|---|---|---|---|---|---|
| 1 | (Constant) | 1.171 | 1.809 | | 0.647 | 0.541 |
| | X1 | 0.032 | 0.010 | 0.779 | 73.8 | 0.020 |
| | X2 | 0.118 | 0.204 | 0.144 | 0.579 | 0.584 |

Based on multi-linear regression, the model of this study would be fitted with equation expressed in Equation 1.

$$Y = a + b_1X_1 + b_2X_2 \quad \text{Eq. 1}$$
$$= 1.171 + 0.032X_1 + 0.118X_2$$

Regression Equation 1 can be explained as follows:

- The biggest constant is 1.171. It implies that that if the value is equal to 0 then the roughness value is 1.171, and if the regression value is equal below 0 then the regression value of the variable decreases.
- The regression coefficient for variable X1 is 0.032. It means that the value of roughness has increased.
- The regression coefficient for variable X2 is 0.118, It means that the value of roughness has increased.

Eventually, From Table 3, it is noted that the $F_c$-value of Fisher test is 5.049. Moreover, $F_t$-value needs to be determined before the decision can be made. By using a formula, the value of $F_t$ is is 4.74.

Because the $F_c$ is greater than the $F_t$ (5.049 > 4.74), it can be concluded that the independent variable feeding speed ($X_1$) and tool diameter ($X_2$) simultaneously have a significant effect on the dependent variable surface roughness (Y).

## 4. CONCLUSION

From the results of the study it can be concluded that tool diameter and feed rates alltogether have a significant effect on the surface roughness value of AISI 1045 product that underwent milling process.

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