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OPTIMIZATION OF SURFACE ROUGHNESS IN TURNING S45C CARBON STEEL MATERIAL USING THE TAGUCHI METHOD

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ABSTRACT

The value of minimal surface roughness is the performance to be achieved in the Takisawa TSL-800 lathe. Therefore, it is necessary to adjust the variables of the Takisawa TSL-800 lathe process precisely in order to obtain a minimal surface roughness response. Determining the proper settings of the Takisawa TSL-800 lathe process variables will result in the expected surface roughness of the workpiece. The variables of the machining process that are varied are spindle speed, feed rate and depth of cut. The experimental design was determined based on the Taguchi method and was in the form of an Orthogonal L9 matrix (3^3).

Keywords: *Takisawa TSL-800; surface roughness; variable.*

1. INTRODUCTION

Along with the development of science and technology, a production result must be balanced with an increase in the quality of production, especially in the production process using machine tools such as lathes [1]. The turning process in the manufacturing industry is one of the processes used in metal cutting. Approximately 80% of all existing activities in metal cutting process operations use the lathe [2]. Cutting operations that can be performed using the lathe process include *straight turning, taper turning, profiling, turning and ecternal grooving, cutting with a form tool, face grooving, boring and internal grooving, drilling, cutting off, threading* dan *knurling* [3]. In a good workpiece cutting process, it is necessary to choose the right variable settings and also the lathe tool is one of the factors in the lathe cutting process.

By considering the aforementioned matters, the material used in the implementation of the research is S45C carbon steel material. The choice of material also has an effect on the turning result, especially in relation to the quality of surface roughness. S45C is a type of medium carbon steel. This material has good mechanical properties so it is widely used in the manufacture of machines, motor shafts, jigs, automotive parts.

The process of finishing work, in addition to the dimensions of the finished product, *surface roughness* is one of the *critical quality characteristics (CTQ)* which is important to show the quality of workmanship. In particular, surface roughness plays an important role in product quality and is an important parameter for evaluating the accuracy of the machining process [4].

Cutting speed, *depth of cut*, and *feed rate* have an influence on tool wear and workpiece surface roughness [5]. The results of the previous CNC NLX 2500 study [6] to reduce the variation of simultaneous responses, the *feed rate* has the largest percentage contribution of 99.48%, *spindle speed* has the largest percentage contribution of 0.0974%, *depth of cut* has the percentage contribution of -0.126%. Minimum *spindle speed* of workpiece surface roughness of 2748 rpm, *feed rate* of 0.15 mm / put, *depth of cut* of 0.5 mm.

However, the conventional Takisawa TSL-800 type lathe and the S45C carbon steel material are not yet known. Research on metal cutting processes is usually focused on the material's wearability which includes tool life, cutting forces, surface roughness, rage removal rate, and rivet shape. In addition, the research is also focused on determining the combination of machining parameters that affect the process efficiency and quality characteristics of the resulting product [7].

The most widely used surface roughness is the arithmetic mean roughness. Rochim [8] defines this arithmetic mean roughness as the arithmetic average price for the absolute price of the distance between the measured profile and the middle profile. The Taguchi method introduces an experimental design approach that can design a product and process that is robust against environmental conditions, developing a robust product quality for variations around the target. This Taguchi method has several advantages when compared to other experimental design methods [9].

Therefore, in this study, surface roughness optimization will be carried out in the process of turning S45C carbon steel material using the Taguchi method with the aim of obtaining a minimal surface roughness response from the performance process of the Takisawa TSL-800 lathe by setting the appropriate variables.

2. METHODS

2.1. Research Factors and Levels

The variables in this study are the factors and levels as shown in Table 1.

Table 1. Research Factors and Levels

Parameter	Factor	Lavel 1	Level 2	Level 3
Spindle speed	A	1800	1030	560
Feed rate	B	0.1	0.21	0.31
Depth of cut	C	0.1	0.2	0.3

2.2. Material

The material used in this study is S45C carbon steel with a dimensions of Ø 20 ± 0.2 mm and a length of 50 ± 0.2 mm. As for the dimensions and shape of the workpiece, it can be seen in Figure 1 and Figure 2.

Figure 1. Workpiece Dimensions

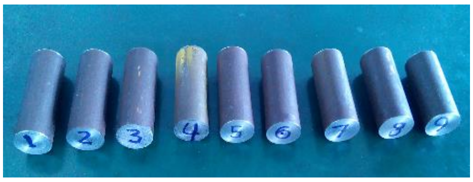

Figure 2. Workpiece Shape

2.3. Equipment Used

With the following lathe specifications:

- Brand : Takisawa
- Type : TSL-800
- Size : = L x W x H
  = 1872 x 725 x 1101 mm
- Weight : 1100 kg

For more details, it can be seen in Figure 3.

Figure 3. Takisawa Lathe [10]

With the following *holder* specifications:

- Brand : Sumitomo
- Type : ETGNR 2020K1604

For more details, it can be seen in Figure 4.

Figure 4. Sumitomo *Holder* [11]

With the following *insert* specifications:

- Brand : Sumitomo
- Type : TNGG160404R-UM

For more details, it can be see Figure 5.

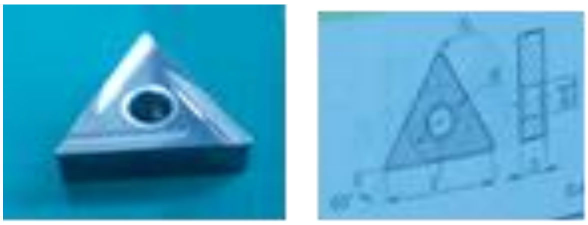

Figure 5. Sumitomo Insert [12]

2.4. Surface Roughness Testing

For surface roughness testing using the Surfcom 1400D tool.

Specifications of the tool:

- *Brand* : Surfcom 1400D
- *Type* : Tokyo Seimitsu Co. Ltd
- *Precision* : 0.41 µm – 16.1 µm

For more details, it can be seen in Figure 6.

Figure 6. Surfcom 1400D [13]

2.5. Testing Procedure

The experimental procedures carried out in this study are shown in Figure 7.

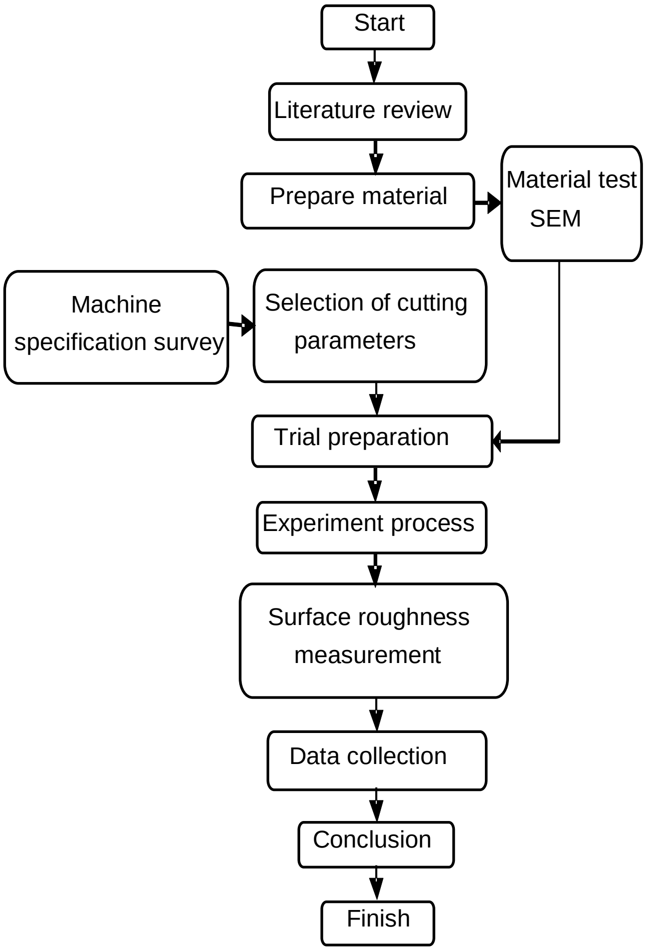

Figure 7. Experiment flowchart

3. RESULTS AND DISCUSSION

The following are the results of the machining experiment can be seen in Figure 8.

Figure 8. Workpiece after processing

For experimental data in the form of surface roughness values can be shown in Table 2.

Table 2. Experimental data

Setting Combination to	*Spindle speed* (rpm)	*Feed rate* (mm/put)	*Depth of cut* (mm)	Surface roughness (μm)
1	1800	0.1	0.1	1.18
2	1800	0.21	0.2	3.90
3	1800	0.31	0.3	8.71
4	1030	0.1	0.2	2.27
5	1030	0.21	0.3	3.98
6	1030	0.31	0.1	8.16
7	560	0.1	0.3	2.56
8	560	0.21	0.1	4.35
9	560	0.31	0.2	8.77
Average				4.87

The surface roughness value above was obtained based on the combination of factors and level settings for 9 times the experiment the results were measured using the 1400D surfcom.

The following is the result of the level effect response to surface roughness which can be shown in Table 3.

Table 3. The level effect response to the mean surface roughness

Factor	Level 1	2	3	Difference (max-min)	*Rank*
Spindle speed (A)	4.59	4.80	5.22	0.63	2
Feed rate (B)	2.00	4.07	8.54	6.54	1
Depth of cut (C)	4.56	4.98	5.08	0.52	3

Based on the data above, the effect of the level response to the average surface roughness can be seen, which is 6.54 µm (rank 1).

For more details, it can be seen through the picture from the graph of the experimental results using the Taguchi method in Figures 9, 10 and 11.

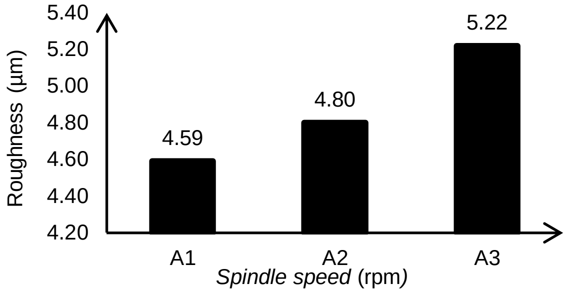

Figure 9. Response to surface roughness level spindle speed

A1: 1800 rpm A2: 1030 rpm A3: 560 rpm

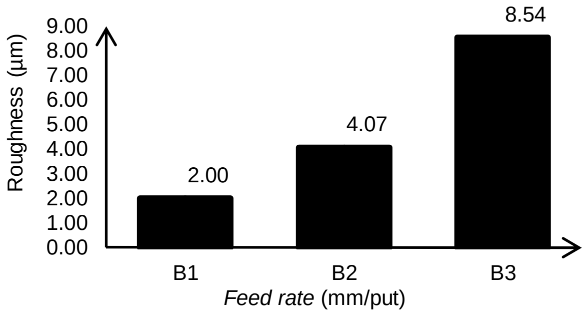

Figure 10. Response to surface roughness level feed rate

B1 : 0.1 mm/put B2 : 0.2 mm/put B3 : 031 mm/put

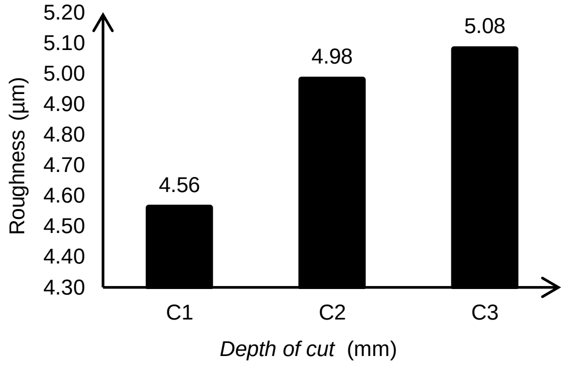

Figure 11. Response to surface roughness level depth of cut

C1: 0.1 mm C2: 0.2 mm C 3: 0.3 mm

By looking at the data in Table 2, the experimental results obtained a surface roughness graph with the smoothest condition of 1.18 µm at *a spindle speed* of 1800 rpm, *a feed rate* of 0.1 mm / put and *a depth of cut* of 0.1 mm shown in Figure 12.

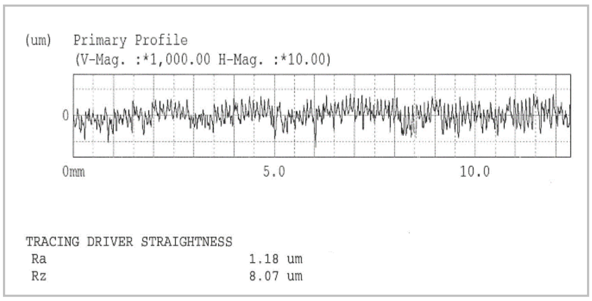

Figure 12. Smoothest condition surface roughness graph

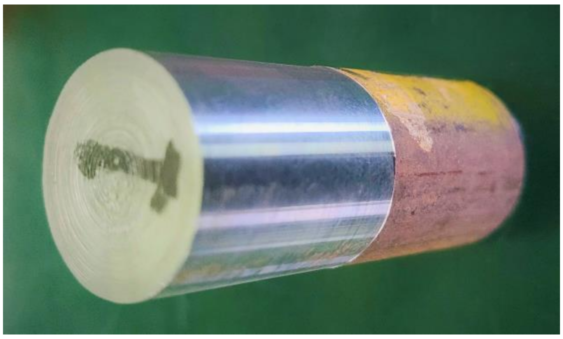

Figure 13. Workpiece after processing the smoothest surface roughness conditions.

Whereas for the surface roughness graph with the roughest conditions of 8.77 µm at *a spindle speed* of 560 rpm, *a feed rate* of 0.31 mm / put and *a depth of cut* of 0.2 mm is shown in Figure 14.

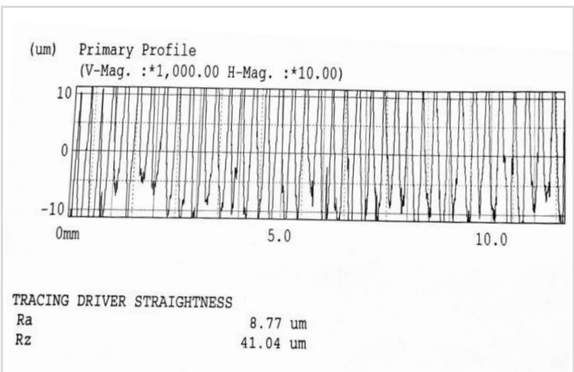

Figure 14. Roughest surface roughness graph.

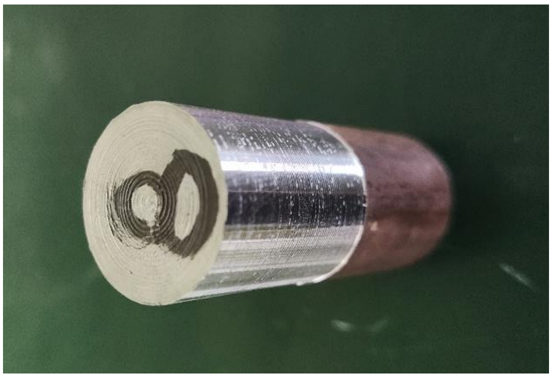

Figure 15. Workpiece after processing under roughest surface roughness conditions.

4. CONCLUSION

From the experimental results of the process of turning the S45C carbon steel material, the factor and level variables using the Taguchi method can be concluded as follows: That the machining conditions for the Takisawa TSL-800 lathe produces the smoothest surface roughness of 1.18 µm at *a spindle speed* of 1800 rpm, *a feed rate* of 0.1 mm / put and *a depth of cut* of 0.1 mm. Meanwhile, the roughest surface roughness is 8.77 µm at a *spindle speed* of 560 rpm, *a feed rate* of 0.31 mm / put and *a depth of cut of* 0.2 mm. In response to the effect of level on the average surface roughness, the *feed rate* was ranked 1st, namely 6.54 µm. This research needs to be continued with variations in setting the appropriate factors and levels so that later surface roughness tables can be made that can support the industrial world.

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