INTERNATIONAL JOURNAL of DYNAMICS in ENGINEERING and SCIENCES (IJDES)
LLDIKTI WILAYAH X
Vol. 6, No. 2, Oct 2021
e-ISSN: 2502-0692

Effect of Coolant Variation and Process Parameters on Surface Roughness of ASTM A36 Steel in Milling Process with Taguchi Method and ANOVA

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doi. 10.22216/jod.v6i2.854
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Article Information

Submitted :
15 May 2021

Accepted :
18 Agust 2021

Published :
25 Oct 2021

Abstract

The machining process is a process carried out to change the shape of a workpiece by removing some of the material from the workpiece so that it becomes the desired product by using machine tools. One example of a machining process using machine tools is a machining process that uses a milling machine. This study aims to determine the optimization of parameters in the milling process. Data were collected using the Taguchi and ANOVA methods for ASTM A36 steel products and to determine the effect of the coolant on the roughness quality of ASTM A36 steel. After calculating and taguchi graphs, the optimal factors and levels are obtained. Where the factors and levels are spindle speed 1100 rpm, depth of cut 0.5 mm, feeding speed 24 mm/minute and oil coolant. Furthermore, from the calculation of ANOVA (Analysis of Variance) which gets the calculated F value. The calculated F will be compared with the F table value with a 95% confidence level. In this calculation, it is explained that the spindle rotation speed factor results in the calculated F of 8.159. This shows that f arithmetic is greater than f table (5.1433) which means the effect is significant. Meanwhile, the depth of cut factor, feeding speed and coolant have no significant effect.

Keywords: Milling, ASTM A36 steel, dromus, process parameters, Taguchi method and ANOVA.

1. Introduction

One example of a machining process using machine tools is a machining process that uses a milling machine, namely krisbow milling (Universal Milling Machine X6328b + 3adro).

The machining process using a Krisbow Milling Machine (Universal Milling Machine X6328b + 3adro) is a machining process used in the manufacture of a product, which produces a smooth or rough surface roughness value.

The surface roughness value is one of the factors that determine the quality of the resulting product, where the smaller the surface roughness value of a product, the better the quality, on the contrary, the greater the surface roughness value of a product, the worse the quality.

Surface roughness affects the durability of components, because components that are not smooth are more prone to structural changes. Surface roughness measurement is carried out with a sensor that is moved above the surface of the component to be measured. The effect of feeding depth has a significant effect on surface roughness.

Several factors that cause differences in surface roughness values are spindle rotational speed, depth of cut, cooling, workpiece material and machine condition.

However, friction between the workpiece and the tool can cause the temperature in the active plane of the tool to be very high, resulting in decreased product quality. Providing cooling on the cutting surface can maintain the quality of the product cut plane.

This research was conducted to analyze and evaluate the effect of variations in spindle rotation speed, feed depth, cutting speed and cooling medium variations on the surface roughness of the workpiece, with soybean oil and oil as the coolant..

2. Literature

In this section, the theory related to this research topic will be described.

A. Milling Machine

Manuscript Universal milling machine is a type of milling machine that can not only do one type of work, but can do two working positions in one milling machine. This universal milling machine is usually larger in size when compared to vertical and horizontal milling machines. By not being limited to only one side of the work, this universal milling machine is more efficient than the two. The universal milling machine can be adapted to a variety of milling or feeding operations. The table can be rotated up to 45 degrees on both sides from its normal position. All operations performed on the shaper can be carried out using a universal milling machine. Universal milling machine can be seen in Figure 1.

Figure 1. Universal Milling Machine X6328b + 3adro

B. Carbon Steel ASTM A36

Low Carbon Steel ASTM A36 (ST37) has a carbon content of less than 0.3%. This steel is often used also for machine constructions that rub against each other such as gears, shafts, etc. because it is very ductile. However, the surface hardness of the steel is low so that before being used for the construction mentioned above, it is necessary to modify or improve the hardness properties of the surface. This low carbon steel cannot be hardened conventionally but through the addition of carbon by the carburizing process. The type of carbon steel St 37 for the purpose of making machine components which are standardized according to tensile strength has a tensile strength of 37-45 Kg/mm^2. Steel ASTM A36 can be seen in Figure 2.

Figure 2. Steel ASTM A36

C. Coolant

Coolant is a cooling medium used to cool the workpiece and cutting tools during the machining process. It is also used to lubricate cutting tools so that they have a longer service life.

The Function of Coolant in the machining process is to reduce the tool temperature at the time of cutting, reduce the cutting force, prolong tool life, lubricate the guide elements (ways), improve the quality of the workpiece surface, remove smudges from the surface of the chip during the cutting process, protect the surface of the newly formed workpiece from corrosion, and protect the workpiece surface from being damaged.

Several variations of coolant that can be used in the machining process are as described below.

1. *Coolant Bromus*, is a coolant that functions as a cleaner or carrier of anger, lubricates the guiding elements (ways) of machine tools and protects the workpiece from corrosion. The density of Dromus Oil is 1100 Kg/m^3 and the viscosity is 400 mm2/sec.

2. *Federal Oil*, is a lubricant specially formulated for motorcycle engines and sport 4T manual transmission with heavy workloads. With specifications SAE 20W - 50 JASO MA,

with Wear protection technology on Federal Oil Ultratec is able to provide maximum protection against wear and tear so that the engine is more durable.

3. *Soybean Oil*, namely oil obtained from processing soybean seeds after going through several stages. The oil content and fatty acid composition in soybeans are influenced by the variety and climatic conditions where it is grown. Basic fat consists of triglycerides by 90-95%, while the rest is phosphatides, free fatty acids, sterols and tocopherols. Soybean oil has a saturated fatty acid content of about 15%.

D. Surface Roughness

Surface roughness is the arithmetic mean deviation from the surface mean line. Usually the surface roughness values vary, according to the needs of the tool. The surface roughness value has a different quality value (N), the surface roughness quality value has been classified by ISO where the smallest is N1 which has a surface roughness value and the highest is N11 which has a roughness value.

Surface roughness has a universal configuration symbol and makes it easy to read which explains the surface roughness symbols can be seen in Figure 3.

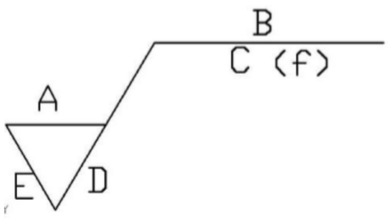

Figure 3. Surface Roughness Configuration

E. Teguchi Method

The Taguchi method is an off-line quality control, meaning preventive quality control, as a product or process design before it reaches production at the production level (shop floor). Off-line quality control is carried out at the beginning of the product life cycle, namely improvements at the beginning to produce the product. The advantages or advantages of the

Taguchi method are:

1. Taguchi's experimental design is more efficient, because it allows to carry out research involving many factors and quantities.
2. Taguchi's experimental design allows to obtain a process that produces a product that is consistent and robust against uncontrollable factors.
3. The Taguchi method produces conclusions about the response factors and the level of control factors that produce the optimum value.

3. Method

This research is an experimental study, starting with the preparation of tools and materials, preparation of the L9 orthogonal array (3^4), milling process, roughness measurement, calculation with Teguchi, ANOVA analysis, and results.

4. Result and Discussion

The surface roughness data collection table adapted to the Taquchi method with L9 3^4 can be seen in Table 1.

Tabel 1. Variation of Data Collection

Y	Factor			
	Spindle speed (rpm)	Depth of cut (mm)	Feed rate (mm/min)	Coolant
1	550	0.5	24	Dromus
2	550	0.75	42	Oli
3	550	1	74	M. kedelai
4	930	0.5	42	M. kedelai
5	930	0.75	74	Dromus
6	930	1	24	Oli
7	1100	0.5	74	Oli
8	1100	0.75	24	m. kedelai
9	1100	1	42	Dromus

A. Measurement Result

Milling machining process that uses ASTM A36 steel workpieces and is adjusted to the provisions of the process parameters which will produce some data. The results of the experimental surface roughness values with variations in cooling media, spindle rotation speed, depth of cut and feeding speed can be seen in Table 2.

Tabel 2. Data 1

Surface roughness			
Ra1 (μm)	Ra2 (μm)	Ra3 (μm)	$\bar{X}$
2.272	2.792	2.348	2.470
2.392	2.295	2.498	2.395
2.294	2.399	2.404	2.365
1.838	1.832	2.066	1.912
2.096	2.403	2.378	2.292
2.022	1.976	2.038	2.012
1.589	1.788	1.544	1.640
1.642	1.497	1.937	1.692
1.429	1.987	1.847	1.754

After the first experiment which consisted of 9 different forms of variation, to strengthen the data obtained, the experiment was repeated once again. The results of the experimental surface roughness values with variations in cooling media, spindle rotation speed, depth of cut and feeding speed can be seen in Table 3.

Tabel 3. Data 2

Surface roughness			
Ra1 (µm)	Ra2 (µm)	Ra3 (µm)	$\bar{X}$
2.288	2.348	2.440	2.358
2.428	2.198	2.359	2.328
2.142	2.216	2.323	2.227
1883	1.199	2.155	2.079
2.519	2.661	2.700	2.626
1.909	2.128	2.305	2.114
0.891	0.961	1.162	1.004
1.361	1.410	1.480	1.417
1.961	1.129	2.354	1.148

The table responses obtained from the Taguchi method can be seen in Table 4.

Tabel 4. Respon

Factor	Level 1	Level 2	Level 3	Level (Lt-Lr)	Rank
A	2.357	2.172	1.609	0,748	1
B	1.910	2.125	2.103	0.214	3
C	2.010	2.105	2.026	0.092	4
D	2.275	1.915	1.948	0.359	2

B. Graphic

The keywords should be avoiding general and plural terms and multiple concepts. Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes.

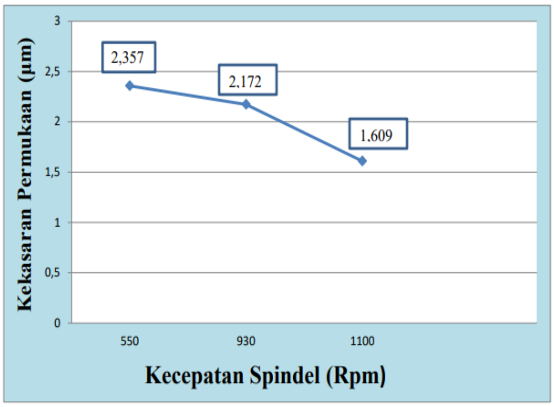

Figure 4. Spindle rotation speed vs surface roughness

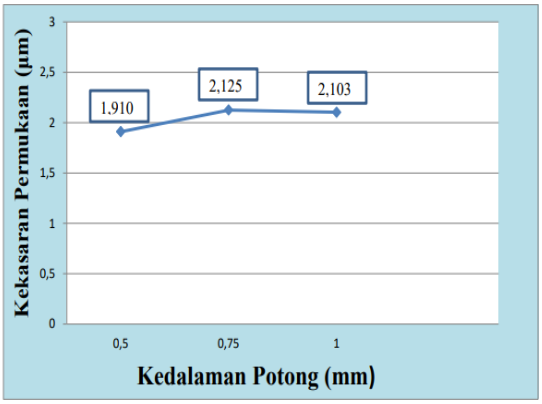

Figure 5. Depth of cut vs surface roughness

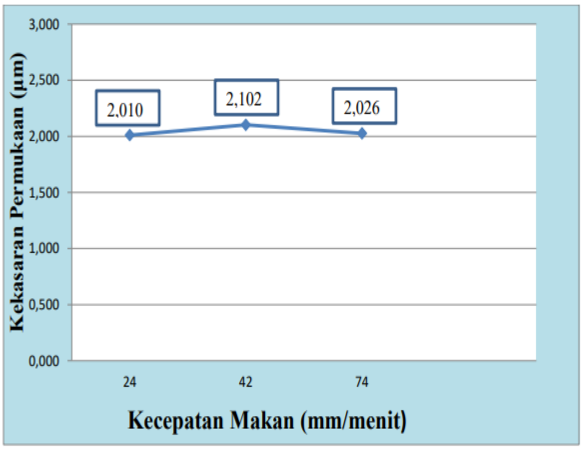

Figure 6. Feed speed vs surface roughness

C. Discussion

After the ASTM A36 steel milling process was carried out with various parameters and cooling media, the surface roughness values were measured. This measurement is carried out in stages to get optimal results. After the experiment was carried out 9 times and each was repeated 2 times, 2 data were obtained for the surface roughness value by taking the average value.

From the results of the total surface roughness, it is known that the lowest value is 1.322 m. The lowest value was obtained with oil cooling media, spindle rotation speed of 1100 rpm, depth of cut 0.5 mm and feeding speed of 74 mm/minute. Then the highest value is 2.459 m. The highest value results were obtained from the dromus cooling medium, the spindle speed was 930 rpm, the depth of cut was 0.75 mm and the feeding speed was 74 mm/minute. Then in the Taguchi calculation, a response table is obtained which explains the highest rank, namely the spindle speed factor, the second rank is the cooling media factor, the third rank is the depth of cut factor and the last is the feeding speed factor.

After that, it was observed from the Taguchi calculation graph that a comparison of the spindle speed graph with the lowest surface roughness was 1100 rpm and the result was 1,609 m. Continue to the graph of the depth of cut with the lowest surface roughness of 0.5 mm, the result is 1.910 m. Furthermore, the graph of the feeding speed with the lowest surface roughness is 24 mm/minute which results in a value of 2.010 m. Then seen from the graph of the cooling medium with the lowest surface roughness of 1.915 m when using oil coolant.

Furthermore, from the calculation of ANOVA (Analysis of Variance) which gets the calculated F value. The calculated F will be compared with the F table value with a 95% confidence level. In this calculation, it is explained where the spindle rotation speed factor is obtained by the calculated F result of 8.159. This shows that f arithmetic is greater than f table (5.1433) which means the effect is significant. Meanwhile, the depth of cut factor, feeding speed and coolant have no significant effect.

5. Conclusion

Based on this research, were obtained the conclusions following:

1. The optimal factor and level is the Taguchi Method. The optimal factors are spindle speed 1100 rpm, depth of cut 0.5 mm, feeding speed 24 mm/minute and oil coolant which most influence the surface roughness value of ASTM A36 steel milling process. The average roughness value obtained from the optimal factor and level is 1.059 m.
2. For the spindle speed factor, the calculated f value is greater than f table, so that the variation in spindle speed has a significant effect with a 95% confidence level. Because the calculated f value is smaller than f table, the variations in depth of cut, variations in feeding speed and variations in coolant have no significant effect with a 95% confidence level.

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