ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers

Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2022. Vol.66 No.2

July 30, 2022

Surface Roughness Analysis and Optimization of CNC Lathe Machining Parameters - Manufacturing of Motorcycle Brake Master Cylinder Piston

Novaldi Andryoga [a,*], and Anita Susilawati [a]

[a)] *Mechanical Engineering Department, Faculty of Engineering, Universitas Riau, Indonesia*

*Corresponding author: yoga17111998@gmail.com

Paper History

Received: 26-May-2022
Received in revised form: 26-June-2022
Accepted: 30-July-2022

ABSTRACT

This study aims to optimize the machining parameters in the manufacture of motorcycle brake piston master cylinder and determine the effect on surface roughness. The Taguchi method was used in this study. Machining parameters were varied based on the Taguchi method, each of which was experimented with using a finishing CNC lathe machine. From these experiments, the results was obtained in the form of surface roughness values, which were then analyzed, in order to obtain the best parameters with the smallest surface roughness values and the effect of each factor on surface roughness. This research produced the best parameters were the spindle speed of 1.755 RPM, feed rate of 0.09 mm/rev, and depth of cut of 0.30 mm. This parameter had a small surface roughness value. Based on surface roughness measurements, the factors that have the greatest influence on the level of surface roughness were 67.9%, spindle speed of 15.4% and depth of cut of 3.3%. This proves that the smaller the value of feed rate, spindle speed and depth of cut, the smaller the value of surface roughness.

KEYWORDS: *Piston master cylinder*, *Taguchi method*, *Surface roughness*.

1.0 INTRODUCTION

At this time, motorized vehicle users in Indonesia have increased every year. Based on data from the Indonesian Central Statistics Agency (BPS), there was an increase of 5.7% from 2018 to 2019, especially motorcycles [1]. From this increasing demand, it can be said that the more motorcycle users, the higher the demand for spare parts availability in the market. One of them is a motorcycle brake master cylinder piston. This component is the part that functions to maintain the kinetic energy of the brake lever into pressure in the brake fluid for braking [2]. One of machining process to make finishing product casting especially brake master cylinder piston can be used the CNC (Computer Numerical Control) machine.

The CNC is a development from conventional machining to machining with computer-based control media with a numeric language, so that the work piece process can be done quickly and accurately. The CNC machines have 2 types of programming systems in determining the coordinates, namely absolute programming systems and incremental programming systems. The absolute programming system is programming with the zero point not moving or being fixed, while the incremental programming system is programming with the zero point moving or not [3,4].

The CNC is a number-based system in the form of a program and can be controlled according to the user's wishes, where the program that has been created will be transferred to a machine to produce tool movement in a product making. The program is set on the CNC, which is then ordered by the NC. The NC (Numerical Control) is a method used to control or regulate tools and processes on the desired machine by using commands in the form of codes. The CNC lathe machines have advantages in precision, turnaround time, and production capacity [5,6]. According to [7], the workings of the CNC lathe machine are almost the same as conventional lathes, where the work piece is rotated and the tool feeds the layer of material along the work piece. In the CNC lathe machining process there are machining parameters that affect the final result of a product to be made and the processing time. In the finishing process, a smooth and good surface roughness can be produced with a low feed rate value and a small depth of cut. The parameters that affect the CNC lathe machining can be seen in Figure 1 [8].

According to [9,10], the Taguchi method is an engineering method that aims to improve a product quality and focuses on setting parameters (factors) that produce the best product quality with minimal treatment. The Taguchi method is considered to be the easiest method to do both in terms of cost and technical implementation because it is quite effective in determining the factors that influence a certain process.

ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers
Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2022. Vol.66 No.2

July 30, 2022

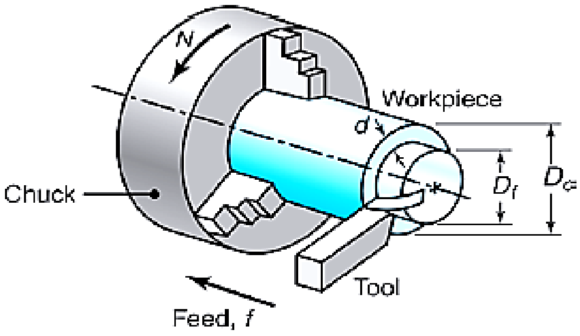

Figure 1: CNC lathe parameter schematic [8]

According to [11], in the Taguchi method there is a matrix called Orthogonal Arrays. The matrix is used to determine the minimum number of experiments that can provide as much data as possible about the parameters that affect the machining process, where these parameters have been calculated previously. According to [12], the parameters commonly used in the machining process consist of spindle speed, feed rate and depth of cut.

According to [13], there are several ways to express surface roughness. One of the most frequently used methods is the deviation of the arithmetic mean from the average profile line (Ra), where this method always follows the development of the measuring instrument. The arithmetic mean deviation (Ra) is a contiguous and irregular deviation in the effective profile of the mean line. The effective profile is the contour of the effective surface cut by a conventionally determined plane against an ideal geometric surface. For the value and class of surface roughness can be seen in Table 2.

Table 1. Simple parameter design in machining process [12]

No	Spindle speed	Feed rate	Depth of cut
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 2: Roughness Ra value and roughness class [13]

Roughness Ra (µm)	Roughness class	Sample Length (mm)
50	N12	8
25	N11	
12.5	N10	2.5
6.3	N9	
3.2	N8	0.8
1.6	N7	
0.8	N6	
0.4	N5	
0.2	N4	0.25
0.1	N3	
0.05	N2	
0.025	N1	0.08

The purpose of this research is to determine the optimal machining parameters in the manufacture of motorcycle brake master cylinder pistons using the Taguchi method. Also, it is to determine the effect of machining parameter optimization on the manufacture of motorcycle brake master cylinder pistons on the surface roughness value. This research would be help the CNC machine operators in making products with better quality, especially in the manufacture of motorcycle brake master cylinder pistons or similar products.

2.0 METODOLOGI

In this research, a summary of the work from start to finish, it can be seen in the flow of activities as shown in Figure 2.

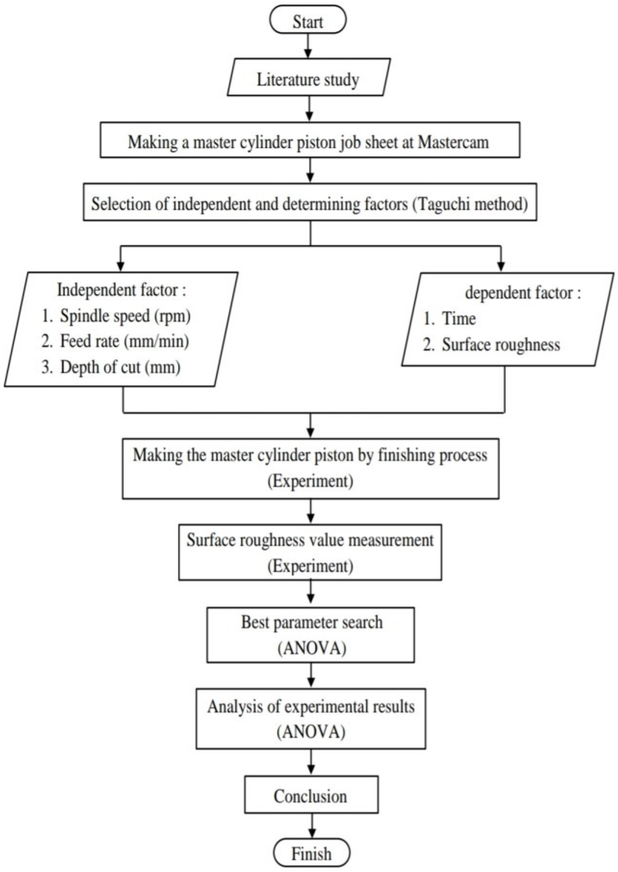

Figure 2: Flow Chart

Tools and Materials

The tools and materials in this research were a Hyundai-KIA SKT160A Fanuc Series 0i-TC CNC Lathe machines, which was used to make a brake master cylinder piston on motorcycles. More, a Mitutoyo Surftest SJ-310 surface roughness tester was used to measure the surface roughness of the work pieces. Furthermore, the aluminum as a material for making brake master cylinder piston.

Manufacture of Piston Master Cylinder Using CNC

The first step that must be done is to install the work piece on the spindle and adjust the tool, where the tool used was a lathe grooving tool.

JOMAse | Received: 26-May-2022 | Accepted: 30-July-2022 | [(66) 2: 57-62]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers

Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2022. Vol.66 No.2

July 30, 2022

The reason for using a lathe grooving tool was a limitation in the geometry of the master cylinder piston, which has several grooves with a small distance. Hence, it is not possible to use other tools in the finishing process. The lathe grooving tool had used a cutting edge of 3 mm. For the installation of work pieces and tool settings, it can be seen in Figure 3.

The next step was to input the program according to the machine standard and simulation was carried out on the machine. If there was an error, the program would be inputted again, as shown in Figure 4.

If all preparations have been completed, it was possible to manufacture the master cylinder piston in the finishing process using the previously designed parameters, while the facing and roughing processes were ignored. In Figure 5 is a master cylinder piston that had been completed using a CNC lathe machine.

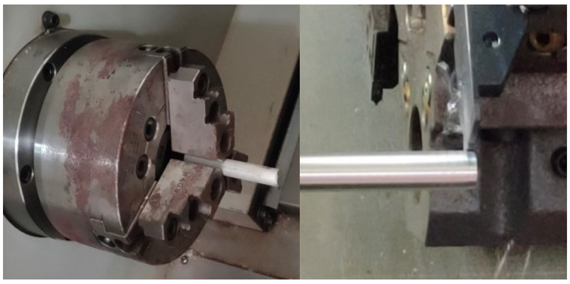

Figure 3: Installation of workpieces and tool setings

Figure 4: Program input on the machine

Figure 5: The result of the work pieces finishing process

Surface Roughness Measurement

In measuring surface roughness, the tools and materials used the surface roughness tester and the work pieces. The work pieces in this study were a brake master cylinder piston, which was done using a CNC lathe machine with a variation of parameters that had been previously designed.

Before measuring surface roughness, make sure the work pieces were on a table or flat place so that the measurement results obtained were maximums. The point to be measured on the piston master cylinder experimental results using a CNC machine was located on the placement of the brake fluid retaining seal. Therefore, first the master cylinder piston was turned flat so that the sensor of the surface roughness measuring instrument can reach and measure its surface roughness, as shown in Figure 8.

Figure 6: Surface roughness tester

Figure 7: Surface roughness test sensor

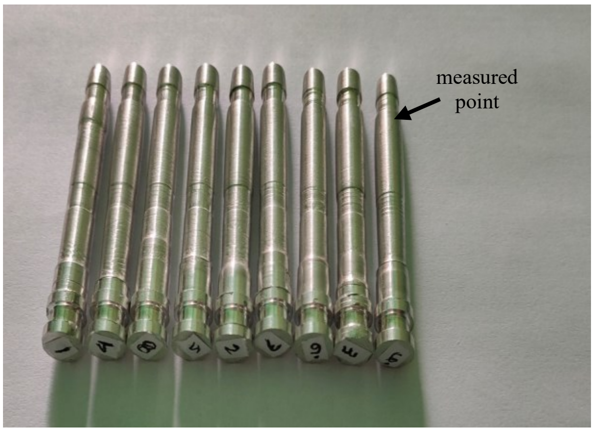

Figure 8: Measured point for surface roughness of work pieces

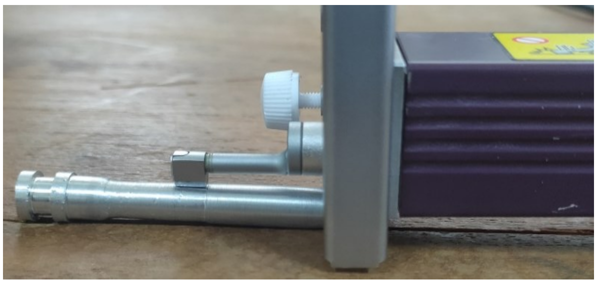

Figure 9: Placement of the sensor at the measured point for surface roughness test

JOMAse | Received: 26-May-2022 | Accepted: 30-July-2022 | [(66) 2: 57-62]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers
Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2022. Vol.66 No.2

The next step was to place the measuring instrument sensor right above the surface to be measured. Then turn on the measuring instrument, when finished, the measurement results can be seen on the screen available on the surface roughness measuring instrument. The sensor placement to measure surface roughness point test can be seen in Figure 9. The value of average surface roughness based on experimental factor levels can be seen in Table 3.

Table 3: The value of average surface roughness based on experimental factor levels

Factor	*Ra* (µm)			Average
A1	1.787	1.133	1.973	1.631
A2	0.866	1.044	1.862	1.257
A3	1.809	0.997	2.209	1.672
B1	1.787	0.866	1.809	1.487
B2	1.133	1.044	0.997	1.058
B3	1.973	1.862	2.209	2.015
C1	1.787	1.862	0.997	1.549
C2	1.133	0.866	2.209	1.403
C3	1.973	1.044	1.809	1.609

2.1 Equation

The factors that influence the design of research parameters on the Taguchi method can be seen in Table 4.

Table 4: Orthogonal array in finishing process

No	Spindle Speed (RPM) (A)	Feed Rate (mm/rev) (B)	Depth of Cut (mm) (C)
1	1504	0.08	0.25
2	1504	0.09	0.30
3	1504	0.10	0.35
4	1755	0.08	0.30
5	1755	0.09	0.35
6	1755	0.10	0.25
7	2006	0.08	0.35
8	2006	0.09	0.25
9	2006	0.10	0.30

a) Degree of freedom factor:

$$\mathrm{Df}_A = K - 1 \tag{1}$$

b) Degree of freedom total:

$$\mathrm{Df}_T = N - 1 \tag{2}$$

c) Correction factor:

$$CF = \frac{T^2}{N} \tag{3}$$

d) Sum of Square factor:

$$SS_f = \frac{k}{N}\sum_{i=1}^{k} T_t{}^2 - CF \tag{4}$$

e) Sum of Square total:

$$SS_{Total} = SS_f + SS_e \tag{5}$$

f) Sum of Square error:

$$SS_{error} = SS_T - (SS_A + SS_B + SS_C + SS_D) \tag{6}$$

g) Mean square factor:

$$V_f = \frac{SS_f}{K-1} \tag{7}$$

h) Mean square error:

$$V_e = \frac{SS_e}{N-K} \tag{8}$$

i) Contribution (%):

$$C = \frac{SS_f}{SS_T} \, x\, 100 \tag{9}$$

3.0 RESULT

The best parameter was carried out using a CNC lathe machine to determine the fastest processing time.

3.1 Effect of Factor Level on Processing Time

To identify the effect of the level of the selected factors on the processing time of the workpiece finishing process, data processing was carried out using ANOVA analysis on the processing time data. ANOVA calculation can be seen in equations (1) to (9). The result of calculation is depicted in Table 5.

Based on the ANOVA calculations have been carried out on the experimental results. The ANOVA table was obtained to see the contribution of the factors that most influence the workmanship of the work pieces in the finishing process. The factor that has the largest contribution was spindle speed with a contribution of 64.3%, then feed rate of 30.2% and depth of cut of 1.7%. With an error contribution was 3.7%.

Based on Table 4, a graph of the response time of the experimental results in the finishing process is obtained to determine the best parameters with the fastest time. In Figure 4, it can be seen that the parameters with the fastest processing time are parameters A3, B3, and C3. Where the average time is A3 (spindle speed level 3) = 0.347 minutes, B3 (feed rate level 3) = 0.366 minutes, and C3 (depth of cut level 3) = 0.386 minutes.

Table 5: ANOVA for time

Factor	Degree of Freedom	Sum of Square	Mean Square	F factor	F table	Contribution
Spindle speed (A)	2	0.0148	0.00738	17.2627	4.46	64.3%
Feed rate (B)	2	0.00693	0.00346	8.1054	4.46	30.2%
Depth of cut (C)	2	0.000403	0.000202	0.4720	4.46	1.7%
Error	2	0.000855	0.000427			3.7%
Total	8	0.02294				99.9%

JOMAse | Received: 26-May-2022 | Accepted: 30-July-2022 | [(66) 2: 57-62]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers
Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2022. Vol.66 No.2

Table 6: Average time based on factor level

Factor	Time (min)		
	Level 1	Level 2	Level 3
Spindle speed (RPM) (A)	0.482 0.459 0.398	0.442 0.382 0.389	0.378 0.353 0.311
Average	0.446	0.404	0.347
Feed rate (mm/rev) (B)	0.482 0.442 0.378	0.459 0.382 0.353	0.398 0.389 0.311
Average	0.434	0.398	0.366
Depth of cut (mm) (C)	0.482 0.389 0.353	0.459 0.442 0.311	0.398 0.382 0.378
Average	0.408	0.404	0.386

Table 8: Surface roughness average by factor level

Factor	Surface Roughness R_a (µm)		
	Level 1	Level 2	Level 3
Spindle speed (RPM) (A)	1.787 1.133 1.973	0.866 1.044 1.862	1.809 0.997 2.209
Average	1.631	1.257	1.672
Feed rate (mm/rev) (B)	1.787 0.866 1.809	1.133 1.044 0.997	1.973 1.862 2.209
Average	1.487	1.058	2.015
Depth of cut (mm) (C)	1.787 1.862 0.997	1.133 0.866 2.209	1.973 1.044 1.809
Average	1.549	1.403	1.609

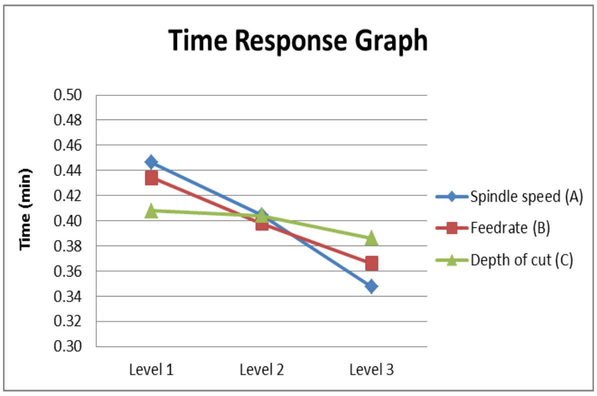

Figure 10: Experiment result of time response graph

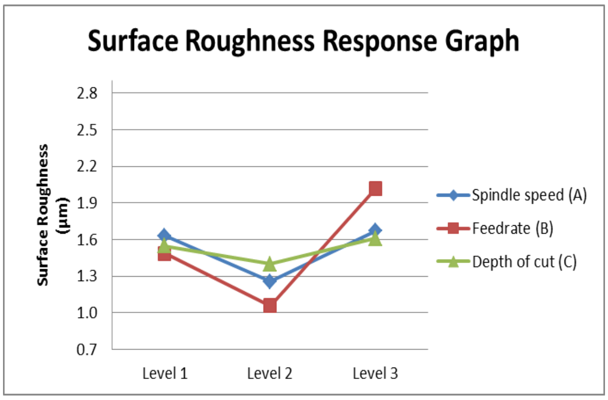

Figure 11: Surface roughness response graph

3.2 Effect of Factor Level on Surface Roughness

To identify the effect of the level of the selected factor on the surface roughness of the workpiece finishing process, data processing was carried out using ANOVA analysis on the roughness measurement data that had been obtained. ANOVA calculation can be seen in equations (1) to (9).

Based on the ANOVA calculations that have been carried out, an ANOVA table is obtained to see the contribution of the factors that most influence the surface roughness of the workpiece in the finishing process. The factor that has the largest contribution is the feed rate with a contribution of 67.9%, then the spindle speed of 15.4% and the depth of cut of 3.3%. With an error contribution was 13.4%.

Based on Table 6, the surface roughness response graph obtained from the experimental results in the finishing process to determine the best parameters with the smallest roughness value. It can be seen in Figure 10, that the parameter variations that produce the smallest roughness values are parameters A2, B2, and C2.

Table 7: ANOVA for surface roughness

Factor	Degree of Freedom	Sum of Square	Mean Square	F factor	F table	Contribution
Spindle speed (A)	2	0.3130	0.1565	1.1532	4.46	15.4%
Feed rate (B)	2	1.3776	0.6888	5.0765	4.46	67.9%
Depth of cut (C)	2	0.0674	0.0337	0.2482	4.46	3.3%
Error	2	0.2714	0.1357			13.4%
Total	8	2.30066				100%

The average surface roughness value is A2 (spindle speed level 2) = 1.257 µm, B2 (feed rate level 2) = 1.058 µm, and C2 (depth of cut level 2) = 1.403 µm.

4.0 DISCUSSION

From the overall ANOVA calculations that have been carried out on the processing time data and surface roughness. There is a significant difference where in the processing time data, spindle speed has the largest contribution. Meanwhile, in the surface roughness measurement data, the factor that has the greatest contribution is feed rate. The best parameter variations based on the fastest time are A3, B3, and C3 with values A3 = 2.006 RPM, B3 = 0.10 mm/rev, and C3 = 0.35 mm. While the best parameter variations based on the smallest surface roughness values are A2, B2, and C2 with values A2 = 1.755 RPM, B2 = 0.09 mm/rev, and C2 = 0.30 mm. This can happen because the best parameters based on time have a high spindle speed, feed rate, and depth of cut. Then, if these parameters are used, it will produce a rough surface roughness due to vibrations in the workpiece with a small cross section with Aluminum 6061 material, which is classified as into a non-ferrous material such as the master cylinder piston. This is in accordance with research conducted by [14,15], the higher the spindle speed, feed rate and depth of cut values, the higher the surface roughness value. Meanwhile, the lower the spindle speed, feed rate and depth of cut values, the lower the surface roughness value [16].

JOMAse | Received: 26-May-2022 | Accepted: 30-July-2022 | [(66) 2: 57-62]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

The measured point on the work pieces, which the brake fluid retaining seal is placed. It is advisable to use the parameters A2 (spindle speed level 2) = 1.755 RPM, B2 (feed rate level 2) = 0.09 mm/rev, and C2 (depth of cut level 3) = 0.30 mm. If the parameters based on processing time are A3 (spindle speed level 3) = 2.006 RPM, B3 (feed rate level 3) = 0.10 mm/rev, and C3 (depth of cut level 3) = 0.35 mm, it will resulted in high surface roughness values at the seal placement. This can cause the seal to wear out more quickly and cause leakage, which causes a loss of pressure for braking and endangers the motorcyclist. Considering the brake master cylinder piston works, which is transmits kinetic energy when the brake lever is pressed to produce braking.

5.0 CONCLUSION

Optimizing the parameters with the Taguchi method to get the best parameters with the fastest time, namely spindle speed 2.006 RPM, feed rate 0.10 mm/rev, and depth of cut 0.35 mm, but these parameters produce a high average surface roughness value. Therefore, the parameters used in the finishing process are spindle speed 1.755 RPM, feed rate 0.09 mm/rev, and depth of cut 0.30 mm. These parameters have a fairly fast processing time with a small average surface roughness value. Based on the experimental surface roughness measurement, the factor that has the greatest influence on the surface roughness level is feed rate of 67.9%, followed by spindle speed of 15.4% and depth of cut of 3.3%. This proves that the optimization of the parameters that have been carried out has a very clear effect on surface roughness, where the smaller the value of feed rate, spindle speed and depth of cut, the smaller the value of surface roughness will be.

REFERENCES

[1] BPS (2021*). Perkembangan Jumlah Kendaraan Bermotor Menurut Jenis (Unit) 2018 – 2020.* https://www.bps.go.id (accessed on September 21, 2021)

[2] Brembo. 2021. *Master Cylinders*. https://www.brembo.com (accessed on September 21, 2021)

[3] Atmadio, N. & Susilawati, A. (2018). Optimasi jalan pahat dan analisis biaya produksi proses pemesinan CNC lathe pembuatan piston master cylinder rem sepeda motor yamaha menggunakan CAM, *Jom FTEKNIK*, 5(1).

[4] Saputra, E. & Susilawati, A. (2018). Optimasi jalan pahat proses pemesinan CNC lathe dan analisa biaya produksi pembuatan dead center berbantukan CAD/CAM, *Jom FTEKNIK*, 5(1).

[5] Napitupulu, A. & Pranandita, N. (2021). Optimasi material removal rate (mrr) baja st 42 pada proses CNC turning dengan menggunakan metode taguchi, *Jurnal Ilmiah Teknk Mesin*, 9(2), 73-77.

[6] Yahuza, R. (2010). *Teknologi CNC*. Jakarta: Untar.

[7] Jadmiko, E. & Wahyunugroho, W. (2020). The use of taguchi method in design of dies propeller production using CNC machine, *International Journal of Marine Engineering Innovation and Research*, 5(1), 20-33.

[8] Kalpakjian, S. & Schmid, S.R.. (2014). *Manufacturing Engineering And Technology*. Edisi 7 SI Units, United Kingdom: Pearson Education Limited.

[9] Krishnaiah, K. & Shahabudeen, P. (2012). *Applied Design of Experiments and Taguchi Methods*. New Delhi: PHI Learning Private limited.

[10] Karna, S.K. & Rajeshwar, D. S. (2012). An overview on taguchi method, *International Journal Of Engineering and Mathematical Sciences*, 1, 11-18.

[11] Nasimuddin, Md., Khan, N.Z., Shihab, S.K. & Siddiquee, A.N. (2017). Optimization of turning parameters using taguchi method. *International Journal of Scientific & Engineering Research*, 8(7).

[12] Permana, D.I. & Yayat (2019). Optimasi parameter permesinan terhadap tingkat kekasaran permukaan aluminium proses pembubutan dengan metode taguchi, *METAL: Jurnal Sistem Mekanik Dan Termal*, 3(1), 10-16.

[13] Purbosari, D., Saputro, H. & Wijayanto, D.S. (2012). Karakterisasi tingkat kekasaran permukaan baja st 40 hasil pemesinan CNC milling ZK 7040 efek dari kecepatan pemakanan (feed rate) dan awal waktu pemberian pendingin, *Nosel* 1(2), 1-15.

[14] Zubaidi, A., Syafa'at, I. & Darmanto (2012). Analisis pengaruh kecepatan putar dan kecepatan pemakanan terhadap kekasaran permukaan material FCD 40 pada mesin bubut CNC, *Momentum* 8(1), 40-47.

[15] Siswanto, B. & Sunyoto (2018). Pengaruh kecepatan dan kedalaman potong pada proses pembubutan konvensional terhadap kekasaran permukaan lubang, *Jurnal Dinamika Vokasional Teknik Mesin*, 3(2), 82-86.

[16] Khair, J., Pranata, D., & Nuhadek, U. (2020). Effect of Cutting Depth and Feed Speed to Surface Roughness in Lathe Process of Screw Conveyor Shaft (Case Study: PT. RAPP). *Journal Of Ocean, Mechanical And Aerospace -Science And Engineering-, 64*(2), 59-62. doi:10.36842/jomase.v64i2.200

JOMAse | Received: 26-May-2022 | Accepted: 30-July-2022 | [(66) 2: 57-62]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085