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OPTIMIZATION OF CUTTING DIRECTION PARAMETERS FOR A CNC MILLING MACHINING PROCESS POCKET ON STRUCTURE AND SURFACE ROUGHNESS ON POSTEP MOTORCYCLE SPARE PARTS

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Abstract

A CNC milling machine is a machine that is widely used for the manufacture of components. Product quality will be related to product selling value and consumer satisfaction; therefore, the best parameters must be known in order to produce quality products. This study aims to determine the effect of the cutting direction on the structure and surface roughness of the pocket feeding CNC milling machining process. Experimental methods are used to improve the quality of products produced by CNC milling machines. The parameters used in this study are variations of spindle speed (500 rpm, 1900 rpm, and 5000 rpm), as well as variations of cutting direction (one way and zig-zag). The tests carried out are in the form of surface roughness testing, microstructure observations, and macrostructures. The data analysis technique used is descriptive statistics. The results obtained show that the use of the cutting direction parameter affects the quality of the resulting product in terms of structure and surface roughness. The zig-zag cutting direction parameter with spindle speed 5000 rpm obtained the lowest average surface roughness value of 0.87 µm, while the one-way cutting direction with spindle speed 500 rpm obtained the highest average roughness value of 2.84 µm. In conclusion, using a higher spindle speed will result in a lower roughness value, while the zig-zag cutting direction produces a lower roughness value and a more even surface structure compared to the one-way cutting direction.

Keywords: Cutting Direction, Spindle Speed, Milling, Pocket Feed, Surface Roughness, Microstructure, Macrostructure.

1. INTRODUCTION

Technological advances are becoming increasingly sophisticated along with the development of increasingly modern times, one example is the development of the manufacturing industry, especially machine tools based on computer numerically controlled (CNC) technology. A CNC machine is a sophisticated machine that is driven by a program and controlled using a computer. A CNC machine is a sophisticated machine that is driven by a program and controlled using a computer. Retyawan [1] noted that the advantages of CNC machines compared to other conventional machines are that there are not many settings, the tool moves automatically according to the requested program, the error rate is small, all machine movements can be monitored on the screen, and there is time efficiency.

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One that can be done using a CNC machine is the milling machining process. The milling machining process is one of the machining processes used to make a component in the form of a profile and also has a complex trajectory. For example, the milling machining process is often used in pocket feeding, such as when making molded products. Nowadays, some consumers require components that have a certain surface smoothness and even demand that these components can achieve the least roughness. Suteja [2] concluded that milling machining process parameters should be optimized and set to maximum conditions in order to achieve a high material feed rate and the desired surface roughness.

Product quality is related to the selling price of the product and is one of the factors that can affect consumer satisfaction. Consumer satisfaction is characterized by product quality, which is determined by the results of its use and function. One of the main elements in determining product quality, in addition to the suitability of the shape of the workpiece and the level of precision and measurement accuracy, is the roughness value of the product. Rawangwonga [3] pointed out that surface roughness is an important way to measure the quality of a product because it has a big effect on how well mechanical parts work and how much it costs to run production.

The surface roughness value of a product can be influenced by several factors. Khorasani [4] stated that milling operations are multi-point cutting processes, and the problem becomes complex. An attempt to study the phenomenon and experimentally ensure the findings or results must refer to the combination of workpieces, cutting tools, and machines used. According to Chang [5], the parameters that most influence the surface roughness of the side milling machining process are spindle speed, feeding speed of each tooth, and tool wear. In addition, cutting direction can also affect the level of surface roughness. According to Ramos [6], the machining strategy (cut type) of the machining process produces different surface roughness, and the 3D offset type is the most suitable for machining components containing complex geometries. Göloğlu [7] used genetic programming for milling machining parameters such as cutting speed, feed speed, and depth of cut, using a zig-zag type machining strategy that will have a major effect on surface roughness. Based on the results of the literature study, this study tries to find the effect of several important process parameters that can affect surface roughness but have not been studied much so that the best parameters can be known.

The machining process given various parameters will of course produce a different shape of the workpiece; therefore, to support data from surface roughness, it is necessary to also observe micro- and macrostructures. Budiana [8] observed the material structure with the goal of seeing the images and determining what phenomena occur in the resulting material after the milling machining process is completed using a variety of predetermined parameters. According to Munandar [9], the value of product quality varies depending on the machining parameters used. Therefore, it is hoped that in the future the best parameters can be found and that we can produce even more quality products. The purpose of this study was to determine the effect of the Cutting Direction parameter on the structure and surface roughness of the Pocket Feed CNC Milling machining process for postep products motorcycle spare parts

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2. MATERIALS AND METHODS

The type of research used is experimental research, which uses observational methods for data collection and descriptive analysis with quantitative data. The results are then presented in the form of graphs and images to make them easier to understand. This method is used to provide an overview of the changes after the specimen is treated by using certain variations between the independent variable and the dependent variable.

1.1. Research Tools and Materials

The parameters of this study consisted of independent variables, namely variations in cutting direction parameters of the one-way and zig-zag types, as well as variations in spindle speed of 500 rpm, 1900 rpm, and 5000 rpm. Surface roughness testing and observations of micro and macro structures are the dependent variables. The control variable uses the Pocket feature for motorcycle postep spare part products; the chisel uses an endmill with a diameter of 10 mm; the feed speed used is 500 mm/min; and the feed depth is 1 mm. To produce variations in cutting direction, CAD software tools are used, namely SolidWorks Professional 2014 and CAM software, namely SolidCam 2013, and this software is also used to create G code, which, after being generated, will be sent to the CNC milling machine. The tools and materials used in this study are as follows:

Tools Used:

a. Pocket Working Tools: CNC Milling Machine, Merk Deckel Maho DMU 50 Eco
b. Surface Roughness Tools: Surface Roughness Tester Mitutoyo SJ-210
c. Microstructure Instruments: Metallurgical Microscope with Inverted (Olympus PME)
d. Macro Structure Tools: DSLR Camera (Digital Single Lens Reflex)
e. Mitutoyo Vernier Caliper Workpiece Measuring Tools
f. Chisel Endmill Diameter: 10, with 4 chisels

Materials Used:

a. Aluminum 6061 (Postep Motorcycle Spare Part Materials)
b. Coolant/dromus cooling media

1.2. Research Methods and Steps

The CNC milling machining process will be given a variation of spindle speed on the specimen with 2 types of cutting direction variations, namely, one-way and zig-zag, which will be observed as a reference in calculating the surface roughness value. The results of the machining process, whose parameters have been varied by pocket feeding, are then tested. first by testing the surface roughness using the Surface Roughness Tester. The second is by observing the microstructure and macrostructure using a microscope and a DSLR camera. The results obtained will be analyzed, presented in the form of tables and figures, and then concluded so that they are easily understood by readers.

Materials that are machined and cut on the surface cannot be completely flat, but inside there will definitely be traces of valleys and peaks. This is called surface roughness. Petropoulos [10] said that the mean roughness (Ra) is arithmetically calculated based on the average value of the absolute value of the distance between the measured profile and the center profile (Equation 1).

$$R_a = \frac{1}{L} \int_o^L |f(x)| dx \quad (1)$$

Description:
Ra = Surface Roughness Arithmetic Average Height
L = Sampling Length
f(x) = Roughness Curve

3. RESULTS AND DISCUSSION

The purpose of this study is to determine the effect of the machining parameters, in this case the spindle speed at variants of 500 rpm, 1900 rpm, and 5000 rpm, and the variation of cutting direction, namely the one-way and zig-zag types, on the pocket feeding process and the CNC milling machining process on the roughness value of the surface microstructure and macrostructure. Material testing and image observation were carried out in the laboratories of Wahid Hasyim University Semarang and Semarang State University (UNNES).

Figure 1. (a) Surface roughness testing process with tools Surface Roughness Tester, (b) The process of observing the micro structure with a microscope, (c) The process of observing the macro structure with a DSLR.

3.1. Surface Roughness Test

Table 1 shows the value of the data from the surface roughness test using the merk Mitutoyo SJ-210 surface roughness tester to obtain the Ra value (arithmetic average according to a certain distance), namely, at 500 rpm spindle speed using one way cutting direction, the highest average roughness value is equal to 2.84 m, while at 1900 rpm spindle speed using zig-zag cutting direction, the roughness value obtained a lower average value of 1.17 From the data above, it can be observed that of all the variations given, the use of a spindle speed of 5000 rpm with a zig-zag cutting direction obtained the best surface roughness value compared to other variations of spindle speed and cutting directions.

Table 1. Surface roughness (Ra) value

Parameters		Surface Roughness Value (µm)			
Spindle Speed	Cutting Direction	Point 1	Point 2	Point 3	Average
500 rpm	One Way	1.58 µm	1.41 µm	5.55 µm	2.84
	Zig-zag	1.50 µm	3.37 µm	1.39 µm	2.08
1900 rpm	One Way	1.28 µm	1.32 µm	1.38 µm	1.32
	Zig-zag	1.20 µm	1.16 µm	1.15 µm	1.17
5000 rpm	One Way	1.01 µm	1.02 µm	1.11 µm	1.04
	Zig-zag	0.95 µm	0.91 µm	0.75 µm	0.87

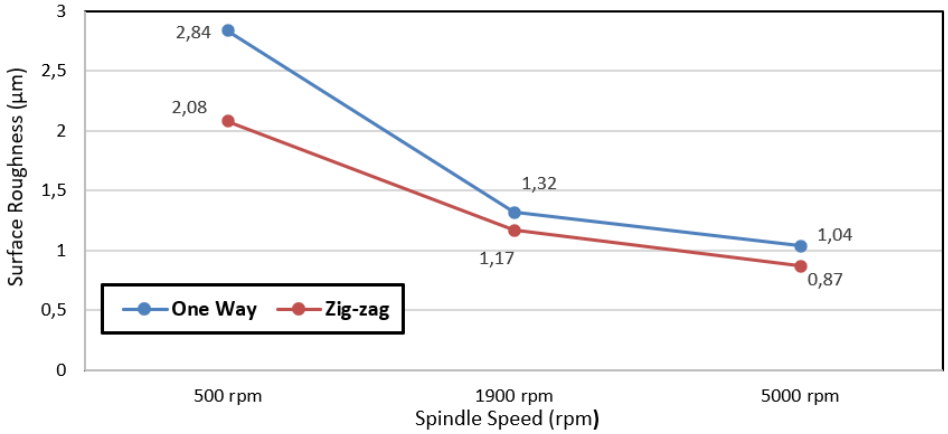

Figure 2. Correlation between cutting direction, spindle speed, and surface roughness

From the surface roughness test that has been carried out and the graph above, it can be concluded that the higher the spindle speed used, the lower the surface roughness level, and the slower the spindle speed used, the higher the surface roughness level. These results are in accordance with research conducted by Kaisan [11]: the higher the spindle speed, the lower the roughness produced because the higher the spindle rotation, the greater the machine's effort to cut the workpiece so that the surface roughness will be low. As for the use of the zig-zag type of cutting direction, the roughness value is lower than that of the one-way type. This result is in accordance with the research conducted by Satriya [12], which indicates that the zig-zag type of cutting direction has a more optimal movement than the one-way type. This indicates that the two types of varied cutting directions can affect the surface roughness of the material.

3.2. Observation of Micro and Macro Structure

The observation of the microstructure was carried out using an Olympus PME microscope with 200x magnification, while the macrostructure was observed using a DSLR camera with 10x magnification. This observation only uses a visual-based method, so it can only produce comparisons as supporting data from the roughness test that has been carried out. Observations of the micro- and macrostructures were carried out in an upright position so that an image was obtained, as shown in Figures 3 and 4.

The purpose of observing this micro and macrostructure is to determine the resulting image after the material has obtained variations in the machining process with each parameter. Based on Figure, it can be seen that the surface of the sample has different images [8]. These different images can occur because each sample has different process parameters. From the results obtained that the highest spindle speed variation of 5000 rpm produces a more even microstructure image and the level of porosity in the image is lower than the slower spindle speed of 1900 rpm and 500 rpm because aluminium grains dominate, at a spindle speed of 1900 rpm porosity begins to appear which is indicated by the presence of lines and the surface structure is not too evenly distributed, at the lowest spindle speed, which is 500 rpm, the porosity level is higher and the surface of the material looks uneven than before. In addition, there are also differences in the macro structure of the results of feeding using One Way and Zig-zag Cutting Directions, the difference lies in the line of chisel feeding used with each type. Alif [13], differences in the results of chisel feeding can occur even though some control parameters and the geometry are the same. This is because each parameter variation produces a different surface plot, so that the surface roughness value and

the shape of the surface structure will also be different. These results are in accordance with research conducted by Margen [14], which states that the spindle speed parameter affects the level of surface roughness, the higher the speed, the smaller the surface roughness and the smoother the surface structure.

The data from the graphs and pictures above show that the spindle speed and cutting direction parameters affect the structure and surface roughness of pocket feeding material in the machining process using a CNC milling machine. The higher the spindle speed used, the smoother the surface roughness value obtained, provided that it does not exceed the permissible speed based on the materials used. Another thing that can affect the machining process is a machining strategy such as cutting direction. As evidenced by the data above, the zig-zag type feeder always gets a lower roughness value than the one-way type.

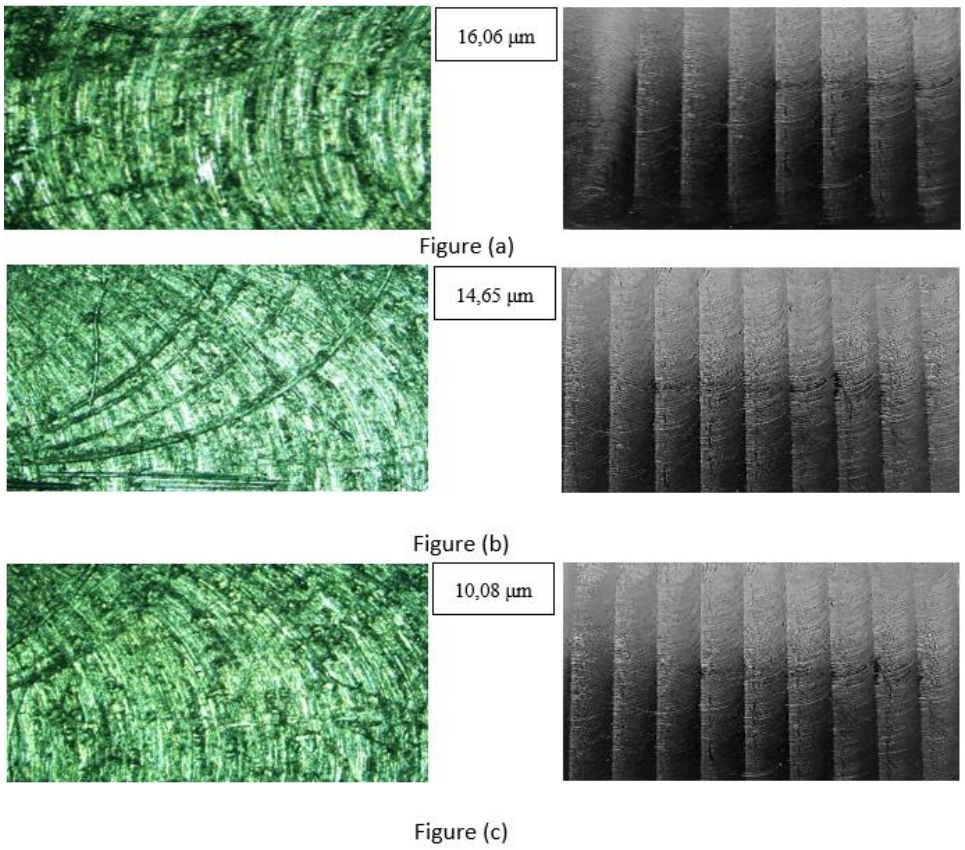

Figure 3. (a) Micro and macro structure 500 rpm (One Way), (b) Micro and macro structure 1900 rpm (One Way), (c) Micro and macro structure 5000 rpm (One Way).

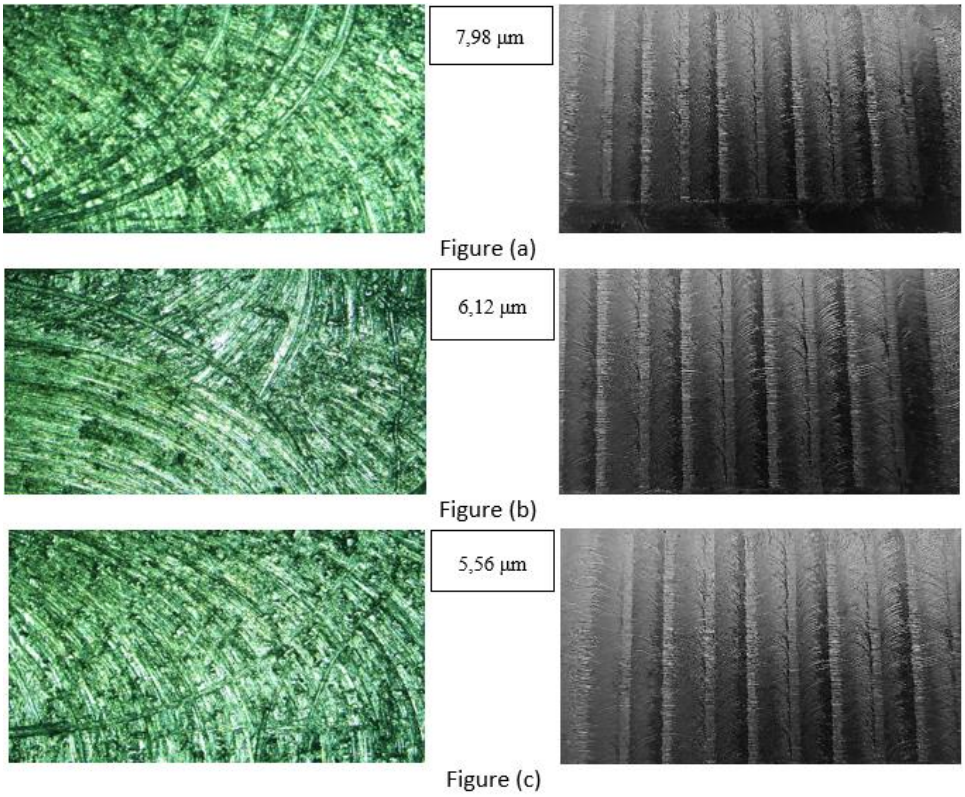

Figure 4. (a) Micro and macro structure 500 rpm (Zig-zag), (b) Micro and macro structure 1900 rpm (Zig-zag), (c) Micro and macro structure 5000 rpm (Zig-zag).

Table 2 displays the surface roughness value in accordance with the ISO 1302 standard. It can be concluded that pocket working on CNC milling machines with variations in spindle speed and cutting direction results in normalization of the roughness level of N6 as a result of the best parameter, namely spindle speed 5000 rpm with zig-zag cutting direction, while the normalization of the lowest level of roughness is N8, which is obtained from the use of a 500 rpm spindle speed variation The other parameters, such as material cutting temperature, vibration, tool deflection, and tool wear, are assumed not to affect the surface roughness and surface structure, which will later be used as parameters for the manufacture of postep motorcycle spare parts products.

Table 2. Conversion of roughness value to price roughness level standard ISO 1302

Parameters		**Surface Roughness Value (µm)**	
Spindle Speed	**Cutting Direction**	**Average Value (Ra)**	**Normalization Price Roughness Level**
500 rpm	One Way	2.84	N7-N8
	Zig-zag	2.08	N7-N8
1900 rpm	One Way	1.32	N6-N7
	Zig-zag	1.17	N6-N7
5000 rpm	One Way	1.04	N6-N7
	Zig-zag	0.87	N6-N7

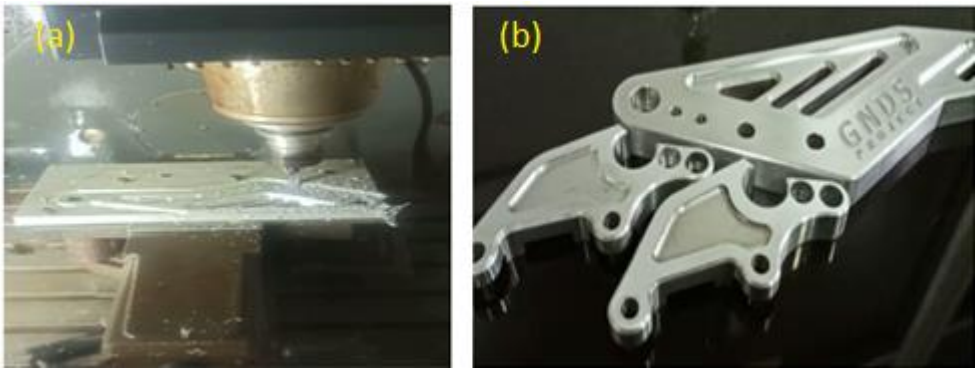

Figure 5. (a) The process of making postep motorcycle spare parts products with CNC milling machines, (b) The results of working on motorcycle postep spare parts products.

4. CONCLUSION

When using a CNC milling machine for pocket feeding, the Cutting Direction parameter influences the surface roughness value. In addition, the spindle speed also affects the surface roughness value; the faster the spindle rotation, the smoother the surface value obtained, provided that it does not exceed the allowed spindle speed based on the materials used. The best roughness value occurs at a spindle speed of 5000 rpm in the zig-zag cutting direction, which is 0.87 μm, and in the one-way cutting direction, which is 1.04 μm. After the specimen is machined on pocket feeding with a predetermined variation of parameters, the cutting direction parameter affects the surface structure of the material. The use of a spindle speed of 5000 rpm resulted in a more even micro- and macrostructure image and a lower level of porosity in the image compared to a slower spindle speed of 1900 rpm and 500 rpm because aluminum grains dominate. Based on the paired T test on the pair of parameter variations, it can be seen that the surface roughness value using the Cutting Direction type is 500 rpm vs. 1900 rpm, 500 rpm vs. 5000 rpm, and 1900 rpm vs. 5000 rpm. There are differences in the Cutting Direction of all pairs except for the 500 rpm vs. 1900 rpm

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REFERENCES

[1] RETYAWAN, N, O., INDRI, Y., HERU, S., “Pengaruh Jenis Proses Pemotongan pada Mesin Milling Terhadap Getaran dan Kekasaran Permukaan Dengan Material Aluminium 6061”, Jurnal Teknik Mesin Indonesia, v. 12, n. 1, pp. 8 – 13, 2017.

[2] SUTEJA, J, T., CANDRA, S., AQUARISTA, Y., “Optimasi Proses Pemesinan Milling Fitur Pocket Material Baja Karbon Rendah Menggunakan Response Surface Methodology”, Jurnal Teknik Mesin, v. 10, n. 1, pp. 1-7, 2008.

[3] RAWANGWONGA, S., JAKNARIN, C., WORAPONG, B., ROMADORN, B., “Influence of Cutting Parameters in Face Milling Semi-Solid AA 7075 Using Carbide

Tool Affected The Surface Roughness And Tool Wear" Energy Procedia Journal, v. 56, n. 1, pp. 448-457, 2014.

[4] KHORASANI, A, M., M, REZA, S, Y., M, SAEED, S., "Analysis of Machining Parameters Effects on Surface Roughness: A Review", Int. Journal Computational Materials Science and Surface Engineering, v. 5, n. 1, pp. 68 – 84, 2012.

[5] CHANG, C, K., H, S, LU, "Study on The Prediction Model of Surface Roughness For Side Milling Operations", The International Journal of Advanced Manufacturing Technology, v. 29, n. 9-10, pp. 867-878, 2006.

[6] RAMOS, A, M., RELVAS, C., SIMOES, J, A., "The Influence of Finishing Milling Strategies on Texture, Roughness, And Dimensional Deviations on The Machining of Complex Surfaces", Journal of Materials Processing Technology, v. 136, n. 1-3, pp. 209-216, 2003.

[7] GÖLOĞLU, C., ARSLAN, Y., "Zigzag Machining Surface Roughness Modelling Using Evolutionary Approach", Journal of Intelligent Manufacturing, v. 20, n. 2, pp. 734-742, 2006.

[8] BUDIANA, B., NAKUL, F., WIVANIUS, N., "Zigzag Machining Surface Roughness Modelling Using Evolutionary Approach", Journal of Intelligent Manufacturing, v. 20, n. 2, pp. 734-742, 2006.

[9] MUNANDAR, M, T, A., "Efektifitas Kinerja Mesin CNC 5 Axis Portable Karya Mahasiswa Terhadap Mesin Milling Konvensional", Jurnal Teknik Mesin, Universitas Pancasakti, Tegal.

[10] PETROPOULOS, G., KECHAGIAS, J., IAKOVAKIS, V., MAROPOULOS, S., "Surface Roughness Investigation of A Reinforced Polymer Composite", Journal International conference on economic engineering and manufacturing systems, v. 10, n. 3, pp. 380-384, 2009.

[11] KAISAN, I., RUSIYANTO, "Pengaruh Parameter Pemotongan CNC Milling Dalam Pembuatan Pocket Terhadap Getaran dan Kekasaran Permukaan pada Crankcase Mesin Pemotong Rumput", Jurnal Rekayasa Mesin, v. 11, n. 1, pp. 41-49, 2020.

[12] SATRIYA, H., WALUYO, J., PURWANTO, A., "Proses Milling CNC Sinumeric 808D pada Material Acrylic Untuk Mendapatkan Kualitas Permukaan Yang Optimum Dengan Menggunakan Parameter Tebal Pemakanan, Voeding, dan Kecepatan Potong", Jurnal SIMETRIS, v. 13, n. 2, pp. 6-16, 2019.

[13] ALIF, M, N., SANTOSA, I., SISWIYANTI, "Analisa Kualitas Hasil Produk pada Pengerjaan Pocketing Dengan Mesin CNC FRAIS 3 AXIS", Jurnal Teknologi Terapan, v. 7, n. 2, pp. 145-152, 2021.

[14] MARGEN, S. Y., RIYADI, S., "Analisa Pengaruh Variasi Putaran Mesin CNC Milling MCV-1100 Terhadap Sifat Mekanik Logam Aluminium AA 5052-H112", Jurnal Momentum Universitas Wahid Hasyim, v.16, n. 2, pp. 122-126, 2020.