MECHTA
International Journal Of Mechanical Engineering Technologies & Applications
ISSN 2722-3213 articles 6, pp. 51 – 60, 2023

V04 N.1

COMPARISON OF CHATTER CONTROL OF VARIABLE AND REGULAR HELIX TOOLS IN THE ALUMINUM END-MILLING PROCESS

Achmad As'ad Sonief, [1] ✉, Moch. Syamsul Ma'arif, [1] Pratikto, [1] Hans Juliano [2]

[1] **Mechanical Engineering Department**
Brawijaya University
167 MT. Haryono St., Malang,
East Java, INDONESIA
sonief@ub.ac.id

[2] **Institute of Electronics,**
National Yang Ming Chiao Tung University
1001號, Daxue Rd, East District, Hsinchu City, Taiwan 30010

Abstract

In the chatter, machining operations are undesirable because of the phenomena that affect product results, machining accuracy, tool life, and high operating value. Chatter is a vibration phenomenon that occurs in cutting tools due to the self-excitation of the influence of cutting parameters during the operation process of the machine. Types of chatter in machinery are regenerative and resonant. Because the pitch angles of variable helix tools vary, the helix angles of variable tools produce different tooth passing frequencies on each tool eye next to each other and can be used to prevent and control resonance. This study aimed to compare chatter control from the variable helix and regular-angle tools in the aluminum end milling process. The method is carried out through the end milling process experiment to determine the chatter control of the variable helix and regular-angle tools through the stability loop diagram. The results from this study were obtained by comparing control chatters in the milling process through controlling variable and standard helix angles as a guideline to produce the best surface roughness in the end milling process made from aluminum. The comparison of estimated control charts from variable helix tools is more comprehensive than regular helix tools.

Keywords: Variable-Regular Helix Tools, Chatter, Stability Loop Diagram, End Milling, Aluminum.

1. INTRODUCTION

The manufacturing process in the industry is required to produce components of the best quality to create superior products so that it will have strong competitiveness in the global market. The quality of elements in the manufacturing process is demonstrated physically in the form of the surface roughness of machining process products. Systemically, the onset of surface roughness in components is very detrimental in its application. Several factors, including cutting parameters, geometry tools, and the machining process, can influence the surface roughness of the workpiece piece cutting system. The milling process is a method of cutting metal that is widely carried out by the manufacturing industry.

Improvement of surface quality in the machining process is still possible with the application of several process strategies, especially machining cutting parameters combined with using variable helical tool angles to control chatter. Varying helix angles with different angles on each flute will result in variations in the time lag. Interpreting this time lag can minimize regenerative chatter and avoid using the same frequency as the machine's natural frequency, so that resonance can be reduced [1]. The axial depth of cut and spindle speed

Corresponding Author:
✉ **Achmad As'ad Sonief**
sonief@ub.ac.id
Received on: 2023-01-14
Revised on: 2023-01-24
Accepted on: 2023-01-24

DOI: 10.21776/MECHTA.2023.004.01.6

play a significant role in the machining process [2]. Controlling chatter can be done through stability diagrams [3]. This study aims to compare the behavior of regular and variable helix angles through the lobe stability diagram (SLD), which is justified by the surface roughness value.

2. MATERIALS AND METHODS

The TU-3A CNC milling machine, an end mill tool with a regular helix angle of 400 and a variable helix angle of 350/380 as shown in figure 1 [4], aluminum alloy 6061, a vibration sensor, myRIO-LabVIEW 2013 software and hardware, and the Mitutoyo SJ-301 surface roughness tester were used in the research design. Data were collected five times for each process with variations in spindle speed (SS) and depth of cut (DOC) by monitoring the amplitude spectrum spikes in each variation.

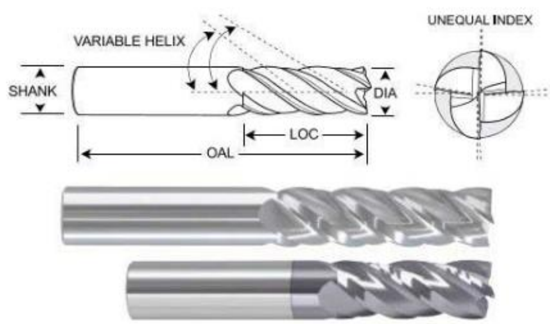


Figure 1. Variable Helix and Normal Helix Angle Tools

While the research scheme looks like in Figure 2, and the research parameters are shown in table 1.

Table 1. Research Parameters

Parameters	Quantity-Unit
Spindle Speed (rpm)	100; 300; 500; 700; 900; 1.100; 1300; 1.500; 1.700; and 1900.
Depth of Cut (mm)	0,5 ; 1,0 ; 1,5 ; 2,0 ; 2,5
Dia. Tool (mm)	6
NHA (^{0})	40
VHA (^{0})	35/38
Flute (units)	4
Overhang (mm)	25
Feed rate (mm/minute)	50
Machine	CNC-TU-3A EMCO
Transducer	Vibration meter sensor
Hardware-Software	Laptop-myRIO-LabVIEW 2013
Roughness Test	Mitutoyo SJ-301

The research scheme looks like in Figure 2.

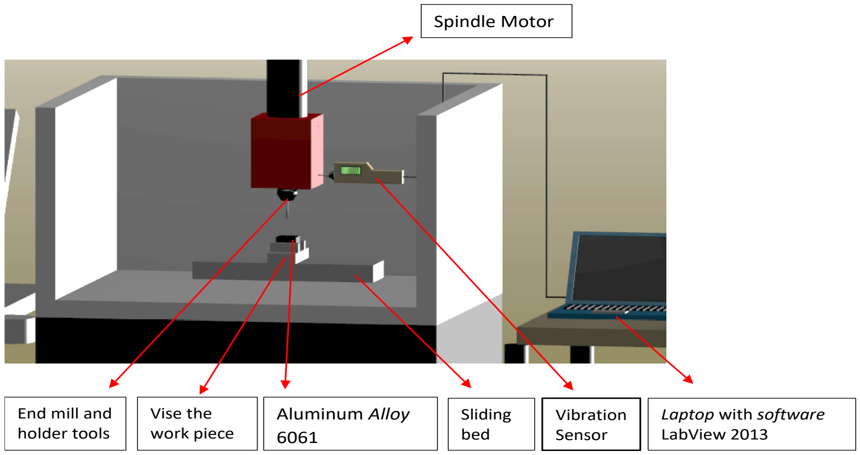


Figure 2. Research installation

3. RESULTS

The results of measurements on the regular helix angle (RHA) and variable helix angle (VHA) tools through variations in spindle speed (SS) where chatter occurs as measured from the spectrum at a depth of cut (DoC) are shown in table 2.

Table 2. Measurable chatter from spectrum analysis.

SS (rpm)	*RHA*	*VHA*
	DoC (mm)	DoC (mm)
100	0.4	0.6
300	0.5	0.7
500	0.5	0.8
700	0.7	1.0
900	0.8	1.1
1100	0.8	1.1
1300	1.0	1.2
1500	1.1	1.4
1700	1.1	1.5
1900	1.2	1.5

Based on Table 2, the approximate chatter stability is visualized through the stability lobe diagram (SLD), as shown in Figure 3. The boundary between a stable cutting process (without amplitude shifting) and an unstable cutting process (with amplitude shifting) can be visualized in a diagram called a stability lobe diagram (SLD) with spindle speed versus depth of cut [5], [6]. Using this SLD, certain combinations of machining parameters can be found with minimum chatter conditions so that the material removal rate will increase and the quality of the machining products will be better. The basic idea is to find an area of stability using the lob effect.

The experimental results of the regular helix angle (RHA) and variable helix angle (VHA) tools through SLD in this comparison show that the VHA tool has a higher stability area than the RHA tool. It is due to the influence of varying helical angles, which will cause variations in time delay or changing tooth passing periods so that it will move away from the area where it meets the natural frequency of the tool [7], [8].

The figure also shows that the stable area (without chatter) increases with increasing spindle speed. This phenomenon occurs because increasing spindle speed will provide more opportunities for material to be cut and also allow changing the position where the excitation load meets the natural frequency of the tool [9], [10].

Furthermore, the comparison of the SLD results is verified with the results of the spectrum measurements and the work piece surface roughness values, as shown in Figures 4, 5, 6, and 7. In Figure 4-a1 and Figure 4-b1, you can see a decrease in the amplitude of the VHA tools, which indicates a reduction in chatter conditions due to the different roles of the load phase from the variable helix angle of the milling process. Figures 5-c1 and 5-d1; figures 6-e1 and 6-f1; all of which reduce the spectrum's amplitude. So, it can be said that the role of VHA is very significant in efforts to reduce chatter.

Then, look at the surface quality of the work piece as shown in Figures 4-a2 and 4-b2; Figures 5-c2 and 5-d2; and Figures 6-e2 and 6-f2, all of which provide better quality results due to the use of VHA tools. So, in terms of surface quality, the results of machining products are getting better with the use of VHA tools [11], [12].

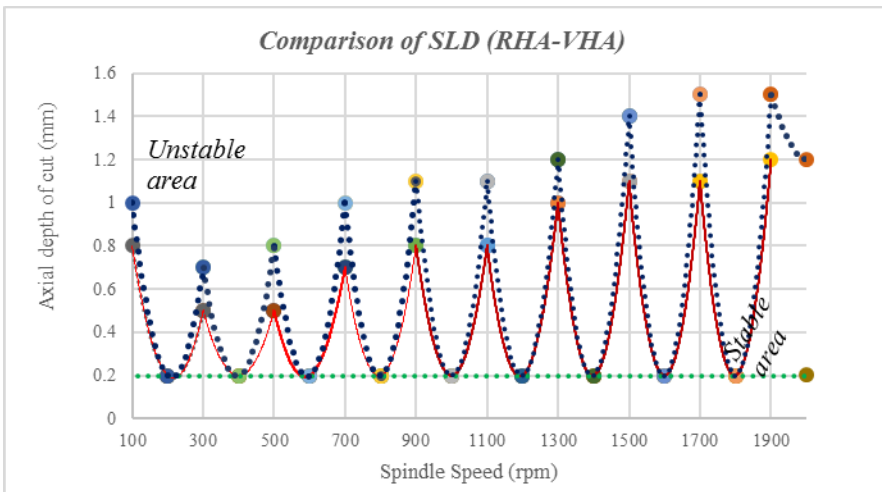
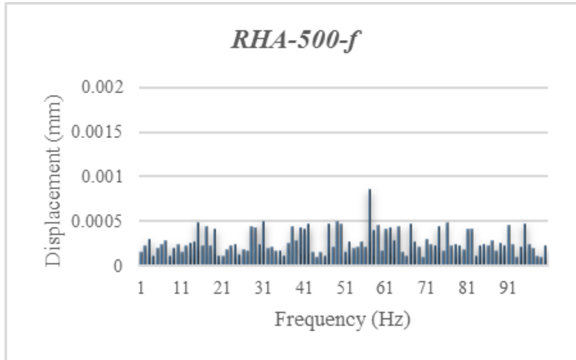
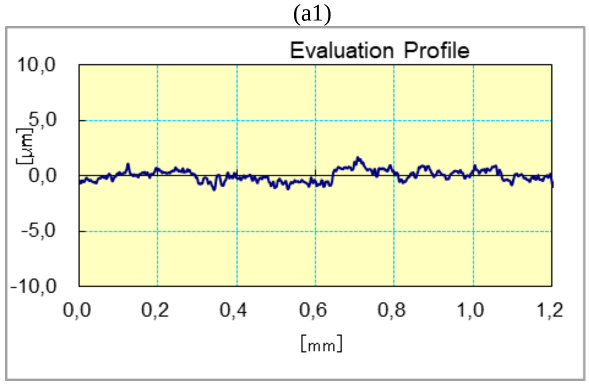


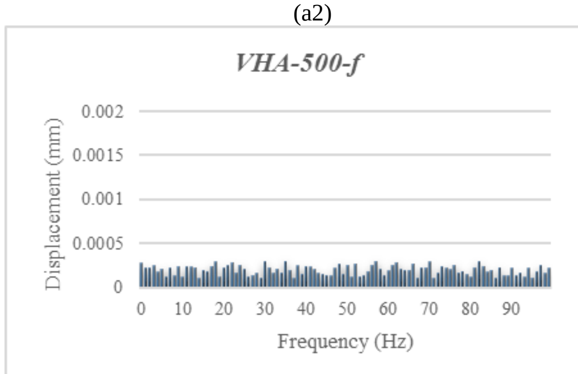
Figure 3. Comparison of SLD (RHA-VHA) in (SS-100 – 1900 rpm).



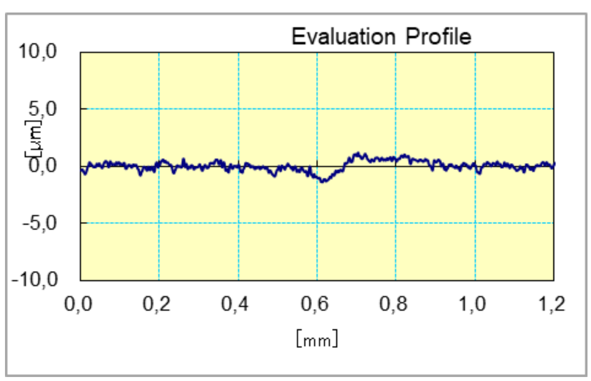
(a1)



(a2)

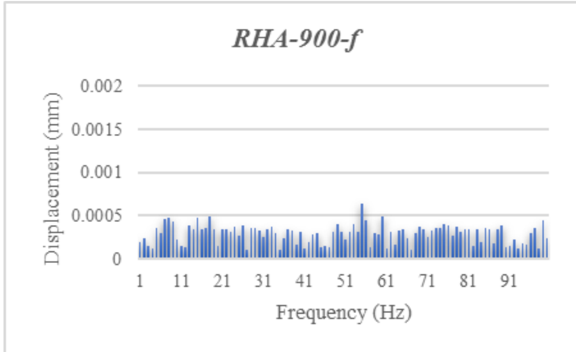


(b1)

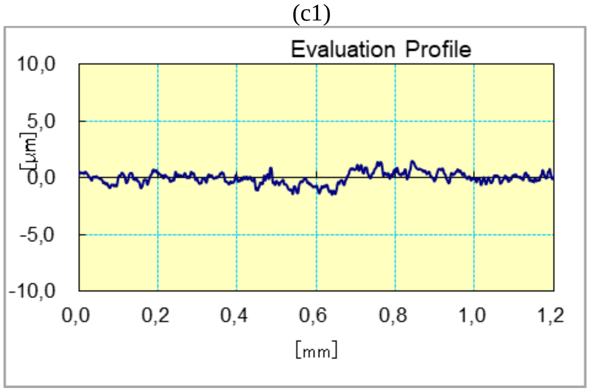


(b2)

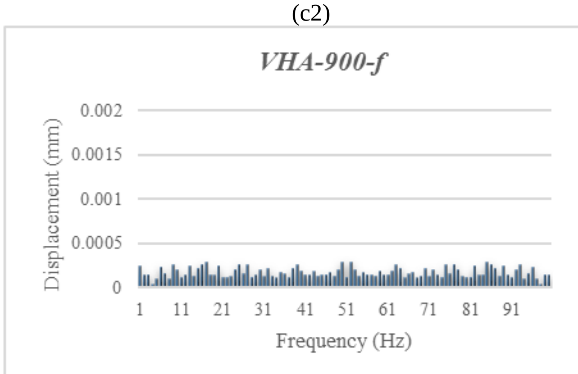
Figure 4. a1,a2,b1,b2. Spectrums and Ra (RHA-VHA in SS 500 rpm).



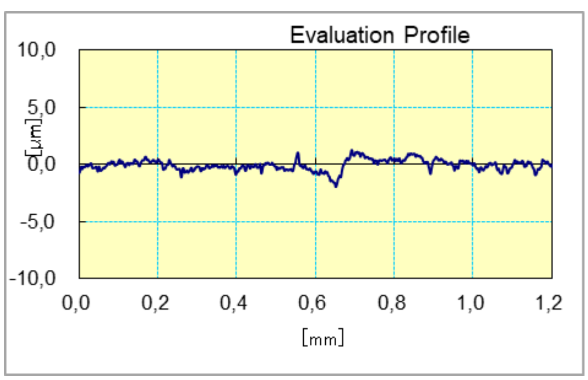
(c1)



(c2)

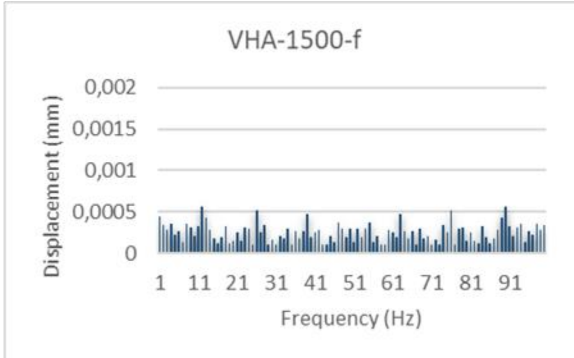


(d1)

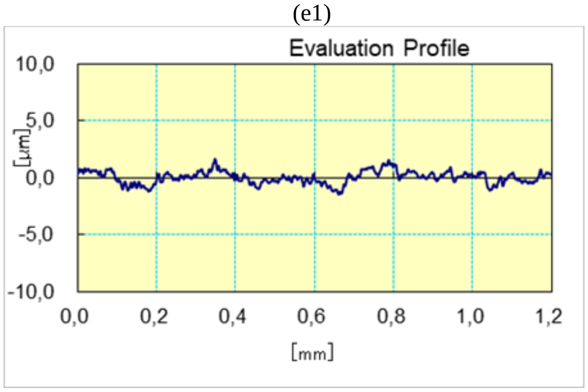


(d2)

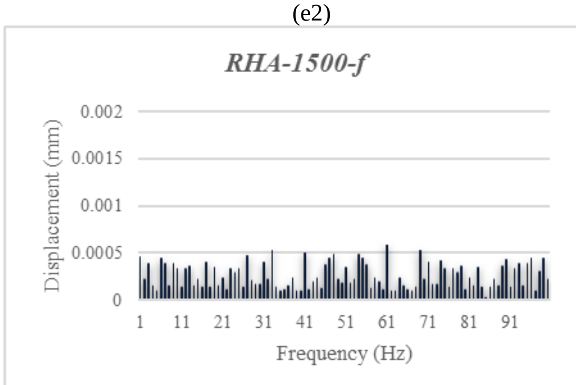
Figure 5. c1,c2,d1,d2. Spectrums and Ra (RHA-VHA in SS 900 rpm).



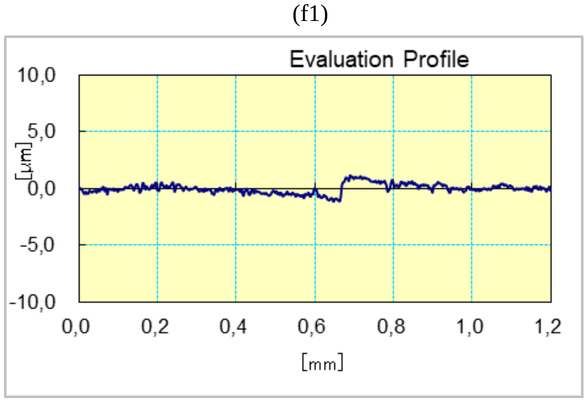
(e1)



(e2)

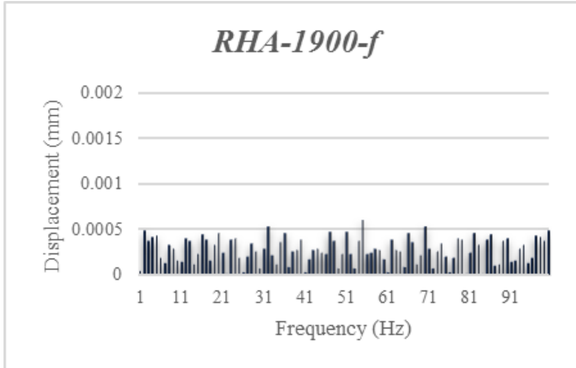


(f1)

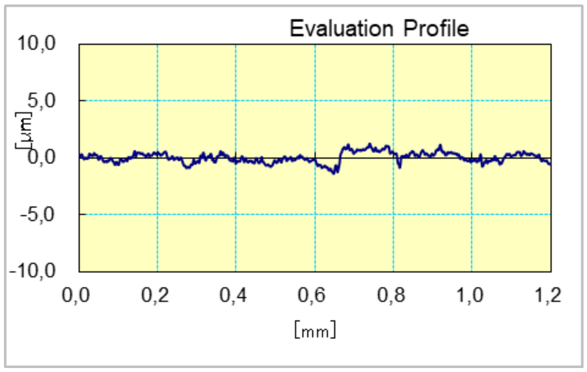


(f2)

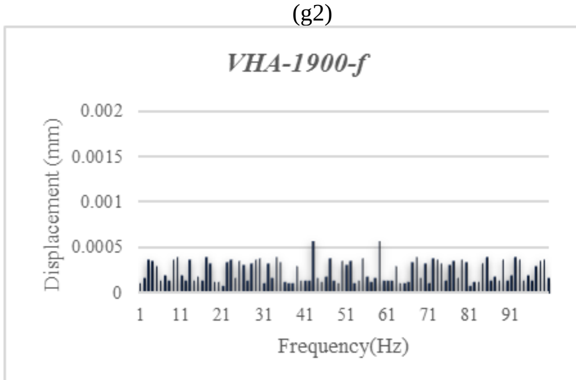
Figure 6. e1,e2,f1,f2. Spectrums and Ra (RHA-VHA in SS 1500 rpm).



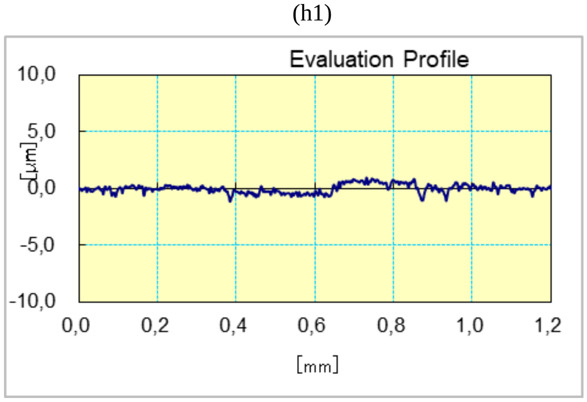
(g1)



(g2)



(h1)



(h2)

Figure 7. g1,g2,h1,h2. Spectrums and Ra (RHA-VHA in SS 1900 rpm).

Overall, the comparison between the use of VHA rather than RHA tools will increase the surface quality of a product, as shown in Table 3.

Table 3. Roughness quality improvement

SS (rpm)	*Ra (μm)* **RHA**	**VHA**	*(+) Quality* **%**
100	0.453	0.342	24.50
300	0.367	0.320	12.81
500	0.364	0.306	15.93
700	0.360	0.303	15.83
900	0.351	0.300	14.53
1100	0.363	0.230	36.64
1300	0.311	0.226	27.33
1500	0.312	0.259	16.99
1700	0.323	0.244	24.46
1900	0.368	0.222	39.67

4. CONCLUSIONS

- The variable helix angle tool provides a wide area of machining stability, which means minimal chatter.
- The Variable Helix Angle tool can vary the delay time so that it is possible to stay away from the tool's natural frequency meeting area, which causes the amplitude spectrum to decrease.
- The variable helix angle tool will increase product quality by an average of 22.87%.

5. REFERENCES

[1] SONIEF., AA., AN FAUZAN, FA, ALAMSYAH., (2019). Evaluation of Aluminum Surface Roughness in the Slot End-Mill Process with Variable Helix Angle, ICOMERA, IOP Publishing, 494 (2019) 012045. http://dx.doi.org/10.1088/1757-899X/494/1/012045

[2] SONIEF, AA., FAUZAN AN., FACHRY AZLAN, MA BASHORI, (2020), Chatter Vibration Comparison Between Normal Helix Angle and Variable Helix Angle in End Milling Process Based on Spectrum Analysis, Rekayasa Mesin, V11 N3, eISSN 2477-6041 article 25, p.531-536. https://doi.org/10.21776/ub.jrm.2020.011.03.25

[3] COMAK ALPTUNC & BUDAK, ERHAN. (2017). Modeling dynamics and stability of varia-ble pitch and helix milling tools for developing a design method to maximize chat-ter stability. Precision Engineering 47 (2017) 459–468. http://dx.doi.org/10.1016/j.precisioneng.2016.09.021

[4] Tools Catalog,
https://www.carbideanddiamondtooling.com/assets/images/Monster/15200.JPG

[5] HARDINSI, FESTO ANDRE, OYONG NOVAREZA, ACHMAD AS'AD SONIEF, (2021), Optimiza-tion Of Variable Helix Angle Parameters In CNC Milling Of Chatter And Surface Roughness Using Taguchi Method, Journal Of Engineering And Management In In-dustrial System 9 (1), e-ISSN 2477-6025, p. 35-44. DOI: 10.21776, https://jemis.ub.ac.id/index.php/jemis/article/view/400/287

[6] MUNOA, JOKIN., BEUDAERT, X., DOMBOVARI, Z., ALTINTAS, Y., BUDAK, E., BRECHER, C., STEPAN, G. (2016). Chatter Suppression Techniques in Metal Cutting. CIRP Annals - Manufacturing Technology 65 (2016) 785-808. http://dx.doi.org/10.1016/j.cirp.2016.06.004

[7] NIU, JINBO., DING, Y., ZHU, L. & DING, H. (2017). Mechanics and multi-regenerative stability of variable pitch and variable helix milling tools considering runout. Inter-national Journal of Machine Tools and Manufacture 123:129-145. https://doi.org/10.1016/j.ijmachtools.2017.08.006

[8] SONG, QINGHUA., JU, G., LIU, Z. & AI, X. (2014). Subdivision of chatter-free regions and optimal cutting parameters based on vibration frequencies for peripheral milling process. International Journal of Mechanical Sciences. 83:172-183. https://doi.org/10.1016/j.ijmecsci.2014.04.002

[9] WAN, MIN., FENG, J., ZHANG, W., YANG, YUN., & MA, Y. (2017) Working mechanism of helix angle on peak cutting forces together with its design theory for peripheral milling tools. Journal of Materials Processing Tech. 249:570-580. https://doi.org/10.1016/j.jmatprotec.2017.06.030

[10] WANG, YONG., WANG, T., YU, Z., ZHANG, Y., WANG, Y. & LIU, H. (2015). Chatter Pre-diction for Variable Pitch and Variable Helix Milling. Hindawi Shock and Vibra-tion. 2015:1-9. http://dx.doi.org/10.1155/2015/419172

[11] YUSOFF, AHMAD R. & SIMS, NEIL D. (2011). Optimization of variable helix tool ge-ometry for regenerative chatter mitigation. International Journal of Machine Tools and Manufacture. 51(2):133-141. https://doi.org/10.1016/j.ijmachtools.2010.10.004

[12] YUE CAIXU, HAINING GAO, XIANLI LIU, STEVEN Y. LIANG, LIHUI WANG (2019). A review of chatter vibration research in milling. CSAA Chinese Journal of Aeronautics. 32(2): 215–242. https://doi.org/10.1016/j.cja.2018.11.007