

CHATTER VIBRATION COMPARISON BETWEEN NORMAL HELIX ANGLE AND VARIABLE HELIX ANGLE IN END MILLING PROCESS BASED ON SPECTRUM ANALYSIS

Achmad As'ad Sonief

Associate Professor
Universitas Brawijaya
Mechanical Engineering Department
sonief@ub.ac.id

Arda Nur Fauzan

Student
Universitas Brawijaya
Mechanical Engineering Department

Fachry Azlan

Student
Universitas Brawijaya
Mechanical Engineering Department

Mohammad Aziz Bashori

Student
Universitas Brawijaya
Mechanical Engineering Department

Chatter vibration in machining processes is often found in cutting processes which will decrease the machining efficiency and the surface quality of the products. Chatter is a relative vibration of the cutting tool and workpiece caused by the fluctuation of cutting force that is concerned to be a self-excited vibration. The variable Helix Angle Cutting tool which has pitch angle variation will also inflict different tooth passing frequencies on the flute that stand contiguous and trim the resonance frequency. This research aims to compare chatter vibrations that occurred between Normal Helix Angle and Variable Helix Angle cutting tool based on spectrum analysis on cutting parameter variety (depth of cut; rotation speed; feed rate milling). The outcome is spectrum analysis can detect the chatter phenomenon, measure the natural frequency (38-42 Hz), and also compare chatter vibrations between two tools appropriately.

Keywords: Chatter Vibration, Normal and Variable Helix Angle, End Mill Process, Spectrum Analysis.

1. INTRODUCTION

Chatter vibration is an important problem that must be solved first before any problems that occurred in machining processes. Chatter is very destructive and harmful, because it will decrease the product quality and the machining efficiency. Regenerative chatter can be occurred because of the intermittent cut on milling process are unstable and result chip load different phase. Regenerative chatter will be occurred continuously with the same time delay. Munoa et al. [1] denoted that regenerative chatter maximum caused by high amplitude vibration. Resonance occurs when the natural frequency and the frequency of passing the tooth have an integer ratio, with amplitude resonance will be increased significantly. Resonance occurred when there is a maximum frequency shifting when the others are stable and will result a bad surface product by Song et al. [2]. An innovative cutting tool geometry is developed to control maximum regenerative chatter and resonance. Helix angle which is one of geometry parts that hold an important role to mitigate maximum regenerative chatter and resonance. Variable helix angle in cutting tool create time delay variation from the contiguous flutes. Time delay variations can mitigate regenerative chatter and avoid tooth passing frequency from machining natural frequency so that resonance can be prevented in certain machining parameters, according to Wang et al.[3].

Chatter can be controlled by right parameter selections such as axial depth of cut, rotation speed, and feed rate milling. The role of that parameters are also important in machining process because there will be cutting force dynamics that cause inaccuracies in chatter fluctuation and surface product by Sonief, et al.[4] and Balasubramanyam, et al.[5]. It also can limit the Material Removal Rate (MRR) in machining process and productivity decrease according to Kashyapi et al.[6]. The detection of the machining chatter can be done by spectrum analysis, which is applied to process the cutting force signal which is closely related to the machining conditions as said by Mei et al.[7]

The efforts to control machining chatter will be based on spectrum frequency analysis when the resonance occurred on each machining parameters role. Therefore, it is required to optimize machining parameter in end milling process. In this study, comparison between end mill process using normal helix and

variable helix angle cutting tool on cutting parameters and justified with surface product qualities..

2. METHODS AND MATERIALS

The experimental machining is using CNC Training Unit 3 Axis (CNC TU-3A), using Normal Helix Angle Tool (NHA) 40° and Variable Helix Angle (VHA) 40°/42° as in Figure 1. Aluminium Al-2011 work piece is set on cnc milling machine. Vibration transducer is installed right on the tool holder which is connected on computer with NI myRio Labview 2013 program to measure the vibration signals and Fast Fourier Transform (FFT). Experimental set up as in figure 2 and cutting parameter in table 1. Measurement data and spectrum analysis were taken in each cutting parameters. The justification will be done by conduct surface roughness value (Ra) test by surface roughness prober (Mitutoyo SJ-301) in every work pieces.

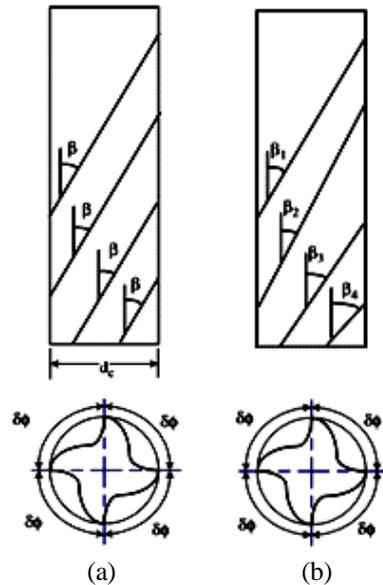


Figure 1. NHA tool (a) and VHA tool (b)

Tabel 1: Cutting Specification

Specification	Grade
Rotation speed (rpm)	600 ; 900 ; 1200
Feed rate milling (mm/min)	50 ; 75 ; 100
Axial depth of cut (ADOC) (mm)	0,6 ; 1,2 ; 1,8
Normal Helix Angle (NHA) (°)	40
Variable Helix Angle (VHA) (°)	40/42
Diameter tool (mm)	6

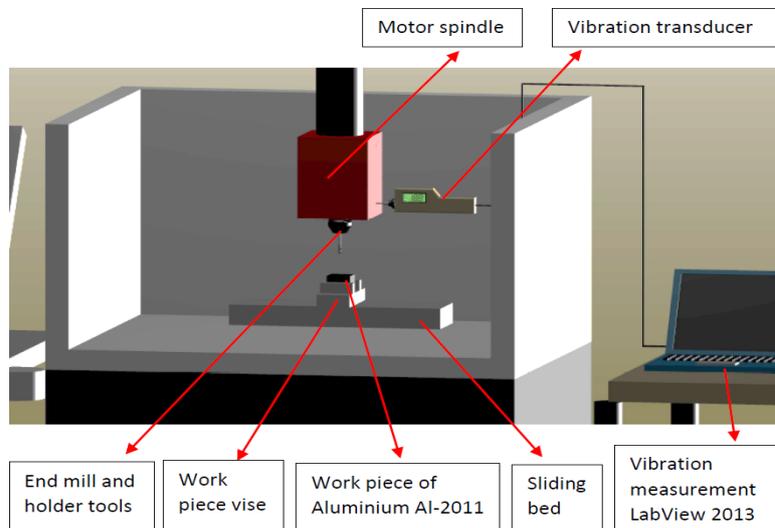


Figure 2. Experimental setup

3. RESULT AND DISCUSSION

The experimental spectrum analysis results in both milling process using normal helix angle and variable helix angle can be seen in these figures. On figure 3.a, shows the spectrum analysis result on 0.6 mm depth of cut variation with normal helix end mill (NHA) tool. In this condition, chatter was occurred in 41 Hz frequency and amplitude 0.893×10^{-3} rms. While in figure 4.b., shows the spectrum analysis results on 600 rpm spindle speeds variation with variable helix angle (VHA) tool, with the same frequency, the amplitude was decreased in to 0.0591×10^{-3} rms.

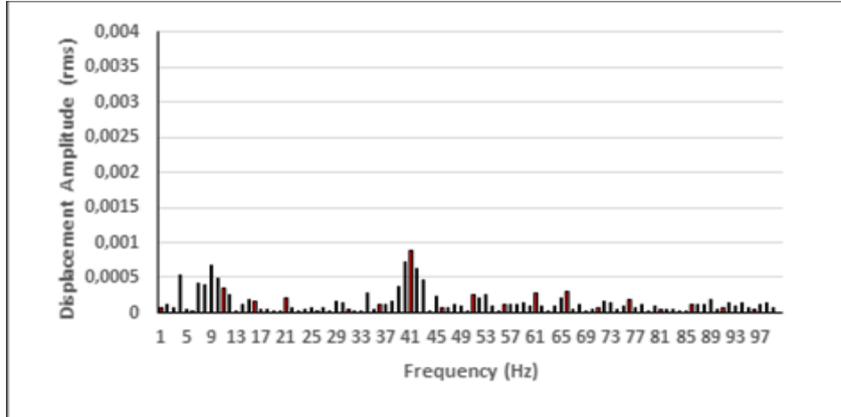


Figure 3.a. Frequency spectrum graphic NHA under doc variation

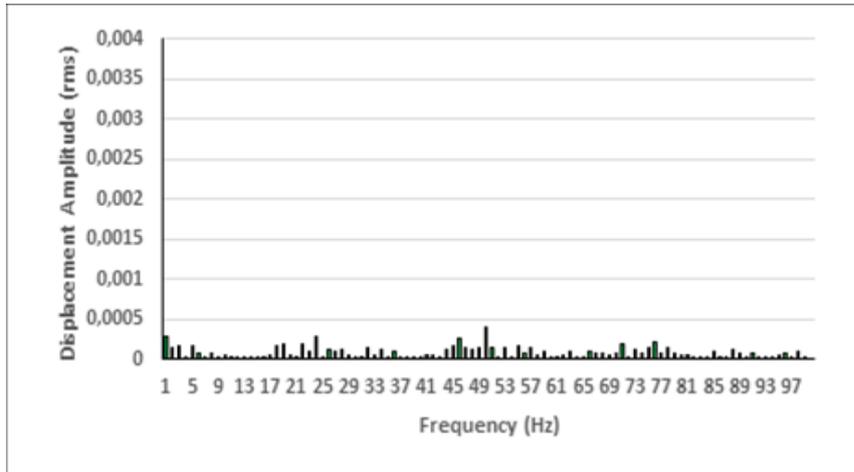


Figure 3.b. Frequency spectrum graphic VHA under doc variation

Figure 4.a., indicate the outcome of spectrum analysis of 600 rpm spindle speed variation for the milling tool (NHA). In this condition it is recorded that chatter take place at a certain frequency for 41 Hz with an amplitude of 0.975×10^{-3} rms. Whereas in Figure 4.b., indicate the outcome of spectrum analysis of 600 rpm spindle speed variation in the Variable Helix Angle (VHA) end-mill tool, with the same frequency the amplitude decreases to 0.1393×10^{-3} rms.

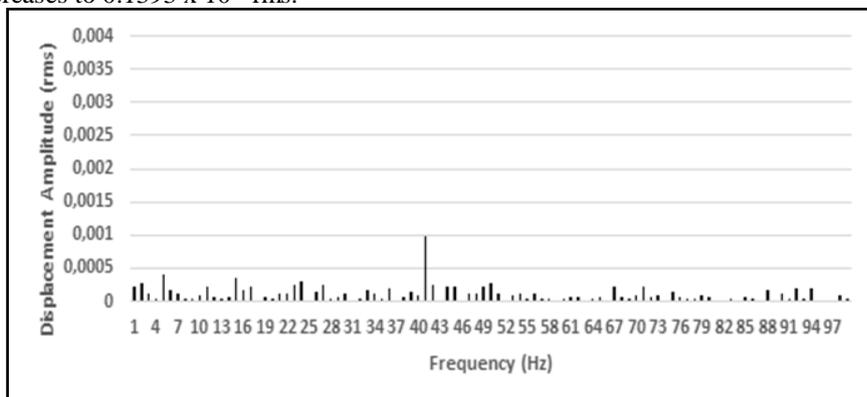


Figure 4.a. Frequency spectrum graphic NHA under ss variation

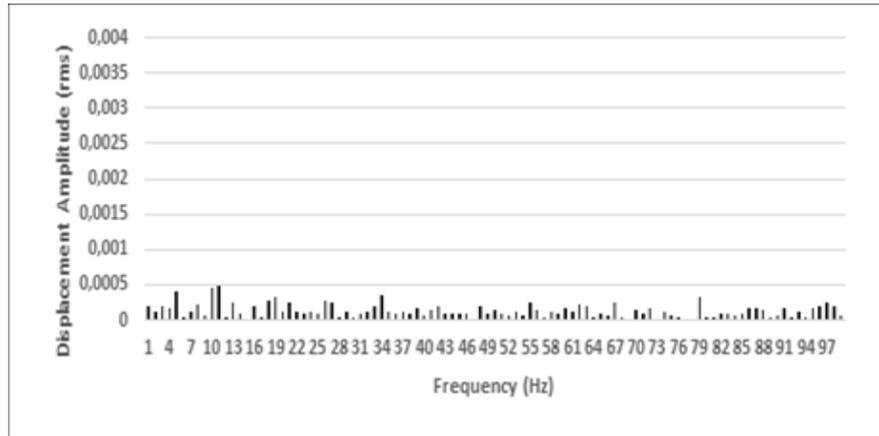


Figure 4.b. Frequency spectrum graphic VHA under ss variation

In figure 5.a., shows the results of spectrum analysis for variation of the feed rate (fr) 75 mm / min on end-mill Normal Helix Angle (NHA) tool. In this condition it is recorded that that chatter take place at a certain frequency for 42 Hz with an amplitude of 1.015×10^{-3} rms. Whereas in Figure 5.b., the spectrum analysis results of the variation of the feed rate (fr) 75 mm / min on the end-mill Variable Helix Angle (VHA) tool, with the same frequency the amplitude decreases to 0.0964×10^{-3} rms.

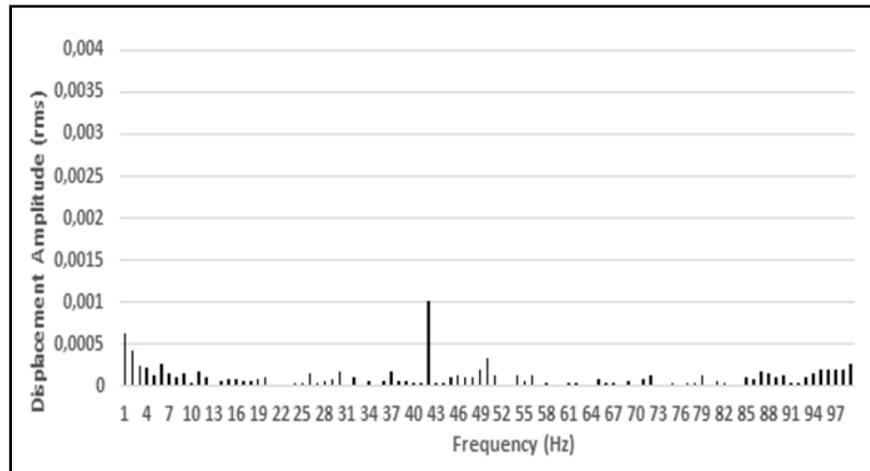


Figure 5.a. Frequency spectrum graphic NHA under fr variation

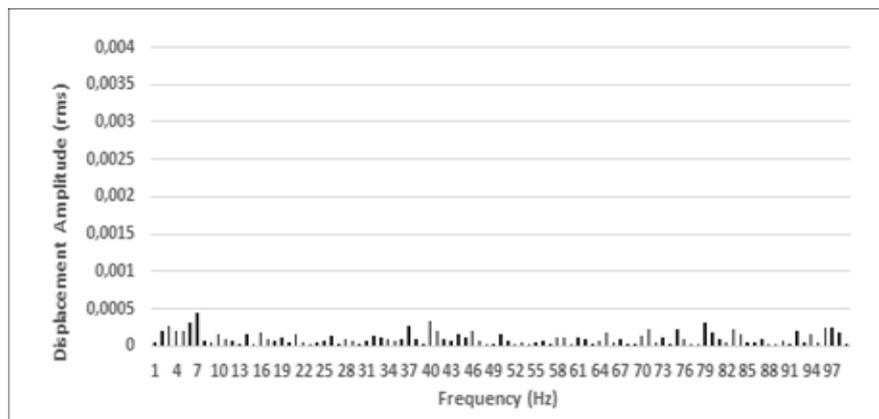


Figure 5.b. Frequency spectrum graphic VHA under fr variation

Overall, all cutting parameters can be seen in tabel 2.

Table 2. Spectrum analysis in NHA and VHA Tools

Cutting Parameter Variation	Normal Helix Angle (NHA)		Variable Helix Angle (VHA)	
	Amplitude (rms) ($\times 10^{-3}$)	Frequency (Hz)	Amplitude (rms) ($\times 10^{-3}$)	Frequency (Hz)
Doc (mm)				
0.6	0.893	41	0.0591	41
1.2	2.112	40	0.1073	40
1.8	3.865	40	0.1144	40
Ss (rpm)				
600	0.975	41	0.1393	41
900	1.034	39	0.2245	39
1200	1.164	42	0.1197	42
Fr (mm/men)				
50	1.351	39	0.0989	39
75	1.015	42	0.0954	42
100	1.018	38	0.1020	38

With spectrum analysis on the NHA tools, it shows the resonance chatter at 38-42 Hz frequency, this also shows the natural frequency of the tool. Resonance occurs when the comparison between the natural frequency and the frequency of passing the tooth have an integer ratio that appears to occur in all variations of cutting parameters. This comparison can be analysed, machining using a normal helix angle tool has the same tooth passing frequency in each flute. This makes the normal helix angle tool tend to be exposed to resonance as seen in all images (a). Whereas in machining with variable helix angle tool which has different tooth passing frequency in each contiguous flute. This makes variable helix angle able to avoid resonance by Niu et al. [8].

Comparison of the occurrence of chatter between NHA and VHA shows a significant decrease in amplitude, this caused by VHA with variable helix angle has varying pitch angle values. Variety in pitch angle causes tooth passing variations in frequency, so that the VHA device may evade maximum regenerative chatter. Likewise, the VHA tool with the pitch angle variation will cause time delay variations on tool so that the tooth passing frequency has a varying value. Therefore, these variations can prevent resonance so that the vibration displacement amplitude does not increase significantly. Although the principle said that both maximum regenerative and resonant chatter can cause an increase in vibration displacement amplitude, YUE et al.[9]. But the VHA tool will be able to prevent the maximum regenerative and resonant chatter, so the amplitude displacement is lower than the tool with NHA tool, Yusoff et al.[10]. This also justified by measuring the average surface roughness as display in table 3., with VHA tool that reduces vibration amplitude, the mean of Ra value also decreases which resulting better product quality, in accordance with Bala et al.[11].

Table 3. Surface roughness analysis in NHA and VHA Tools

Cutting Parameter Variation	Normal Helix Angle (NHA)	Variable Helix Angle (VHA)
	Mean Surface Roughness (μm)	Mean Surface Roughness (μm)
Doc (mm)		
0.6	1.150	0.390
1.2	1.558	0.469
1.8	1.633	0.543
Ss (rpm)		
600	0.473	0.411
900	0.364	0.313
1200	0.383	0.290
Fr (mm/men)		
50	0.384	0.368
75	0.488	0.440
100	0.786	0.555

4. CONCLUSIONS

Based on the comparative spectrum chatter vibration analysis between normal helix angel (NHA) and variable helix angel end-mill tools as follows:

- Spectrum analysis is able to detect the emergence of resonance chatter
- Spectrum analysis can assess natural frequency in the range of 38-42 Hz
- Variable helix angel could degrade chatter than normal helix angel tool.
- The highest chatter from successive cutting parameter variations is depth of cut, spindle speed and feed rate.
- Depth of cut and spindle speed variations as chatter stability parameters.

5. REFERENCES

- [1] MUNOA, J., BEUDAERT, X., DOMBOVARI, Z., ALTINTAS, Y., BUDAK, E., BRECHER, C, & STEPAN, G. 2016 Chatter suppression techniques in metal cutting *CIRP Annals*, 65 (2):785-808.
- [2] 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.
- [3] WANG, YONG, WANG, T., YU, Z., ZHANG, Y., WANG, Y. & LIU, H. 2015 Chatter Prediction for Variable Pitch and Variable Helix Milling *Hindawi Shock and Vibration*. 2015:1-9
- [4] SONIEF ACHMAD AS'AD, ARDA NUR FAUZAN, FIKRUL AKBAR ALAMSYAH 2018 Evaluation of Aluminum Surface Roughness in the Slot End-Mill Process with Variable Helix Angle *International Conference on Mechanical Engineering Research and Application (ICOMERA 2018)*, IOP Conference Series: Materials Science and Engineering Volume 494, ISBN:9781510884861, Malang, Indonesia.
- [5] BALASUBRAMANYAM ER. N., ER. P. GNANA PRAKASH., V.PALVANNAN, ER.M.YUGANDHAR 2015 Effect of Machining Parameters on Surface Roughness of End Milling *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, Volume 3 Issue II, ISSN: 2321-9653.
- [6] KASHYAPI, GAUTAM, SUHAS MOHITE, NACHIKET BELWALKAR. 2015. Formation of Stability Lobe Diagram (SLD) for Chatter Free Milling on Aluminium Alloy *Manufacturing Science and Technology India*, 3(2): 32-37, 2015.
- [7] MEI YONGGANG, RONG MO, HUIBIN SUN & KUN BU 2017 Chatter detection in milling based on singular spectrum analysis *The International Journal of Advanced Manufacturing Technology*, volume 95, and pages 3475–3486.
- [8] NIU, JINBO., DING, Y., ZHU, L. & DING, H. 2017 *Mechanics and Multi-Regenerative Stability of Variable Pitch and Variable Helix Milling Tools Considering Runout*, Shanghai : Shanghai Jiao Tong University.
- [9] YUE CAIXU, HAINING GAO, XIANLI LIU, STEVEN Y. LIANG, LIHUI WANG 2019 A review of chatter vibration research in milling *Chinese Journal of Aeronautics*, 32(2): 215–242.
- [10] YUSOFF, AHMAD R. and NEIL D. SIMS 2011 Optimization of Variable Helix Tool Geometry for Regenerative Chatter Mitigation *International Journal of Machine Tools and Manufacture*, Volume 51, issue 2, February 2011, pages 133-141.
- [11] BALA LULZIM, AFRIM GJELAJ, AVDYL BUNJAKU and AVDI SALIHU. 2012. Surface Roughness of Material Processing during Milling Process. *Journal of Mechanics Engineering and Automation* 2 (2012) 601-605.