Effect Of Technology Parameters On Tool Wear In Milling Process: An Overview

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***Abstract*—This paper presents an overview of the efect of technology parameters on tool wear in milling process. In this research, a number of previous researches are provided to analyze the effect of machining process parameters on milling tool wear. From this, researchers can identify the parameters which are choosen as input parameters when experimenting on tool wear. Based on this, the selection of input parameters of the experimental process can be given to survey the tool wear when milling gears.**

Keywords—Overview study; tool wear in milling process; technology parameters.

I. INTRODUCTION

In machining processing, milling is commonly used because of the capable of ensuring productivity and high accuracy [1, 2]. There are many different criteria to evaluate the efficiency of the milling process. When the tool is worn, it not only affects the accuracy of the machining surface profile, but also the material removal rate and tool life and thereby greatly affecting to the economic and technical efficiency of the milling process. Therfore, tool wear is comomly chosen as one of the criteria for evaluating the milling process [3]. Tool wear in milling process is affected by a number of parameters; tool wear was affected by the cutting heat, cutting force and friction between the tool and the machining surface. To investigate the influence of technology parameters on tool wear in milling process, it is necessary to conduct experimental studies in each specific case. However, the parameters selected as the input parameters were not the same in each research. In this paper, an overview of a number of previous works will be presented in order to identify the technology parameters commonly used to investigate tool wear on milling process.

II. OVERVIEW

Karaguzel et al. [4] investigated tool wear in the back side when milling a helical groove for three materials: Inconel 718, Waspaloy and Ti6Al4V. The cutting tool used in this study was cutting tool with three cutting pieces F40M. In this study, for each type of material they also conducted experiments with three methods such as dry, flood cooling and minimum quantity lubricant (MQL). Tool wear on the back side for each material is shown in Fig. 1, Fig. 2 and Fig. 3. It can be draw from these figures as follows:

- For all three cases with three different materials, the tool wear when machining with dry is greatest among these cases. This is also noticeable because when machining is dry, the friction between the back of the tool and the machining surface of workpiece is very large; the cutting heat in this case is also very large which are causes for quickly wearing the tool compared to the other methods.

- For Inconel 718 steel, in the starting machining process, machining time is less than 10 minutes when using MQL method; the tool wear will be slower than when using the flood cooling method. However, when the machining time is over 10 minutes, the tool wear rate for both cases is similar.

- For machining alloy material, in the first period of cutting process (less than 5 minutes), the wear speed for the two cases with MQL and flood cooling methods will have a similar tool wear rate. When the machining time is in the range of 5 to 7 minutes, using MQL method has a much smaller tool wear rate than the flood cooling method. However, if after a period of 7 minutes, the MQL method makes the tool wear rate much greater than the flood cooling method.

- For Ti6Al4V material, the rate of tool wear is the same for both cases using MQL and flood cooling methods; however the tool wear using flood cooling thethod is always greater than using the MQL method.

Fritz Klocke et al. [5] investigated the effect of cutting speed on the tool wear when machining by using a coated cutting tool (Al, Cr)N as shown in Fig. 4. In this figure, VB is the tool wear (mm), "I" is an index to estimate the durablity of cutting tool. When I = 1, the cutting tool should be replaced or sharpened.

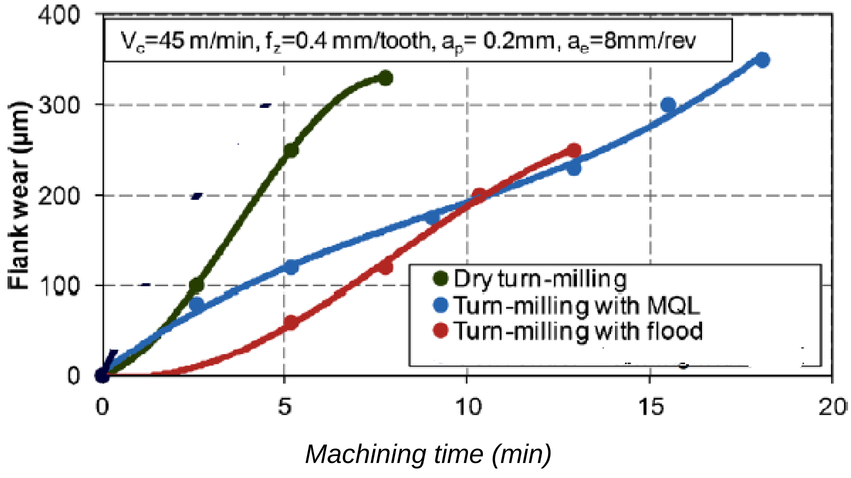


Fig. 1. Effect of three methods on tool wear when milling Inconel 718 [4]

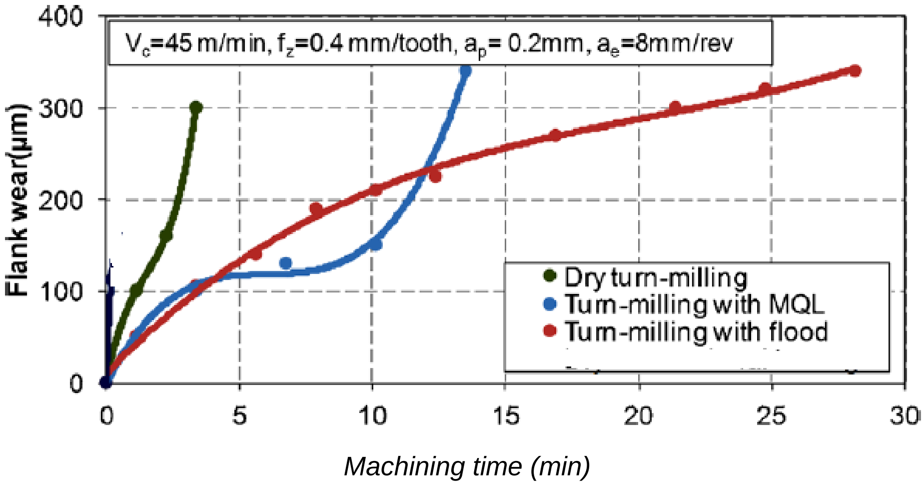


Fig. 2. Effect of three methods on tool wear when milling waspaloy [4]

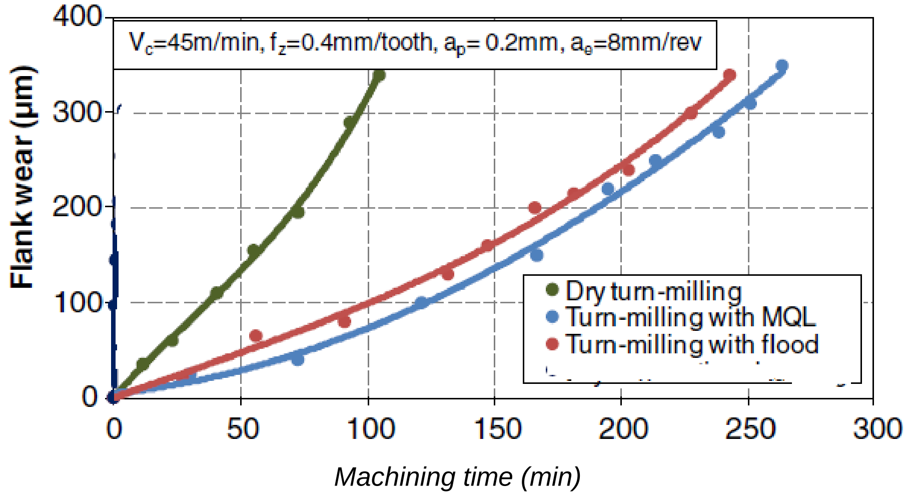


Fig. 3. Effect of three methods on tool wear when millingTi6Al4V [4]

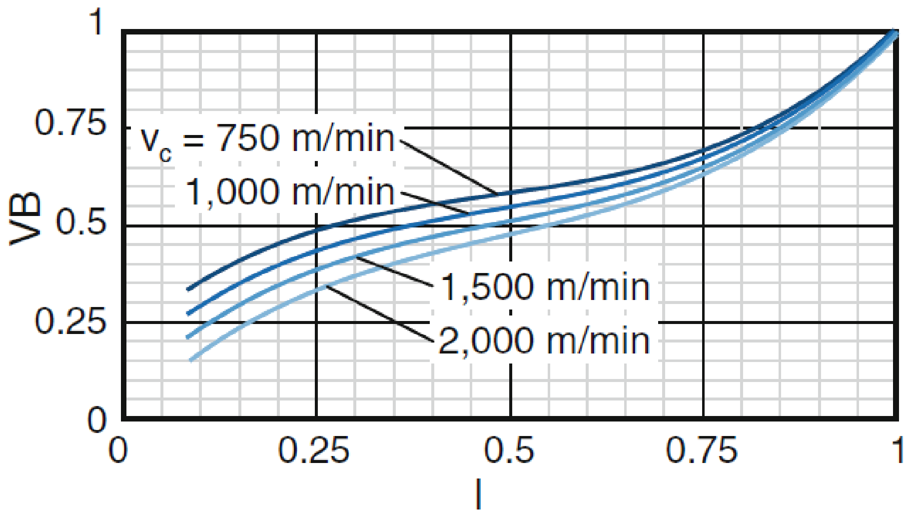


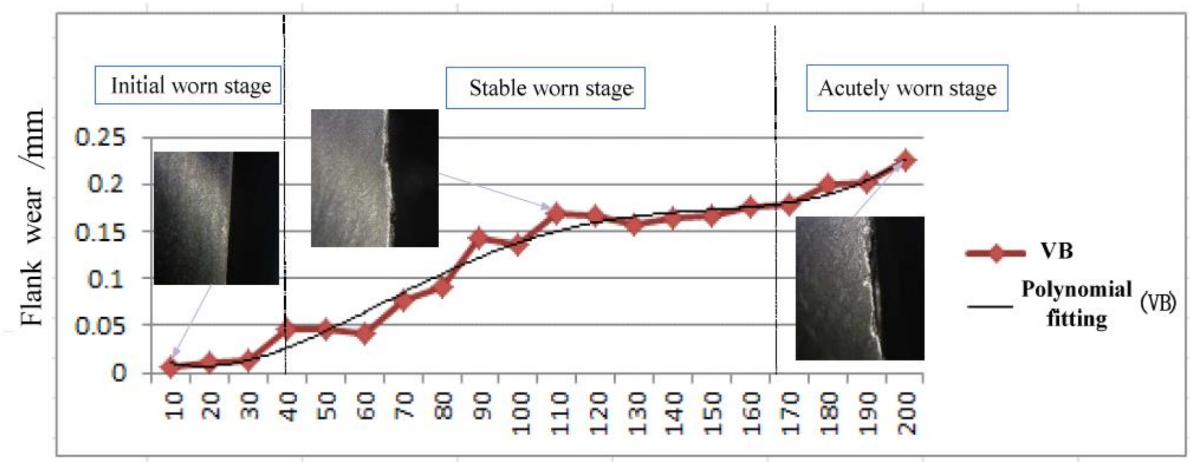
Fig. 4. Effect of cutting speed on tool wear when machining with a coated cutting tool (Al,Cr)N [5]

From the observation of Fig. 4, the tool wear rate will increase if the cutting speed is reduced. However, the effect of the cutting speed on the tool wear is not much. When the cutting speed changes nearly 3 times (from 750 m /min to 2000 m/ min), the tool wear also changes slightly.

Zhaoju Zhu et al. [6] experimented for milling titanium alloy (Ti6Al4V) with a cutting piece denoted by Walter JDXTIZY4GWT/20 * 40 * 50R0 to evaluate the rate of tool wear on the back side. Sevaral cutting parameters used in this study are presented in Table 1. The results of this research is shown in Fig. 5

Table 1. Cutting parameters and their values [6]

Number of cutting piece : 4	Helical angle: 450
Diameter of cutting tool: 20 mm	Length of cutting tool: 105 mm
Cutting speed: 120 m/min	Feed rate per tooth: 0.1mm/tooth
Depth of cut: 18 mm	Width of cut: 0.8 mm
Speed of main shaft: 1909.92 v/min	Feed rate: 763.97 mm/min



Machining time (min.)

Fig. 5. Tool wear in back side when milling Ti6Al4V by Walter JDXTIZY4GWT/20*40*50R0 tool [6]

The observation of Fig. 5 shows that the initial wear period of the cutting tool lasts about 40 minutes with values of cutting parameters as shown in Table 1. After this period, the tool wear on the back side is 0.05mm. The tool wear in the period of 130 minutes is about 0.12mm. When the cutting time exceeds 170 minutes, the tool is worn very fast, which is also the limit of the tool life.

Ibrahim et al. [7] compared the durability of four cutting tools when machining two alloys i.e., Ti5553 and Ti6Al4V. The four types of cutting tools used in this study include H13A, 1105, cement-coated cutting tools (denoted by Variant 1) and cement-coated cutting tools in which coarse particles of carbide (WC) has a rough size (denoted Variant 4). In this study, they chose the allowable wear limit of the tool on the back side i.e., 0.4mm. The results are presented in Fig. 6 and 7, where V_c is the cutting velocity and fz is the feed rate, a_p is the depth of cut.

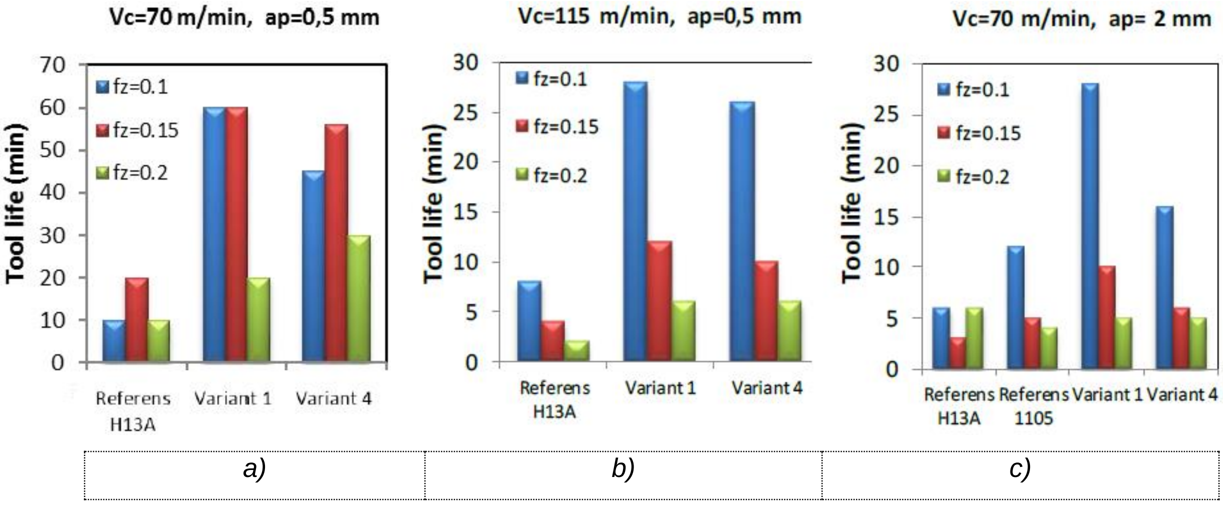


Fig. 6. Tool life when machining alloy Ti5533 with different values of cutting parameters [7]

The results from Fig. 6 with the cutting speed 70 (m/min) and the deep of cut 0.5 (mm) can be presented as follows:

- For H13A cutting tools, the tool life during machining with the feed rate per tooth 0.15 (mm/tooth) is much greater than that for machining with the feed rate per tooth in 0.1 (mm / tooth) and 0.2 (mm / tooth).

- Using variant 1 for a cutting tool, if the feed rate per tooth is 0.1 (mm/ tooth) and 0.15 (mm/ tooth), the tool life is much greater than that with the feed rate 0.2 (mm / tooth).

- With variant 4 used for cutting tools, when machining with the feed rate per tooth 0.15(mm / tooth), the tool life reaches the maximum value, then decreasing the tool life with the case of the feed rate 0.1 (mm/ tooth). When machining with the feed rate 0.2 (mm / tooth), the tool life is the smallest.

As shown in Fig. 6b, machining with the cutting speed of 115 (m/ min), the depth of cut 0.5 (mm) and the tool materials including H13A, Variant 1 and Variant 4 shows that the tool life in machining with the feed rate 0.1 (mm / tooth) has a much greater value than that with the feed rate 0.15 (mm / tooth) and 0.2 (mm / tooth). This means that increasing the feed rate will reduce the tool life.

It is observed from Fig. 6c that machining with the cutting speed 70 (m/ min) and the depth of cut 2 (mm) is resulted as follows:

- The tool life with H13A material when machining with the feed rate per tooth 0.1 (mm / tooth) and 0.2 (mm / tooth) has a greater value than when mwchining with the feed rate 0.15 (mm / tooth).

- For using the three types of cutting tool materials 1105, Variant 1 and Variant 4, the tool life when machining with the feed rate per tooth 0.1 (mm / tooth) is the largest, and then decreasing the tool life when the feed rate per tooth 0.15 (mm / tooth). In the tool life with the feed rate 0.2 (mm / tooth) is the smallest. Thus, it can be seen that increasing the feed rate will reduce the tool life with these three types of cutting tools (1105, Variant 1 and Variant 4).

Fig.7 is resulted as

- For the feed rate per tooth of three different cases (H13A, Variant 1 and Variant 4) is (0.1 mm / tooth - Figure 7a, 0.15 mm / tooth - Figure 7b and 0.2 mm / tooth - Figure 7c), when machining Ti6Al4V alloy, the tool life is bigger than that when machining Ti5533 alloy.

- When machining Ti6Al4V material by using the Variant 1 cutting tool with the feed rate per tooth 0.1 mm / tooth and 0.15 mm / tooth the tool life is the largest, and then decreasing the tool life with the Variant 4 and H13A cutting tool, respectively. This result is also consistent with the case when machining Ti5533 material.

- When machining Ti6Al4V material with the feed rate per tooth 0.2 mm / tooth, the tool life is reduced in three cases of tool material sush as the Variant 4 Variant 1and H13A, respectively.

- When machining Ti5533 with the feed rate 0.2 mm / tooth, the tool life in two cases i.e., Variant 1 and Variant 4 is equivalent and greater than the tool life when using H13A for cutting tool.

- With all three types of cutting tools, increasing the fedd rate will reduce the tool life. However, the effect of the feed rate on the tool life is not the same for different types of tools. For example, considering the case with Variant 1 for tools to machine Ti6Al4V material, the tool life is reduced from 72 down to 38 minutes when the feed rate increases from 0.1 mm / tooth to 0.15 mm / tooth that is equivalent to 50%. When the feed rate increases from 0.15 mm/ tooth to 0.2 mm/ tooth, the tool life decreases from 38 down to 12 minutes. The same results applied for different types of tools when machining different types of materials also ocurr.

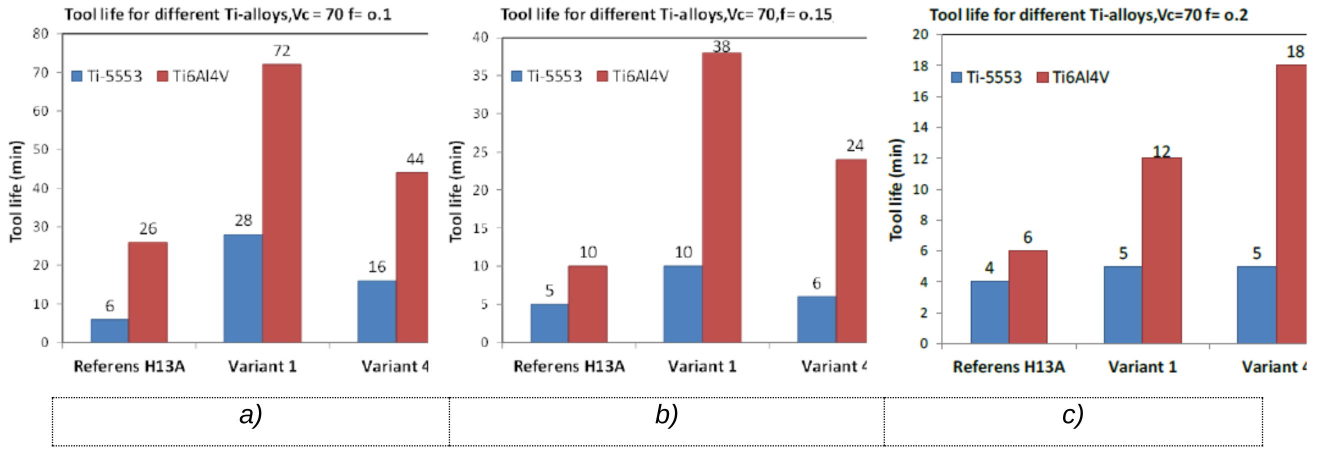


Fig. 7. Comparison between two types of material i.e., Ti5533 và Ti6Al4V with different values of cutting parameters [7]

Mohamed Konneh et al. [8] conducted experiments to determine the effect of cutting speed, feed rate and depth of cut on tool wear on the back side when machining Soda lime glass. The research shown that when the cutting speed is less than 502 m/min, all cutting parameters have a significant effect on tool wear. The feed rate has the most influence on the tool wear, followed by the influence of the cutting speed, the depth of cutt on tool wear, respectively. When the cutting speed is greater than 502 m / min, the depth of cutting does not affect to the tool wear.

Palanisamy et al. [9] proposed the effect of cutting speed, feed rate and depth of cut on tool wear when machining AISI 1020 steel using a cutting tool made by P20. The influence those parameters on tool wear are descended by the cutting speed, feed rate and depth of cut, respectively. In addition, in this study, the influence of the cutting parameters on the tool wear is shown from Fig. 8 to Fig. 10.

It is observed from Fig. 8 to Fig.10 that when the cutting speed, feed rate and depth of cut increase, the tool wear increases.

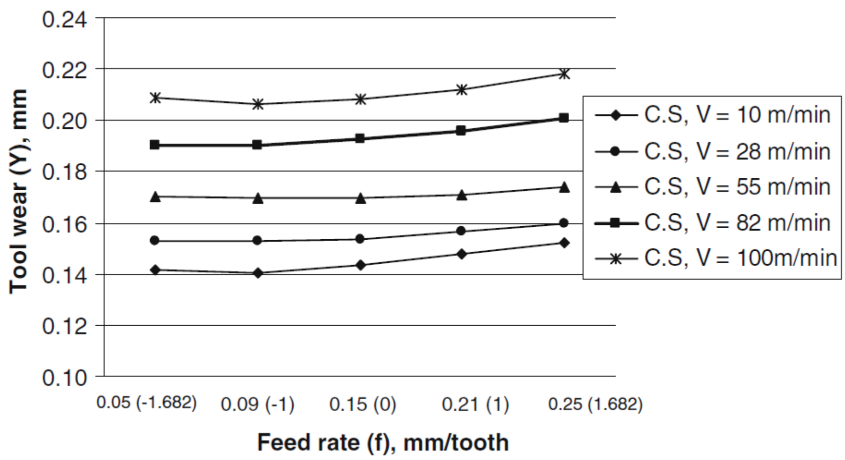


Fig. 8. Effect of the feed rate on tool wear when machining AISI 1020 alloy by using tool P20 [9]

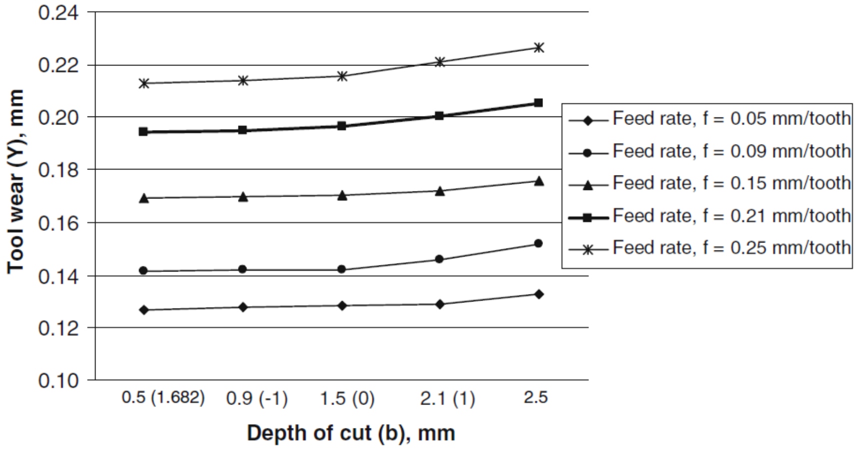


Fig. 9. Effect of the depth of cut on tool wear when machining AISI 1020 alloy by usin tool P20 [9]

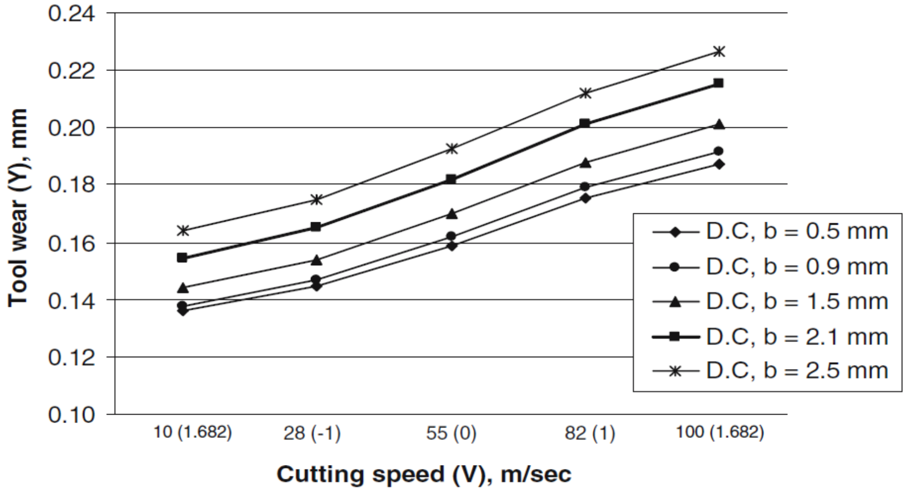


Fig. 10. Effect of the cutting speed on tool wear when machining AISI 1020 alloy by usin tool P20 [9]

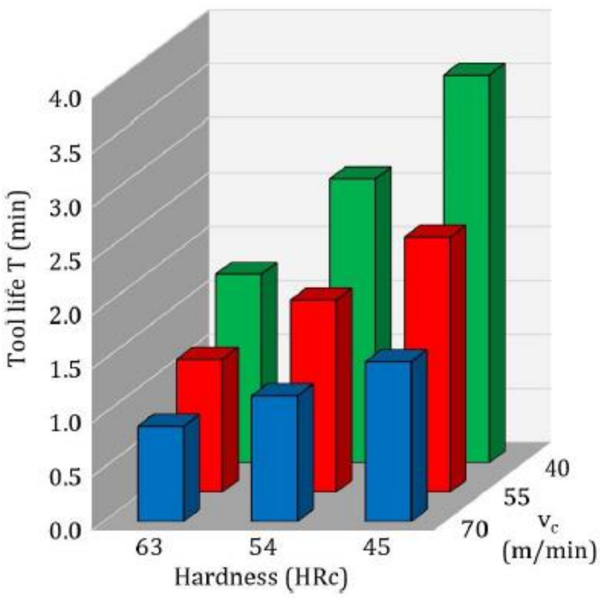


Fig. 11. Tool life when changing hardness and cutting speed [10]

Sredanović et al. [10] investigated the effect of material hardness of workpiece and cutting speed on the tool life coated by TiAlN with using the MQL method. The workpiece material used in this study is X155CrVMo12 steel with hardness levels of 45, 54 and 63 HRC. The three values of cutting speed are 40, 55 and 70 (m/ min). The results are shown in Fig. 11.

Fig.11 shows that when the hardness of the workpiece and the cutting speed increase, the tool life decreases. The tool life will have the greatest durability when machining a material with 45HRC hardness at a cutting speed of 40 (m / min), whereas machining a material with 63 HRC hardness at a cutting speed of 70 (m / min), the tool life is the minimum. However, the results demonstrate that the tool life is quite small i.e., the tool life with the highest value is only about 3.5 minutes. This shows that the use of TiAlN coated for cutting tool to machine X155CrVMo12 steel is not suitable.

Duong Xuan-Truong et al. [11] investigated the tool wear with using a PVD-coated for cutting tool to machine Inconel 718 steel. In this research, results shows that cutting parameters including cutting speed, feed rate and depth of cut have a significant effect on tool wear. The cutting speed has the most influence on the tool wear, and then the influence of the cutting depth and the feed rate on tool wear decreases, respectively.

Ali Riza Motorcu et al. [12] studied the effect of cutting speed and tool material on the tool wear when milling Inconel 718 steel. The two types of cutting tools including TiAlN and TiNN + TiN are used in this research. Result is shown in Fig. 12.

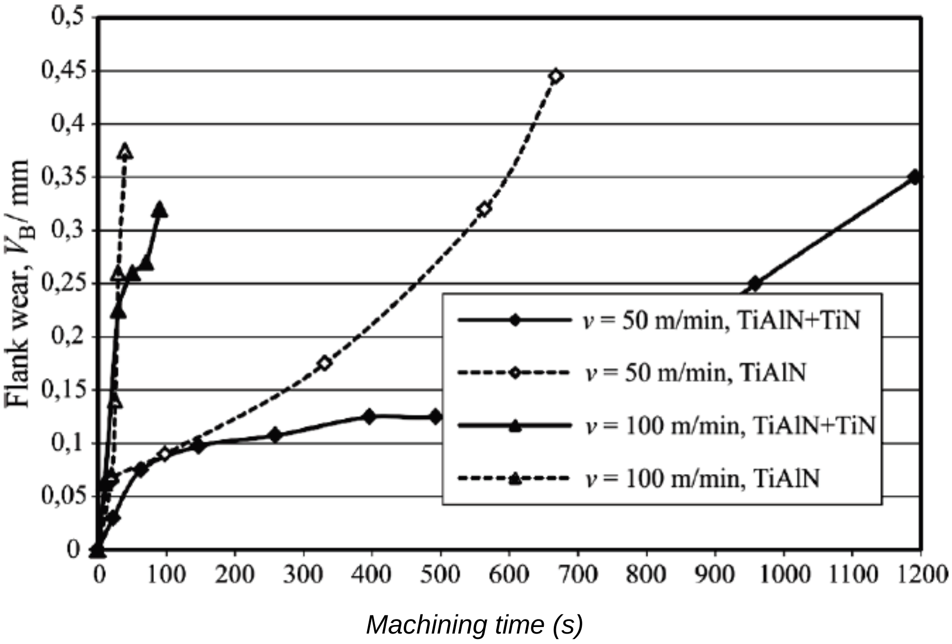


Fig. 12. Effect of cutting speed and tool material on tool wear when Inconel 718 [12]

It is observed from Fig. 12 that the results can be concluded as follows:

- Using TiAlN + TiN coated for cutting tools has a smaller tool wear rate than using TiAlN coated for cutting tools.

- For both types of cutting tool materials, when the cutting speed increases, the tool wear increases quickly.

III. CONCLUSION

From an overview of a number of privious works on tool wear in milling process, there are many factors that affect tool wear, such as cutting parameters, tool parameters, parameters of cooling lubricatio, and parameters of processed materials. Those researches are usually conducted by experimental methods. However, with a large number of parameters that affect tool wear, it is difficult to consider all of these parameters within a study. In addition, from the studies reviewed above, the cutting parameters and tool parameters are often selected by scientists as the input parameters of the experimental process. The number of studies referring to these two groups of parameters accounts for a large proportion of the studies. However, in each research, the effect of cutting parameters and tool parameters on tool wear varies in specific conditions. Therefore, in order to have a basis to control the tool wear in each specific case, it is advisable to examine the effect of cutting parameters and tool parameters on tool wear.

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REFERENCES

[1]. Tran Van Dich, Nguyen Trong Binh, Nguyen The Dat, Nguyen Viet Tiep, Tran Xuan Viet (2003), *Manufacturing technology*, Science and technics publishing House.

[2]. Tran Van Dich (2001), *Milling techonoly*, Science and technics publishing House.

[3]. Banh Tien Long, Tran The Luc, Tran Sy Tuy (2013), *Principles of Materials Processing*, Science and Technics Publishing House, Ha Noi.

[4]. U. Karaguzel, U. Olgun, E. Uysal, E. Budak, M. Bakkal (2014), *Increasing tool life in machining of difficult-to-cut materials using nonconventional turning processes*, Int J Adv Manuf Technol, DOI 10.1007/s00170-014-6588-7

[5]. Fritz Klocke, Christof Gorgels, Gerd-Thomas Weber, Rolf Schalaster (2011), *Prognosis of the local tool wear in gear finish hobbing*, Prod. Eng. Res. Devel, Vol. 5, pp.651–657, DOI: 10.1007/s11740-011-0343-9

[6]. Zhaoju Zhu , Jie Sun, Laixiao Lu (2016), *Research on the Influence of Tool Wear on Cutting Performance in High-Speed Milling of Difficult-to-Cut Materials*, Key Engineering Materials, Vol. 693, pp. 1129-1134

[7]. M. Ibrahim. Sadik, José Garcia (2018), *Wear development in machining of titanium alloys (Ti6Al4V and Ti5553) with specific designed carbide substrate*, XIVth International Conference on High Speed Machining

[8]. Mohamed Konneh, Mst. Nasima Bagum, Mohammad Yeakub Ali, Tasnim Firdaus Bt. Mohamed Arif (2018), *Tool Wear Mechanisms during Cutting of Soda Lime Glass*, IOP Conference Series: Materials Science and Engineering, DOI:10.1088/1757-899X/290/1/012039

[9]. P. Palanisamy, I. Rajendran, S. Shanmugasundaram (2007), *Prediction of tool wear using regression and ANN models in end-milling operation*, Int J Adv Manuf Technol, Vol. 37, pp. 29–41, DOI: 10.1007/s00170-007-0948-5

[10]. B. Sredanović, G. Globočki-Lakić, D. Kramar, F. Pušavec (2018), *Influence of Workpiece Hardness on Tool Wear in Profile Micro-milling of Hardened Tool Steel*, Tribology in Industry, Vol. 40, No. 1, pp. 100-107, DOI: 10.24874/ti.2018.40.01.09

[11]. Duong Xuan-Truong, Tran Minh-Duc (2013), *Effect of cutting condition on tool wear and surface roughness during machining of Inconel 718*, International Journal of Advanced Engineering Technology, pp.102-112

[12]. Ali Riza Motorcu, Abdil Kuş, Rıdvan Arslan, Yücel Tekin, Rıdvan Ezentaş (2013), *Evalutation of tool life – tool wear in milling of Inconel 718 superalloy and the investigation of effects of cutting parameters on surface roughness with Taguchi method*, Tehnički vjesnik, Vol. 20, No. 5, pp. 765-774.