PAPER • OPEN ACCESS

Tool Wear Analysis of Coated Carbide Tools on Cutting Force in Machining Process of AISI 4140 Steel

To cite this article: Sobron Lubis *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **852** 012083

Tool Wear Analysis of Coated Carbide Tools on Cutting Force in Machining Process of AISI 4140 Steel

Sobron Lubis[1]*, Rosehan[1], Steven Darmawan[1], Benny Indra[1]
[1]Mechanical Engineering Department, Faculty of Engineering Universitas Tarumanagara

*Sobronl@ft.untar.ac.id

Abstract. In manufacturing industries specifically in metal machining, the use of the cutting tool is important to consider. The use of the cutting tool has not been used optimally, as well as cutting parameters. In the cutting process, the wear of the cutting tool and cutting force has a very close relationship. This research was carried out to analyze the wear of coated carbide cutting tool and cutting forces produced in turning AISI 4140 steel workpieces. This study was conducted with a variation of five cutting speed levels consisting of 180 m/min, 220 m/min, 260 m/min, 300 m/min, 340 m/min and depth of cut 0.7 mm. To observe the tool wear, every 5 minutes with a maximum limit value of V_B of 0.3 mm and for the cutting force values taken every 1 minute. From the results of the study obtained: The increase in the value of the cutting force is affected by the increase in wear that occurs in the cutting tool due to a change in tool geometry due to wear on the cutting tool. The highest feeding force value is at the cutting speed (Vc) 340 m / min at 368 N and the greatest cutting force value is at the cutting speed (Vc) 340 m / min at 371 N.

1. Introduction

When cutting metals, it is very important to consider cutting tools in their use to form raw material into a product. Several cutting parameters can affect the results of machining. Variations of these cutting parameters can affect the level of wear of the cutting tool and cutting force. The greater the value of the cutting tool wear is directly proportional to the surface roughness of the workpiece the higher the value. This is because, at the time of cutting, the cutting edge of the cutting tool is no longer cutting work objects, but rather because of cutting caused by friction from the worn cutting tool. [1].Increased cutting speed increases the shear angle, causing the shear section to shrink. Reducing the shear plane results in a decrease in the cutting force, in the phenomenon of a decrease in the cutting force it causes deformation that occurs smaller, thus increasing the surface roughness of the workpiece. [2] This increase in roughness is undesirable because surface conditions do not match what is desired.Cutting tools have an important role in the machining process. Discrepancies in the use of the slightest cutting tool can influence the results of the machining process. The choice of the cutting tool, the exact cutting parameters are necessary to consider because it can affect the level of wear that occurs in the cutting tool and the surface roughness of the workpiece produced can be controlled. The wear and tear that occurs in the contact area of the cutting tool and the workpiece when cutting metal in long machining and high cutting speed causes friction and friction which causes heat, and certainly causes wear and tear on the cutting tool, therefore it certainly affects the cutting force. The main cause of wear and tear on cutting tools is high cutting temperatures as a result of friction of the workpiece and cutting tool, which affects the tool life and surface roughness of the workpiece, which in turn will affect the quality of the product. Cutting tool wear is a gradual loss of the cutting tool surface brought about by mechanical action. This if not immediately addressed will cause the machining process of a component to be imperfect, in this case, it will cause a high value of surface roughness.
Generally, tool wear is characterized by a loss of the ideal tool geometry influencing the process conditions. Changed process conditions have an impact on the achievable component surfaces using the macroscopically visible roughness as well as microscopic defects of the surface layer.

[3]. From research conducted by Sampsa (2018) states that Tool edge geometry has the most significant effect on the feed force, Initial flank wear contributes 20–50% to the feed force even without friction. [4]. The increased cutting force will certainly affect the ability to cut tools in cutting, which in turn will cause a shorter tool life, tool life determination can be done by using Taylor's tool life equation. Taylor's Equation for Tool Life Expectancy, formulated by F. W. Taylor 1906 [1], provides a good approximation of tool life for varying cutting speed VC. The Taylor equation is presented in (1) where VC is the cutting speed, T is the expected tool life and m and CT are constants derived from measured data analytically or computed by curve fitting using the least squared method.$Vc.Tl^{m}=Ct$.[5]. Schematic of flank and crater wear on the cutting tool is presented in the following figure:

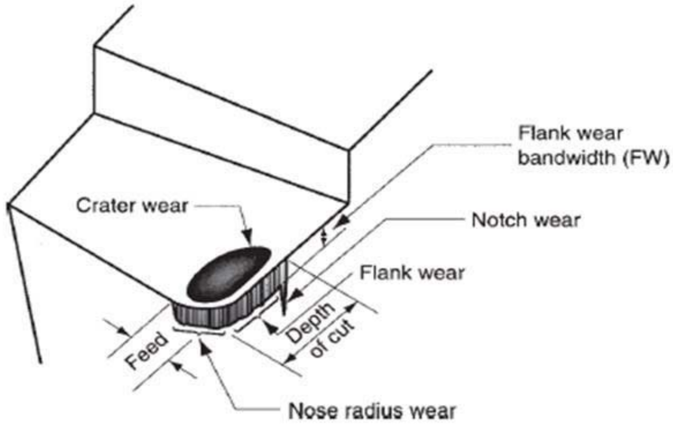

Figure 1. Flank and Crater Wear of Cutting Tools [7]

Cemented carbide cutting tools are widely used in metal machining operations. The performance of these cutting tools with regards to tool life travel path, the required power for machining, and the surface quality of the generated workpieces improve remarkably using coated cemented carbide cutting tools. [6].

Based on this, this study was conducted to analyze the wear of coated carbide cutting tools and their correlation to the cutting forces produced.

2. Method and materials

Metal cutting process using CNC Lathe "Mazak Mazatech Quick Turn 8N"

Figure 2. CNC Lathe "Mazak Mazatech *Quick Turn* 8N" The workpiece materials are AISI 4140 Steel

IOP Conf. Series: Materials Science and Engineering **852** (2020) 012083 doi:10.1088/1757-899X/852/1/012083

Element	*Content (%)*
Chromium, Cr	0.80 – 1.10
Manganese, Mn	0.75 – 1.0
Carbon, C	0.380 – 0.430
Silicon, Si	0.15 – 0.30
Molybdenum, Mo	0.15 – 0.25
Sulfur, S	0.040
Phosphorus, P	0.035
Iron, Fe	*Balance*

Figure 3. (a) AISI 4140 Steel Cutting force measurements using Force Dynamometer equipment

Figure 4. Force Dynamometer The cutting tool used Coated Carbide type DNMG 150404

Specifications	
Colour	*Silver – Grey*
Coating Thickness	3 – 5 μm
Microhardness	1750 HV
Thermal Stability	*Up to 700ºC*
Coeff. Friction vs Steel	0.5

Figure 5. Coated Carbide cutting tool type DNMG 150404 The cutting tool insert is attached to the tool holder

Figure 6. Tool Holder

Cutting tool wear observations were made using a digital microscope.

Figure 7. Digital Microscope

The force dynamometer measures two (2) axes, the X and Z axes. Where the X-axis is at the diameter of the workpiece and the Z-axis at feed motion. Cutting speeds used include: (Vc) 180 m / min, 220 m / min, 260 m / min, 300 m / min, and 340 m / min with a feed speed (Vf) of 337 mm / min and depth of cut of 0.7 mm and without using coolant. The turning process is carried out with a cut depth of cut of 0.7 mm and a feeding speed of 337 mm/min with a cutting length of each process of 150 mm and repeated. Observation and measurement of cutting tool wear are done every 5 minutes, observations and measurements are carried out using a digital microscope. If the tool wear value (V_B) has not yet reached the set wear limit of 0.3 mm, then machining is continued and recording of wear and force values is carried out so that cutting tool wears.

3.Result and discussion

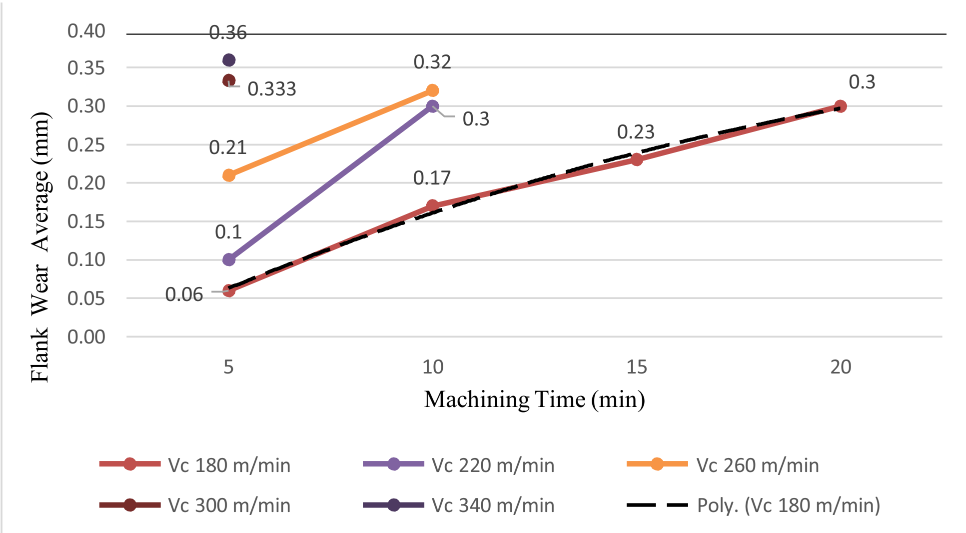

Figure 8. Flank wear Vs Machining time

From the results of research data that have been obtained, it can be seen that the increase in cutting tool wear is in line with the increase in machining time. When the cutting tool starts cutting at the surface of the workpiece, there will be friction and friction in the contact area, if the longer the friction occurs, causing the cutting temperature to occur the longer the cutting takes place, the increase in cutting temperature occurs significantly, although some of the heat occurs will be carried by chips and workpieces, partly it is distributed on the surface of the cutting tool and this affects the structure of the cutting tool itself, where the longer the cutting lasts and the higher the cutting speed, then the heat distributed to the cutting tool also increases, thus causing the contact tool cutting area and the workpiece to experience abrasives which contributes to the wear and tear on the cutting tool. Abrasive wear occurs whenever a hard rough surface and/or a surface containing hard particles slide on top of a softer surface [7]. In tool wear, abrasive wear is the removal of tool material by hard, abrasive phases in work material. Depending on the morphology of the abrasive phases, both 2- and 3-body abrasion is possible. The abrasive phase with complex morphologies results in 2-body abrasion while the abrasive with simple morphologies result in 3-body abrasion. In figure 7., it can be seen that a large increase in cutting tool wear occurs at a machining time of 10 minutes with a cutting speed of Vc 220 m / min. At a cutting speed of Vc 300 m / min, and Vc 340 m / min the average V_B value has reached or exceeded 0.3 mm at 5 minutes machining time.

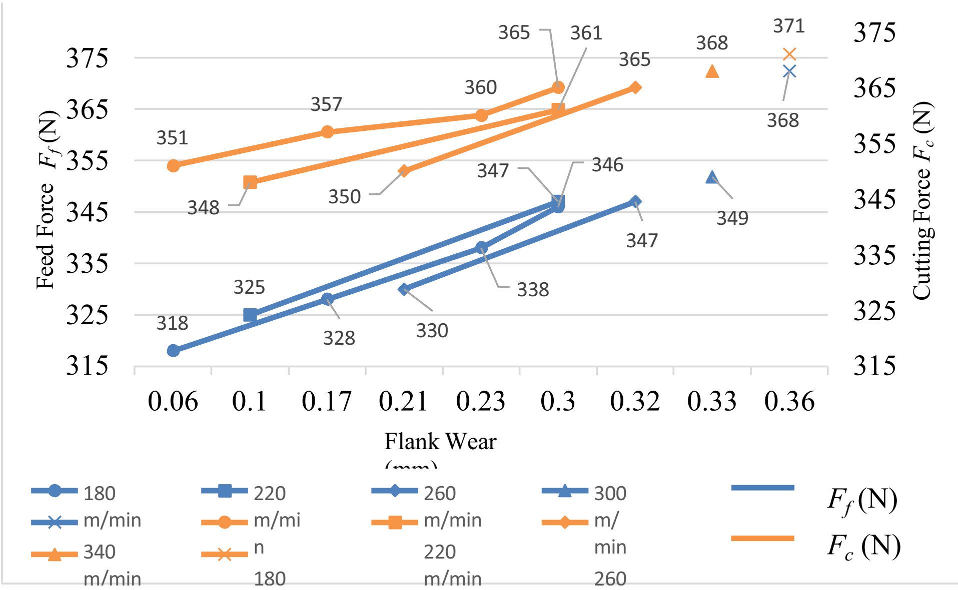

Figure 9. Flank Wear Vs Cutting Force

Based on Figure 9 it can be seen that the high cutting tool wear has an effect on increasing the cutting force produced. The increase in cutting force is due to the cutting tool which is starting to experience wear and tear resulting in a change in the geometry of the cutting tool. In this process, the cutting tool cannot cut metal, because the wear angle of the cutting tool requires high cutting force to separate the workpiece that is in direct contact with the tip of the cutting tool. The change in the geometry of the cutting tool is related to the change in the nose radius tool on the cutting edge. Changing the nose radius tool causes the chips to form larger. The larger the chips that are formed affect the force produced. This is because the greater the chips that are formed causing an increase in the force needed to make the shift.

4. Conclusion

From the research and analysis that has been done, it can be concluded that:

Cutting tool wear value is directly proportional to the machining time, the longer the machining time, the greater the resulting wear. At a cutting speed (Vc) of 180 m / min the 5th minute had a cutting tool (V_B) wear value of 0.06 mm and at the 20th minute had a cutting tool (V_B) wear value of 0.3 mm.

Increased cutting speed and machining time contribute significantly to the change in the geometry of the cutting tool which results in more chips being produced.

The increase in the value of the cutting force is affected by the increase in wear that occurs in the cutting tool due to a change in tool geometry due to wear on the cutting tool. The highest feeding force value is at the cutting speed (Vc) 340 m / min at 368 N and the greatest cutting force value is at the cutting speed (Vc) 340 m / min at 371 N.

5. References

[1].S. Lubis, S. Darmawan, R. and T. Tanuwijaya. (2016).Analisa pertumbuhan keausan Pahat Karbida coated dan uncoated pada alloy steel AISI 4340," *Jurnal Energi dan Manufaktur,* vol. IX, no. 2, p. 117.

[2].Rosehan, S. Lubis, and M. Firmansyah.(2014). Analisis Parameter Pemesinan Terhadap Gaya Potong Pada Proses Pembubutan Logam S45C," *Prosiding SNMI,* vol. IX, no. 1, pp. 303-304.

[3].F. Zangera, V. Schulzea.(2013). Investigations on Mechanisms of Tool Wear in Machining of Ti-6Al-4V using FEM Simulation. *Procedia CIRP 8* 158 – 163

[4]. Sampsa V.A. Laakso, Mathias Agmell, Jan-Eric Ståhl. (2018).The Mystery of Missing Feed Force - The Effect of Friction Models, Flank Wear and Ploughing on Feed Force in Metal Cutting Simulations *Journal of Manufacturing Processes* 33 (2018) 268–277.

[5].Daniel Johansson, Sören Hägglund, Volodymyr Bushlya, Jan-Eric Ståhl. (2017).Assessment of Commonly Used Tool Life Models in Metal Cutting. *Procedia Manufacturing* 11 602 – 609

[6].Jan C. Aurich, Tina Eyrisch, and Marco Zimmermann. (2012).Effect of the Coating System On The Tool Performance When Turning Heat-Treated AISI 4140. *Procedia CIRP* 1, 214 – 219

[7] M. P. Groover.(2010). Fundamentals of Modern Manufacturing,Materials, Process, and System.
Fourth Edition.John Wiley & Sons, Inc.

[8] Rabinowicz, E. (1995). *Friction and Wear of Materials*, 2nd edition, New York: John Wiley & Sons, Inc.

[9].Tool-Life Testing With Single-Point Turning Tools. (1993) Switzerland: International Organization for Standardization 3685.

[10].A. Mahamani.(2014). Influence of Process Parameters on Cutting Force and Surface Roughness During Turning of AA2219-TiB2/ZrB2 In-situ Metal Matrix Composites,*3rd International Conference on Materials Processing and Characterisation.*

[11].Thangarasu, S K; Shankar S; Thomas Tony; Sridhar G.(2017).Prediction of Cutting Force in Turning Process-an Experimental Approach," *IOP Conference Series: Materials Science and Engineering,* vol. I, no. 1.

[12].C. Yao, Z. Zhou, J. Zhang, D. Wu, and L. Tan,.(2017). Experimental Study on Cutting Force of Face-Turning Incone1718 with Ceramic Tools and Carbide Tools,*Advances in Mechanical Engineering,* vol. 9, no. 7, pp. 1-9.

[13].G. Zheng, R. Xu, X. Cheng, G. Zhao, L. Li and J. Zhao.(2018).Effect of Cutting Parameters on Wear Behavior of Coated Tool and Surface Roughness in High-Speed Turning of 300M. *Measurement,* pp. 99-108.

[14].M. Sparham, A. A. D. Sarhan, N. A. Mardi, M. Dahari and M. Hamdi. (2016).Cutting Force Analysis to Estimate The Friction Force in Linear Guideways of CNC Machine. *Measurement*

[15].K. Orra and S. K. Choudhury.(2018).Mechanistic Modelling for Predicting Cutting Forces in Machining Considering Effect of Tool Nose Radius on Chip Formation and Tool Wear Land," *International Journal of Mechanical Sciences*.