SINERGI Vol. 24, No. 3, October 2020: 171-176
http://publikasi.mercubuana.ac.id/index.php/sinergi
http://doi.org/10.22441/sinergi.2020.3.001 .

EFFECT OF CUTTING SPEED IN THE TURNING PROCESS OF AISI 1045 STEEL ON CUTTING FORCE AND BUILT-UP EDGE (BUE) CHARACTERISTICS OF CARBIDE CUTTING TOOL

Sobron Lubis*, Sofyan Djamil, Yehezkiel Kurniawan Zebua
Mechanical Engineering Departmen, Faculty of Engineering Universitas Tarumanagara
Jl. Let. Jen. S. Parman No.1, Jakarta 11440, Indonesia
*Corresponding Author Email: sobronl@ft.untar.ac.id

Abstract -- *In the machining of metal cutting, cutting tools are the main things that must be considered. Using improper cutting parameters can cause damage to the cutting tool. The damage is Built-Up Edge (BUE). The situation is undesirable in the metal cutting process because it can interfere with machining, and the surface roughness value of the workpiece becomes higher. This study aimed to determine the effect of cutting speed on BUE that occurred and the cutting strength caused. Five cutting speed variants are used. Observation of the BUE process is done visually, whereas to determine the size of BUE using a digital microscope. If a cutting tool occurs BUE, then the cutting process is stopped, and measurements are made. This study uses variations in cutting speed consisting of cutting speed 141, 142, 148, 157, 163, and 169 m/min, and depth of cut 0.4 mm. From the results of the study were obtained that the biggest feeding force is at cutting speed 141 m/min at 347 N, and the largest cutting force value is 239 N with the dimension of BUE length: 1.56 mm, width: 1.35 mm, high: 0.56mm.*

Keywords: *Tool Wear; Coated Carbide; Cutting Force; AISI 1045 Steel; Built-Up Edge*

Received: October 30, 2019 *Revised: March 30, 2020* *Accepted: May 5, 2020* *Published: July 15, 2020*

INTRODUCTION

In the metal forming manufacturing industry, the metal cutting process is one of the activities that is often carried out, especially when producing machine components. The metal cutting process is a process that is used in forming basic metals into machine components by using the cutting tool as its main component [1]. The machining process is the process of producing a product by cutting the workpiece using cutting tools and machine tools.

The turning process is one of the most widely used metal cutting operations in the engineering industry to form the surface of workpieces. In the turning process, generally using several cutting parameters such as depth of cut, cutting speed, feed rate [2][3]. During the cutting process, the cutting tool interacts directly with the workpiece. Chips are produced from the cutting process of the workpiece. The heat is generated through the plastic deformation of the workpiece and the friction of the cutting tool interface, which causes heat transfer to the cutting tool, chip, and the surface of the workpiece.

The temperature contained in the workpiece and cutting tool has increased substantially. This situation causes the cutting conditions to be made more severe. Cutting tools must have resistance to higher thermal loading.

In the metal cutting process, there is always a large cutting force, friction, and high temperature, this is caused by continuous and intensive friction between the active cutting tool surface and the workpiece surface. These conditions cause wear on the cutting tool surface, which leads to damage to the surface quality and a decrease in precision in the machined workpiece. The wear on the cutting tool surface is very complicated because it is accompanied by chemical phenomena that appear on the contact surface between the cutting tool, the workpiece, and the chip. In other words, wear is a destructive process of the surface layer of the active plane of a cutting tool that leads to progressive modification of the machine workpiece shape and surface quality. This situation changes in the geometry of the cutting tool (tool angle and nose radius), temperature, geometric cutting force, macro and micro-precision of the machine surface [4][5].

Therefore, the workpiece cutting process is accompanied by cutting tool wear, which has an effect on reducing the quality of the cutting tool and causes vibrations. The cutting force occurs higher because the cutting tool has worn and the nose radius tool forms an increasingly rounded tip.

When this happens, the vibrational amplitude becomes dramatically increased, resulting in a chatter [6][7].

Inaccuracies in the metal machining process can also be experienced by the presence of chips that accumulate and are attached to the cutting tool called the Built-Up Edge (BUE). In cutting tools, the occurrence of BUE is undesirable, because the BUE can cause damage to the cutting tool, the effect can affect the surface of the workpiece produced, and the cutting tool life becomes shorter and will undoubtedly increase machining costs.

BUE is a problem that affects the machining process so that the surface conditions of the resulting workpiece become inaccurate. In addition, BUE causes damage to the cutting tool surface because the chip is attached to the cutting edge, then peels off [8]. One of the BUE problems occurs with AISI 1045 steel workpieces with coated carbide cutting tools.

Along with environmental problems in the present, the process machining is expected not to use coolant. Machining without coolant or regarded as dry cutting helps to prevent emissions from the atmosphere caused by residual use of the coolant. But, one of the effects of dry cutting is the emergence of BUE. BUE is a new cutting surface formed at the end of the cutting tool caused by a chip stacking. This condition causes the cutting tool cannot be used anymore and must be cleaned first. The emergence of BUE has caused many problems among small industries, because the use of cutting tools has become more numerous, or has often sharpened cutting tools, and of course, has caused an increase in the cost of machining processes that are being carried out [9]. The concentration of heat at high temperatures due to the cutting process that occurs in the cutting zone is due to low thermal conductivity. High workpiece hardness causes high adhesion of the workpiece material to the cutting tool and results in an unstable chip that forms BUE [8].

BUE consists of several layers of damaged material. These layers are attached to the surface of the cutting tool contact area. They can cause changes to the cutting tool geometry and the metal cutting process mechanism [9]. BUE chips that occur at the angle of the cutting tool are not permanently formed but are periodically released from cutting tools, and sometimes the chips are attached to the surface of the tools [9][10].

BUE has low structural stability, which can cause cracking and damage to the cutting tool surface. However, under the same conditions, BUE with thin and stable thickness can be used to protect the cutting tool from wear by reducing friction between the cutting tool and the workpiece [11][12]. In particular, it will affect the final surface condition and residual stress of the machine surface due to its effect on the component operation and reliability [13][14]. Creep, fatigue, and stress cracking are the causes of product failure [15].

Coated carbide is a cutting tool suitable for use in turning processes with workpieces such as steel, iron, and stainless with very hard steel particles and increasing wear resistance in high temperatures [6]. In the automotive industry, AISI 1045 steel metal material is mostly used because of its excellent machinability, weldability, and high strength [16][17].

In the cutting process, the use of higher cutting speeds causes an increase in cutting temperature cutting zone, which leads to faster cutting tool wear which in turn affects dimensions accuracy, surface roughness and tool life [18][19][20].

This research was conducted to examine the effect of cutting speed on cutting force on the formation of BUE on the carbide cutting tool so that the characteristics of the BUE dimension are known and identify effective cutting speeds to prevent BUE.

METHOD

Metal cutting is carried out using a Micro Tara Turn Master 35 lathe as shown in Figure 1. The workpiece material is AISI 1045 steel as depicted in Figure 2. The chemical composition of AISI 1045 Steel as listed in Table 1.

Figure 1. Lathe Machine *Microtara Turnmast*35

Figure 2. AISI 1045 Steel

Table 1. Chemical Composition of AISI 1045 Steel [2]

Composition	(%)
C	0.42-0.50
Mn	0.50-0.80
Mn Si maximum	0.40
S maximum	0.40
Cr + Mo + Ni Max	0.63

Cutting force measurements are carried out using a dynamometer as shown in Figure 3.

Figure 3. Force Dynamometer

The cutting tool is coated carbide cutting tool TNMG 331MA type as shown in Figure 4.

Figure 4. Coated Carbide cutting tool type TNMG 331MA

BUE observations and measurements that occur in cutting tools using a digital microscope is illustrated in Figure 5.

Figure 5. Microscope Jenco Model BC 4-311

The research step was cutting AISI 1045 steel with a size of Ø 2.5 x 120 mm, determining five variations of cutting speed, 141, 142, 148, 157, 163, and 169 m / min, cutting depth of 0.4 mm and set the cutting force gauge. The cutting process is carried out using a carbide cutting tool. When the machining process takes place, the measurement of the cutting force is carried out. Dynamometer tool used to measure the cutting force that occurs in a cutting tool consisting of 2 (two) axes, namely the X and Z axis, for the X-axis is measured in the diameter of the workpiece and the direction of the Z-axis in the direction of feeding. Tip cutting tool is observed, if BUE occurs, machining is stopped, and its dimensions are measured. When cutting temperatures increase, between objects work and cutting tools produce chips with high temperature, then the lathe is off. BUE reviews and evaluates using a digital microscope to determine the size of BUE.

RESULTS AND DISCUSSION

From the experiments conducted, the built-up edge that occurs in the cutting tool is shown in Figure 6.

(a)

(b)

Figure 6. the built-up edge that occurs in the cutting tool
(a) Built-up edge attached to the cutting tool
(b) Built-up edge visible from the microscope

The results of observing and measuring the cutting force using variations in cutting speed are shown in Figure 7.

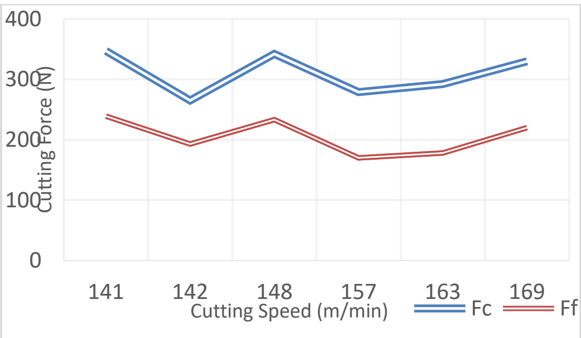

Figure 7. Cutting speed VS Cutting Force

Based on Figure 7, it can be seen that the value of the cutting force varies and shows a decrease when the cutting speed increases. Figure 6 shows that at a cutting speed of 141 m/min, the cutting force (F_c), and the feeding force (F_f) produced is large. Then with increasing cutting speed, it causes a reduced cutting force. This situation occurs if the cutting speed increases based on the speed of feeding the workpiece, which is getting bigger, causing the chip to stick to some of the corners of the cutting tool. This condition is caused by high cutting temperatures, which affect the formation of BUE at the tool angle, and an increase in cutting force also causes cutting power to increase.

From observations made during the machining process, BUE can occur at any cutting speed, but the BUE shape that occurs includes varying lengths, widths, and thicknesses, as presented in Figure 8.

Figure 8. Effect of Cutting Speed on Built-Edge Size

Based on Figure 8, it can be seen that the BUE that occurs does not depend on the cutting speed (V_c). But due to the release of the cutting temperature that does not occur properly. So, some of the heat still occurs on the chip and eventually spreads and increases to the cutting tool angle. BUE size is different at each cutting speed. In Figure 8 it can be seen that the cutting speed of 141 m/min in experiment 1 produces a size larger than BUE than the cutting speed of 142 m/min in experiment 2 which results in a size smaller than BUE, this occurs because when the cutting speed increases, there is an increase in temperature and the tip of the chip attached to the cutting tool is peeled off from the cutting tool, this causes the BUE dimension that occurs on the cutting tool to be smaller compared to the previous cutting speed.

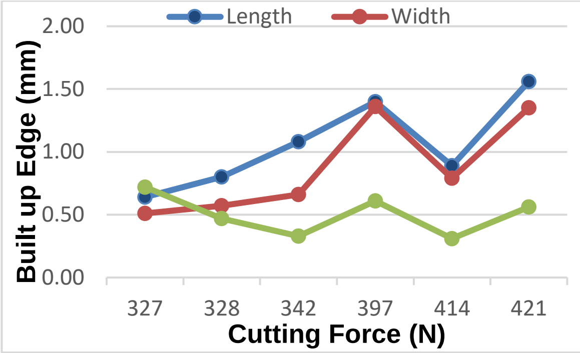

Figure 9. Cutting force on the Built-Up Edge dimensions

Based on Figure 9, the effect of increasing cutting speed affects the cutting force. With the occurrence of BUE on the cutting tool, the cutting force that occurs in the cutting process is greater because the angle of cutting tool no longer performs its function for metal cutting. Still, the BUE is rubbing, so it requires a force greater to do a metal cutting process. Other effects arising from the presence of this BUE the surface condition of the workpiece becomes rougher, and cracks occur on the cutting tool faster because of BUE shifts and peels off the surface of the cutting tool attached to the BUE. Based on Figure 8, it can be seen that the increase in the length and width of BUE is more significant than the height of BUE. The situation is especially true for the cutting force of 397 N.

The size of the built-up edge is also influenced by increased cutting force. The built-up edge that occurs in the cutting tool affects the cutting of uneven workpieces. From these results, it can also form large chips due to changes in the force produced and high temperature when rubbing between the cutting tool and the workpiece, so that the surface conditions of the workpiece produced are high roughness.

CONCLUSION

In general, the built-up edge that occurs in the cutting tool when the cutting process temperature is high and results in large chip size and can be seen from a higher cutting force than the cutting process. The most significant feeding force is at cutting speed (V_c) 141 m/min at 347 N, and the most extensive cutting force value is 239 N the dimension of BUE length:1.56 mm, width:1.35 mm, high:0.56mm. While the minimum feeding force occurs at a cutting speed of 142 m/min at 265 N, BUE length: 0.8 mm, width:0.57 mm, high:0.47 mm, and the value the smallest cutting force at a cutting speed of 157 m/min with a value of 170 N, BUE length: 0.64 mm, width: 0.51, high:0.72 mm. With a cutting speed of 141 m/min at machining time of 43 minutes. Cutting speed does not directly influence the occurrence of BUE. At a cutting speed of 141 m/min, the BUE dimension that occurs is higher than the speed compared to the cutting speed of 142 m/min.

ACKNOWLEDGMENT

A research institute and community service of Tarumanagara University supported of this research.

REFERENCES

[1] S. Lubis, E. Siahaan, S. Darmawan, A. Adianto, and R. Ronald, “Variation of Cutting Parameters in the Process of Turning AISI 4340 Steel on Surface Roughness,” *SINERGI,* vol. 23, no. 2, pp. 139-144, June 2019. DOI: 10.22441/sinergi.2019.2.007

[2] S. Lubis, S. Darmawan, R. Rosehan and T. Tanuwijaya, “Analisa pertumbuhan keausan pahat karbida coated dan uncoated pada alloy steel AISI 4340,”*Jurnal Energi dan Manufaktur,* vol. 09, no. 2, pp. 117, March 2017

[3] V. Nagandran, T. V. Janahiraman, and N. Ahmad, "Modeling and Optimization of Carbon Steel AISI 1045 Surface Roughness in CNC Turning Based on Response Surface Methodology and Heuristic Optimization Algorithms," *American Journal of Neural Networks and Applications,* vol. 3, no. 6, pp. 56-62, December 2017. DOI: 10.11648/ 20170306.11

[4] M. Aruna, V. Dhanalakshmi, S. Mohan, "Wear Analysis of Ceramic Cutting Tools in Finish Turning of Inconel 718," *International Journal of Engineering Science and Technology*, vol. 2, no. 9, pp. 4253-4262, September 2010

[5] ISO, *Tool-life testing with single-point turning tools*. Switzerland: International Organization for Standardization 3685, 1993

[6] O. Gutnichenko, V. Bushlya, J.Zhou, J. Eric Ståhl, “Tool wear and machining dynamics when turning high chromium white cast iron with CBN tools,” *Wear*, vol 390-391, pp. 253-269, Nov 2017. DOI: 10.1016/j.wear.2017.08.005

[7] R. Rosehan, S. Lubis and M.Firmansyah, “Analisis Parameter Pemesinan Terhadap Gaya Potong Pada Proses Pembubutan Logam S45C,” *Prosiding Seminar Nasional Mesin dan Industri (SNMI9),* Bali, Indonesia, November 2014. pp. 303-304

[8] S. Atlati, B. Haddag, M. Nouari, A. Moufki, "Effect of local friction and contact nature on the Built-Up Edge formation process in machining ductile metals," *Tribology*

International, vol. 90, pp. 217-227, October 2015. DOI: 10.1016/ j.triboint.2015.04.024

[9] H. Agus P., P. J. Widodo, and M. Nizam, "Pengaruh Parameter Permesinan Bubut Terhadap Munculnya Built-Up Edge (BUE) Dalam Proses Pembubutan Aluminium," *Mekanika*, vol. 10, no. 1, pp. 41-44, September 2011

[10] Y. S. Ahmed, G. Fox-Rabinovich, J. M. Paiva, T. Wagg, and S. C. Veldhuis, "Effect of Built-Up Edge Formation during Stable State of Wear in AISI 304 Stainless Steel on Machining Performance and Surface Integrity of the Machined Part," *Department of Mechanical Engineering,* vol. 10, no.11, pp.1230, November 2017. DOI: 10.3390/ ma10111230

[11] V. D. Kuznetsov, *Metal Transfer and Build up in Friction and Cutting*. Moscow, Russia: Gostekhizdat, 1966

[12] K. Orra and S. K. Choudhury, "Mechanistic modeling for predicting cutting forces in machining considering the effect of tool nose radius on chip formation and tool wear land," *International Journal of Mechanical Sciences*, vol. 142-143, pp. 255-268, July 2018. DOI: 10.1016/j.ijmecsci.2018.05.004

[13] G. S. F. Rabinovich, J. Paiva, L. S. Gershman, M. Aramesh, D. Cavelli, K. Yamamoto, G. Dosbaeva, S. C. Veldhuis, "Control of self-organized criticality through adaptive behavior of nano-structured thin film coatings," *Entropy*, vol. 18, pp. 290, August 2016. DOI: 10.3390/e18080290

[14] D. Y. Jang, T. R. Watkins, K. J. Kozaczek, C. R. Hubbard, O. B. Cavin, (1996)." Surface residual stresses in machined austenitic stainless steel," *Wea*r, vol. 194, no. 1-2, pp. 168-173, June 1996. DOI: 10.1016/0043-1648(95)06838-4

[15] R. M. Saoubia, J.C. Outeirob, B. Changeuxa, J.L. Lebruna, A. M. Dias, "Residual stress analysis in orthogonal machining of standard and desulfurized AISI 316L steels," *Jurnal of Materials Processing Technology*, vol. 96, no. 1-3, pp. 225-233, 1999

[16] A. E. Diniz, F. C. Marcondes, N. L. Coppini.*Tecnologia da Usinagem dos Materiais*. São Paulo, Brazil: 5th Ed. Artliber, 2006

[17] R. Suresh, S. Basavarajappa, G.L. Samuel, "Some studies on the hard turning of AISI 4340 steel using multilayer coated carbide tool," *Measurement,* vol. 45, no. 7, pp. 1872-1884, August 2012. DOI: 10.1016/ j.measurement.2012.03.024

[18] M. J. Mir and M. F. Wani, "Performance evaluation of PCBN, coated carbide and mixed ceramic inserts in finish-turning of AISI D2 steel," *Jurnal Tribologi,* vol. 14, pp. 10-31, 2017

[19] X. Sauvage, J.M. Le Breton, A. Guillet, A. Meyer, J. Teillet, "Phase transformation in surface layers of machined steels investigated by X-ray diffraction and Mössbauer spectrometry," *Material Science and Engineering*, vol. 362, no.1, pp. 181–186, Dec 2003. DOI: 10.1016/S0921-5093(03)00531-8

[20] Z. Cassier, Y. Prato and P. M. Escalona, "Built-Up Edge Effect on Tool Wear When Turning Steels at Low Cutting Speed," *Journal of Materials Engineering and Performance,* vol. 13, no. 5 pp. 542-547, October 2004. DOI: 10.1361/ 10599490420629