Effect of cutting speed on temperature cutting tools and surface roughness of AISI 4340 steel

by Steven Darmawan

Submission date: 19-Sep-2022 07:35PM (UTC+0700)
Submission ID: 1903521443
File name: Lubis_2019_IOP_Conf._Ser.__Mater._Sci._Eng._508_012053.pdf (521.2K)
Word count: 3921
Character count: 18996

IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

Effect of cutting speed on temperature cutting tools and surface roughness of AISI 4340 steel

To cite this article: Sobron M. Lubis *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **508** 012053

Effect of cutting speed on temperature cutting tools and surface roughness of AISI 4340 steel

Sobron M. Lubis*, Steven Darmawan, Adianto,Ericsen
Mechanical Engineering, Faculty of Engineering, Universitas Tarumanagara

*sobronl@ft.untar.ac.id

Abstract. *During the machining process, a few cutting parameters are implemented such as cutting speed, depth of cut, and feeding speed. Variation of cutting speed beside affect the result of machining also could affect the rise of temperature during the machining process. In this study, carbide and ceramic cutting tool was used to see the comparison of temperature growth between two different tools. Tool temperature was estimated by simultaneous temperature measurement using K-type thermocouple and a digital thermometer to measure on tool temperature. Experiments were carried out in dry machining using workpiece material of AISI 4340 alloy steel. A DNMG 150404HQ CVD-coated carbide insert and the ceramic insert was used during the turning process. The result of the experiment show The highest measured temperature value on carbide cutting tool was 114 ^{O}C at 240 m / min cutting speed while the lowest temperature value was 87.8 ^{O}C at 160 m / min cutting speed. While on the ceramic cutting tool the highest measured temperature value is 52,5 ^{O}C at 240 m / min cutting speed and lowest is 47,5 ^{O}C at cutting speed 160 m / min*

1.Introduction

In the lathe machining process, the parameters specified to affect the resulting machining results. Machining parameters, such as cutting speed, depth of cut, and feeding speed have an influence on the final results of the machining process. One of the things that are also affected by the variation of the machining parameters specified is the temperature in the machining process. By varying the machining parameters give effect to the temperature changes that occur, both on cutting tools or workpieces. The temperature increase in lathe machining can be affected by cutting speed, depth of cutting, feeding speed, and others. Heat is produced by several sources, namely through the deformation of the workpiece in the shear plane, and through the friction generated when the chip friction occurs on the cutting tool surface [2]. Based on the results of the research on various cutting conditions, the percentage of heat distributed in the shear plane, furious plane, and the main fields respectively ranged from 80%, 18%, and 2%. Some of the heat is carried by the chip, some flows towards the cutting tool and workpiece. The heat that occurs during the cutting process is largely carried away by the chip, some of it propagates through the tool, and the rest propagates through the workpiece. The heat that is formed is quite large, and because the area of the contact area is relatively small, the cutting tool temperature, especially in the furious area and the main plane, will be very high. Due to the large pressure due to the cutting force causes high temperatures. [1]

Low and high temperatures during the machining process can affect the life of cutting tools [5]. Wear of cutting tools certainly also affect the performance of the tool which has an impact on the value of the resulting surface roughness.

Based on this, this study was conducted to determine the effect of cutting speed on the steel turning process of AISI 4340 using cutting tools carbide to the cutting temperature and its relation to the value of the surface roughness of the workpiece.

2. Method and Materials

This research was conducted using Mazak CNC lathes. The cutting tool used is Carbide inserts DNMG 150404HQ CA5515 type which is attached to the VMDJNR-2020-15 tool holder.

IOP Conf. Series: Materials Science and Engineering **508** (2019) 012053 doi:10.1088/1757-899X/508/1/012053

Figure 1**.** *Carbide* dan *tool holder* VMDJNR-2020-15

Table.1 The chemical composition of Steel AISI 4340

Element	Content (%)
Iron, Fe	95.195 - 96.33
Nickel, Ni	1.65 - 2.00
Chromium, Cr	0.700 - 0.900
Manganese, Mn	0.600 - 0.800
Carbon, C	0.370 - 0.430
Molybdenum, Mo	0.200 - 0.300
Silicon, Si	0.150 - 0.300
Sulfur, S	0.0400
Phosphorous, P	0.0350

Table.2 Mechanical properties

Properties	Metric	Imperial
Density	7.85 g/cm^3	0.284 lb/in^3
Melting point	1427°C	2600°F
Properties	**Metric**	**Imperial**
Tensile strength	745 MPa	108000 psi
Yield strength	470 MPa	68200 psi
Bulk modulus (typical for steel)	140 GPa	20300 ksi
Shear modulus (typical for steel)	80 GPa	11600 ksi
Elastic modulus	190-210 GPa	27557-30458 ksi
Poisson's ratio	0.27-0.30	0.27-0.30
Elongation at break	22%	22%
Reduction of area	50%	50%
Hardness, Brinell	217	217
Hardness, Knoop (converted from Brinell hardness)	240	240

Hardness, Rockwell B (converted from Brinell hardness)	95	95
Hardness, Rockwell C (converted from Brinell hardness. Value below normal HRC range, for comparison purposes only)	17	17
Hardness, Vickers (converted from Brinell hardness)	228	228
Machinability (annealed and cold drawn. Based on 100 machinability for AISI 1212 steel.)	50	50

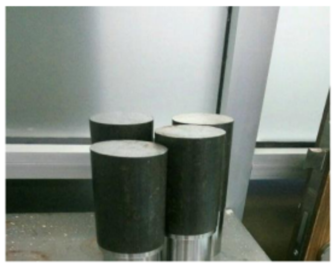

Figure 2. Steel AISI 4340

1. *Surface tester*

Figure 3.*Surface Tester*

2. Measuring the cutting temperature is carried out using a thermocouple type K attached to the end of the cutting tool. Cutting temperature reading using a digital thermometer. Turning results in the value of the surface roughness of the workpiece. Measurement of the value of the surface roughness of the workpiece is done using a surface tester.

2. Digital Thermometer

Figure 4.Digital Thermometer

3. Thermocouple Type-K

Figure 5**.** Thermocouple Type K

4. Clamp

Figure 6. Clamp

Thermocouple mounting mechanism at the cutting tool.

The research used cutting speed variation 160-250 m / min and feed rate 0.12 mm / rev which was determined based on the specifications of the tool used and paying attention to the capacity of the CNC turning machine in supporting high rotation speeds. In experiments, thermocouples are used to measure temperature. The thermocouple is attached to the cutting tool using a clamp made of 7075 aluminium. Before attaching it to the cutting tool, the clamp is first made into a groove so that the

IOP Conf. Series: Materials Science and Engineering **508** (2019) 012053 doi:10.1088/1757-899X/508/1/012053

thermocouple cable can be clamped properly. The clamp is coated with sealer glue and epoxy to prevent heat coming from the cutting tool to the thermocouple sensor to move to the clamp. An experiment in determining the position point of the thermocouple sensor to obtain the most accurate and safe measurement point does not interfere with furious income movements. The measurement point is carried out at a distance of 0.3 cm from the angle of the cutting tool.

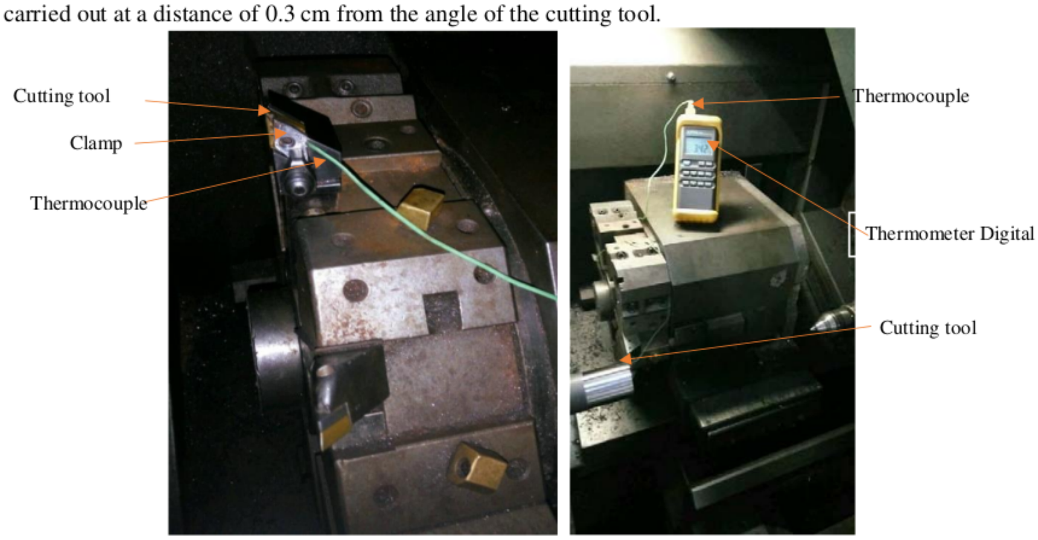

Figure 7. Clamp circuit, cutting tool and Testing Tool

Experimental procedure

The studies begin with the calculation of spindle (n) which will be used based on the diameter of the workpiece and the cutting speed to be achieved.

$$V = \frac{\pi d n}{1000} \text{ ; m / min} \qquad (1)$$

d : workpiece diameter (mm)

n : spindle speed (rpm)

v : cutting speed (m/min)

Then the workpiece is attached to the chuck and the cutting tool is placed close to the workpiece. The spindle is activated and the cutting process is carried out, the cutting tool is moved to the surface of the workpiece. At this time there is an interaction between the cutting tool and the workpiece so that heat occurs. The machining process is carried out for 5 seconds to obtain a stable temperature value to be noted in the table. Then the machining process continues with a span of 5 seconds to reach 25 seconds. After machining is complete, measurement of the surface roughness of the workpiece is carried out. Then changes in cutting speed are carried out. With the same method, the cutting process is carried out to measure the temperature of the tool and the surface roughness value of the workpiece.

3. Result and Discussion

The results of the machining temperature measurement at the cutting tool based on the average time and temperature obtained from 3 experiments are presented in the following table. From the data obtained it can be seen that the temperature at the cutting tool increases with time.

Table.3 Temperature Measurement Based on Time

Cutting Speed (m/min)	Temperature (^{0}C) 5 second	Temperature (^{0}C) 10 second	Temperature (^{0}C) 15 second	Temperature (^{0}C) 20 second	Temperature (^{0}C) 25 second
160	55,4	67,8	75,3	83,2	87,8
180	53,6	71,1	82,3	91,4	96,4
200	56,7	74,1	85,7	95,7	101,7
220	58,03	76,5	87	100,2	106,2
240	77,1	92,2	101,8	108,6	114

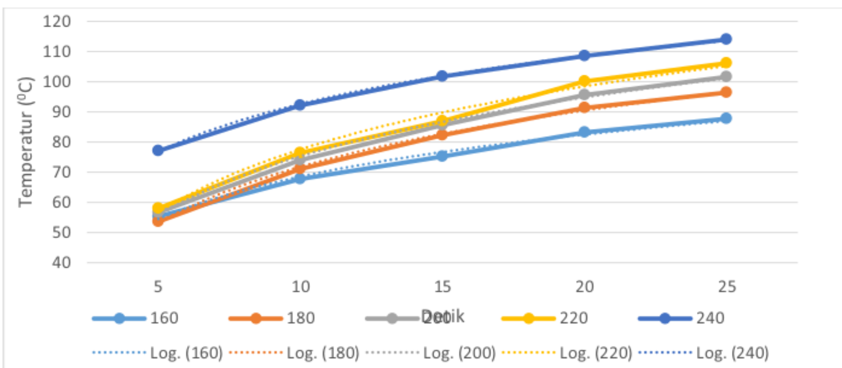

Figure 8. Temperature Change Chart Based on Machining Time at different cutting speeds

From Fig. 10 it can be seen that the increase in the time of the cutting process increases the temperature at the cutting edge of the tool. This happens because the friction that occurs is increasing due to the longer cutting time.

The following are the data taken with 3 attempts at each different cutting speed. From the 3 trials the average temperature was taken to obtain valid data.

Table.4 Average Measurement Results

Cutting Speed (m/min)	Temperature (°C) experimental 1	Temperature (°C) experimental 2	Temperature (°C) experimental 3	Average Temperature (°C)
160	82,1	89,5	92	87,8
180	90,1	95	104,3	96,4
200	97,8	102.3	105	101,4
220	104,4	106,9	107,5	106,2
240	112,2	114,1	115,8	114

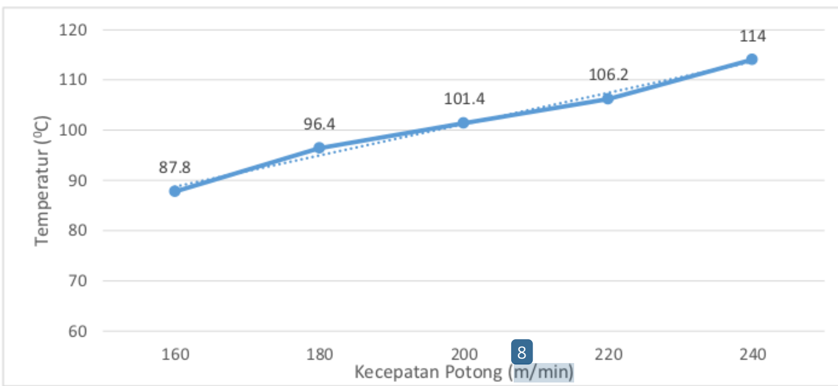

Figure 9. Effect of cutting speed on temperature on Cutting tools

Based on the above data it can be concluded that if the cutting speed is higher, it has an influence on the temperature changes that occur in the tool's eye, along with the cutting speed that increases the temperature in the tool's eye increases. The smallest temperature is 87.8 0C which can be obtained at a cutting speed of 160 m / min and the highest temperature of 114 0C can be obtained at a cutting speed of 240 m / min.

From Figure 3 and Figure 4 it can be seen that the measurement of ceramic cutting tools also increases the temperature along with the change in cutting speed. However, it can be seen that the measured temperature is lower than the temperature at the carbide cutting tool.

* Example calculation of heat transfer rate that occurs at cutting speed of 160 m / min

$$Q = k.A.\frac{\Delta T}{\Delta L} \qquad (2)$$

$$Q = 34\,.0{,}16x10^{-4}.\frac{360{,}8°K - 339{,}5°K}{0{,}003\,m}$$

$Q = 3{,}86$ W

Based on the formula used above can be calculated heat transfer that occurs at each cutting speed with the results as obtained in table 4

Table 5. Heat Transfer value

Carbide cutting tool	
Cutting speed	Q (W)
160	3,86
180	2,06
200	2,72
220	3,37
240	4,49

From the table, it can be seen that the increasing cutting speed and accompanied by an increase in temperature at the cutting tool, the rate of heat transfer that occurs is greater. The value of Q obtained at the carbide cutting tool is greater than that of the ceramic cutting tool. This means that the heat delivered by carbide cutting tools is greater than that of ceramic cutting tools. From the Q value obtained then it can be predicted that the heat that occurs at the end of the cutting tool is based on the formula of heat transfer.

Based on the heat transfer rate data at each cutting speed obtained. The temperature that occurs at the tool nose radius of the cutting tool is calculated. The temperature is calculated based on the first point temperature measurement data on the tool.

$$Q = k.A.\frac{T_1 - T_2}{\Delta L} \quad \text{[3]}$$

Where:

Q = Heat transfer rate

k =Conductivities Thermal

A = Cross-sectional area (m^2)

$T_1 = T_{Tip}$

T_2 = The temperature at the first measurement point (^{0}K)

ΔL = length (m)

* Example calculation of the temperature of the carbide cutting tool insert taken at a cutting speed of 160 m / min

$$Q = k.A.\frac{T_1 - T_2}{\Delta L}$$

$$3{,}86 = 34\ .0{,}16x10^{-4}.\frac{T_1 - 360{,}8}{0{,}003}$$

$5{,}45 \text{ x } 0{,}003 = 0{,}000544T_1 - 0{,}1962$

$$T_1 = \frac{0,01158 + 0,1962}{0,000544} = 381,94\,°K = 108,7\,°C$$

Table.6 Temperature theory values In the nose radius of cutting tool

Carbide cutting tool	
Cutting speed	T_{tip} (^{0}C)
160	108,9
180	107,7
200	116,2
220	124,6
240	137,7

From the calculations that have been done, it is obtained the temperature results at the end of the cutting tool. Temperature changes obtained are directly proportional to the increase in cutting speed. As observed at the first and second measurement points there is a temperature difference at the end of the cutting tool between carbide and ceramic cutting tools. Where the temperature at carbide cutting tools is higher than in ceramic cutting tools. The lowest temperature was obtained at a cutting speed of 160 m / min and the highest temperature was obtained at a cutting speed of 240 m / min.

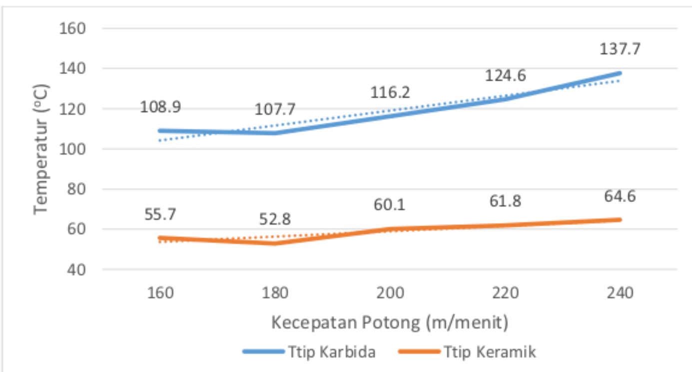

Figure 10. Comparison of temperature at the tip cutting tool

Based on the results presented in the graph, it can be seen that the temperature calculation at the end of the cutting tool has increased in temperature along with the increase in cutting speed. It can also be seen that there are temperature differences between carbide and ceramic cutting tools, this is due to differences in the constituent materials of each cutting tool. Based on the formula used, the temperature that occurs at the bottom of the cutting tool can be predicted. The calculated temperature is at the same point but on a different side. in this case, the heat transfer that occurs is assumed to occur by conduction.
* Example calculation of carbide cutting tool temperature at a cutting speed of 160 m / min.

T_{tip} calculation at the bottom side of the cutting tool.

$$Q = k.A.\frac{T_1 - T_2}{\Delta L} \quad (3)$$

$$3{,}86 = 34\,.\,0{,}18x10^{-4}.\frac{381{,}996 - T_2}{0{,}004}$$

3,86 x 0,004 = 0,233 – 0,000612T_2

$$T_2 = \frac{0{,}01504 - 0{,}233}{-0{,}000612} = 356{,}1\,°K = 83{,}1\,°C$$

The temperature at the first point

$$Q = k.A.\frac{T_1 - T_2}{\Delta L}$$

$$3{,}86 = 34\,.\,0{,}18x10^{-4}.\frac{360{,}8 - T_2}{0{,}005}$$

3,86 x 0,004 = 0,2208 – 0,000612T_2

$$T_2 = \frac{0{,}01504 - 0{,}2208}{-0{,}000612} = 347{,}3\,°K = 63{,}2\,°C$$

The temperature at the second point

$$Q = k.A.\frac{T_1 - T_2}{\Delta L}$$

$$3{,}86 = 34\,.\,0{,}18x10^{-4}.\frac{339{,}5 - T_2}{0{,}005}$$

3,86 x 0,004 = 0,2077 – 0,000612T_2

$$T_2 = \frac{0{,}01504 - 0{,}207}{-0{,}000612} = 313{,}5\,°K = 40{,}6\,°C$$

Table 7. Results of temperature calculation on the bottom side of a carbide cutting tool

Cutting speed	T_{tip} (^{0}C)	T_1 (^{0}C)	T_2 (^{0}C)
160	83,1	63,2	40,6
180	93,5	82,9	71,5
200	97,3	83,7	68,7
220	100,9	84,1	65,5
240	108	84,6	59,8

IOP Conf. Series: Materials Science and Engineering **508** (2019) 012053 doi:10.1088/1757-899X/508/1/012053

The uses of varying cutting speeds turned out to produce different surface roughness values. If the cutting speed used varied the higher, then the measurement of the surface roughness of the workpiece obtained the value of roughness getting smaller. In the graph, it can be seen that with higher cutting speeds, the temperature that occurs at the cutting tool also increases. The increase in cutting speed and temperature is inversely proportional to the change in the surface roughness value of machining results. This is due to the contact area of the cutting tool that friction with the workpiece undergoes a deformation change due to temperature rise in the cutting tool area, so that the cutting corner cutting surface undergoes a change of shape, which of course gives an effect on the impression of scratches that occur on the surface of the workpiece.

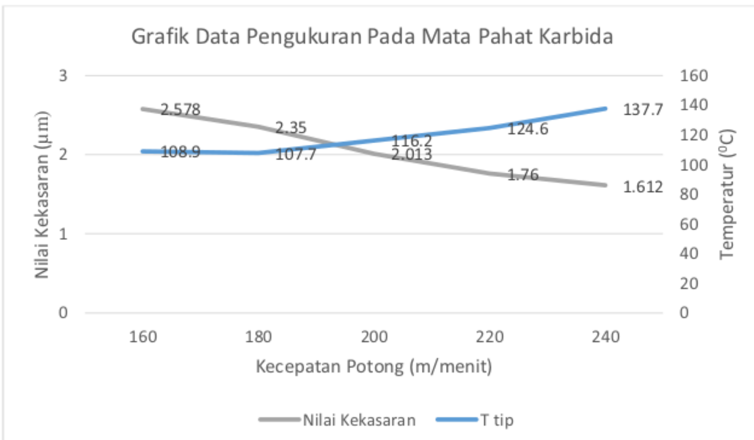

Figure.11 Graph Effect of cutting speed on roughness value and carbide cutting tool temperature

Based on the graphs in Figures 10 and 11 it can be seen that the increase in cutting speed has an effect on increasing the temperature at the temperature on the cutting tool. The intersection between the temperature curve and the roughness value can be seen the optimum point of machining parameters for the conditions of roughness and cutting tool wear. The optimum value becomes a reference for the use of cutting speed which causes a temperature rise not too high but still has a good roughness value. The increase in temperature occurs because the heat generated due to deformation that occurs in the sliding plane on the workpiece and friction between growls and cutting tools is greater. [3] A similar thing happened to both cutting tools. But at the cutting tool carbide, the temperature during the cutting process is higher than the temperature in ceramic ceramics. This is because carbide cutting tools have a higher thermal conductivity compared to ceramic cutting tools. With increasing temperatures can be seen the value of surface roughness decreases. This shows that the machining with variations in speed increases the surface roughness value produced is inversely proportional to the temperature at the cutting tool.

IOP Conf. Series: Materials Science and Engineering **508** (2019) 012053 doi:10.1088/1757-899X/508/1/012053

4.Conclusion

Based on the analysis of carbide and ceramic cutting tool temperature points on the AISI 4340 Steel turning machining process that has been carried out, it can be concluded that the temperature of machining results is directly proportional to the cutting speed. The higher the cutting speed, the higher the temperature measured at the cutting tool. The highest measured temperature value at the carbide cutting tool is 114 °C at a cutting speed of 240 m / min while the lowest temperature value is 87.8 °C at a cutting speed of 160 m / min. While at the ceramic cutting tool the highest measured temperature value is 52.5 °C at a cutting speed of 240 m / min and the lowest is 47.5 °C at a cutting speed of 160 m / min. With increasing cutting speed, the smaller the roughness obtained. As the cutting speed increases, the temperature at the cutting tool increases. The lowest roughness value in the carbide tool was 1.612 µm at a cutting speed of 240 m / min with a cutting tool temperature of 114 °C and the lowest roughness value at ceramic cutting tool was 0.88 µm at a speed of 240 m / min with a temperature at the cutting tool 52.5 °C. This shows that the value of surface roughness is inversely proportional to the value of cutting speed and cutting tool temperature.
Based on the analysis of carbide and ceramic cutting tool temperature points on the AISI 4340 Steel turning machining process that has been carried out, it can be concluded that the temperature of machining results is directly proportional to the cutting speed. The higher the cutting speed, the higher the temperature measured at the cutting tool. The highest measured temperature value at a carbide cutting tool is 114 °C at a cutting speed of 240 m / min while the lowest temperature value is 87.8 °C at a cutting speed of 160 m / min. While at ceramic cutting tool the highest measured temperature value is 52.5 °C at a cutting speed of 240 m / min and the lowest is 47.5 °C at a cutting speed of 160 m / min.
With increasing cutting speed the smaller the roughness obtained. As the cutting speed increases, the temperature at the cutting tool increases. The lowest roughness value for carbide cutting tool was 1,612 µm at a cutting speed of 240 m / min with a cutting tool temperature of 114 °C and the lowest roughness value for ceramic cutting tools was 0,88 µm at a speed of 240 m / min with a temperature at the cutting tool 52.5 °C. This shows that the value of surface roughness is inversely proportional to the value of cutting speed and cutting tool temperature.

Reference

[1] R. Taufiq, "Teori Dan Teknologi Proses Pemesinan", Institut Teknologi Bandung: Bandung, 1993.
[2] Abdil Kus. *Thermocouple and Infrared Sensor-Based Measurement of Temperature Distribution in Metal Cutting*. Turkey : Sensors, pp 1274-1291, 2015
[3] A. Hosseini and H. A. Kishawy. Chapter 2 Cutting Tool Materials and Tool Wear. University of Ontario Institute of Technology (UOIT), Oshawa, ON L1H 7K4, Canada, 2014
[4] Holman, J.P., "Heat Transfer", sixth edition, McGraw Hill, Ltd., New York, 1986.
[5] Xu Chuangwen. The Relationships Between Cutting Parameters, Tool Wear, Cutting Force and Vibration. Advances in Mechanical Engineering 2018, Vol. 10(1) 1–14

Effect of cutting speed on temperature cutting tools and surface roughness of AISI 4340 steel

ORIGINALITY REPORT

11%	4%	8%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Proceedings of the Twenty-First International Machine Tool Design and Research Conference, 1981. Publication	2%
2	"Machining of Titanium Alloys", Springer Science and Business Media LLC, 2014 Publication	2%
3	Submitted to Solihull College, West Midlands Student Paper	2%
4	Submitted to New Jersey Institute of Technology Student Paper	1%
5	Submitted to Coventry University Student Paper	1%
6	Submitted to University of Birmingham Student Paper	1%
7	Bonifacio, M.E.R.. "Correlating tool wear, tool life, surface roughness and tool vibration in	1%

finish turning with coated carbide tools",
Wear, 199404
Publication

8	H. Kishawy. "AN EXPERIMENTAL EVALUATION OF CUTTING TEMPERATURES DURING HIGH SPEED MACHINING OF HARDENED D2 TOOL STEEL", Machining Science and Technology, 2002 Publication	1%
9	Shengqiang Yang, Wenhui Li. "Chapter 3 Magnetic Abrasive Finishing Technology", Springer Science and Business Media LLC, 2018 Publication	1%
10	Ning Huang, Ying Yan, Ping Zhou, Renke Kang, Dongming Guo, Saurav Goel. "Elastic recovery of monocrystalline silicon during ultra-fine rotational grinding", Precision Engineering, 2020 Publication	1%

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		