

PAPER • OPEN ACCESS

## Tool wear analysis of ceramic cutting tools in the turning of gray cast iron materials

To cite this article: S Lubis *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **857** 012003

View the [article online](#) for updates and enhancements.



The Electrochemical Society  
Advancing solid state & electrochemical science & technology

**240th ECS Meeting** ORLANDO, FL

Orange County Convention Center **Oct 10-14, 2021**



Abstract submission due: April 9

**SUBMIT NOW**

# Tool wear analysis of ceramic cutting tools in the turning of gray cast iron materials

S Lubis<sup>1\*</sup>, S Darmawan<sup>1</sup>, Rosehan<sup>1</sup>, W Winata<sup>1</sup>, M Zulkarnain<sup>2</sup>

<sup>1</sup> Departement of Mechanical Engineering, Faculty of Engineering, Universitas Tarumanagara Jl. Let.Jend S.Parman No.1. Jakarta, 11440 Indonesia

<sup>2</sup> Universiti Kuala Lumpur, Malaysian Institute of Marine Engineering Technology, Dataran Industri Teknologi Kejuruteraan Marin, Bandar Teknologi Maritim, Jalan Pantai Remis, 32200 Lumut, Perak, Malaysia.

\*E-mail: sobronl@ft.untar.ac.id

**Abstract.** The development of mechanical and physical properties of metal materials is so fast, that it requires cutting tools that are capable of cutting the metal. Cutting tools must have high temperature resistance, high wear and hardness. Ceramic cutting tools have these properties, so they are suitable for use in cutting hard metals. In the metal machining process, especially machining of cast iron which has high hardness and strength, has a strong reason to use the ceramic cutting tool. This research was conducted to determine wear on ceramic cutting tools when cutting cast iron. The study was carried out experimentally using a Mazak CNC lathe. When the turning process is done, the cutting tool cuts the metal cast iron. Every 10 minutes, the turning process is stopped to observe and measure the wear that occurs on the ceramic cutting tool. Observations and measurements are carried out using a digital microscope. The wear criteria are determined if the tool edge ( $V_B$ ) has been worn at 0.3 mm. The results showed that wear at the cutting speed of 200 m / min at 60 minutes is an adhesion process. BUE (Build Up Edge) wear is a buildup of material layers in the chip area near the cutting tool.

**Keywords:** Turning, ceramic insert, tool wear, gray cast iron, build up edge

## 1. Introduction

The cutting tools are the main thing to consider when choosing the cutting process of metal materials. The high hardness of a material requires cutting tools that have high toughness to do the cutting. Ceramics is one of the cutting materials that is currently developing, ceramics have high hardness, strong resistance to high temperatures.

In the process of metal formation, cutting speed is important to consider to increase high production, and relatively low processing time. The use of high cutting speeds, of course, has an impact on decreasing machining time and increasing the number of products produced. But another effect is the wear of cutting tools that occur faster. The use of cutting tools that have a higher temperature resistance so that they can last longer is very helpful. Cutting tools ceramics are one of the cutting tools that have high temperature resistance, higher hardness compared to carbides. So that this cutting tool can be operated at high cutting speeds.

The tool wear is a general finding in the machining process that significantly affects the size of the product, the quality, the efficiency of the operation of machining, judgments of production and financial feasibility. The wear of the insert have a great influence upon economy of machining. [1].

Cast iron work piece material is a metal material that has high hardness, but also has fragile properties. Cast iron is one type of metal that has been used for a very long time, found by humans among many metals. This metal is widely applied, around 80% for vehicle engines made of cast iron. Cast iron is basically the eutectic iron and carbon alloy. With a melting point around 1200 °C. The low melting point is very profitable, because it is easily liquidated, so that the use of fuel for the metal smelting process is



more efficient and low cost. For machinery in austempered ductile iron (ADI), the most widely used type of ceramic cutting tool is the alumina-based class.

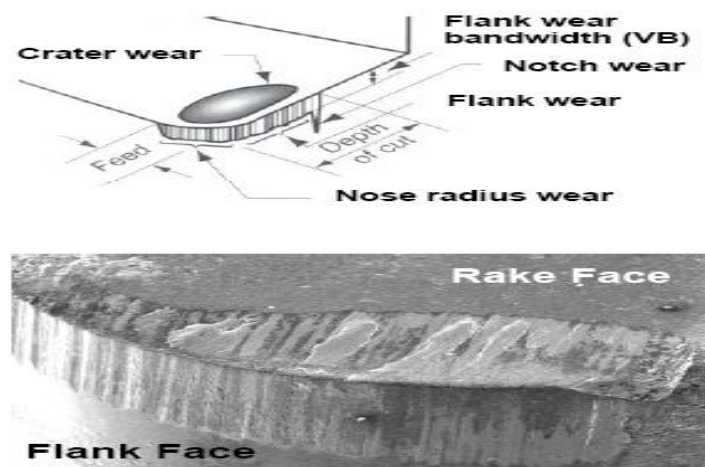
There are different classes of ceramic materials for cutting tools, each with different properties. There are two main types of ceramics for cutting tools namely aluminum oxide ( $\text{Al}_2\text{O}_3$ )-based, and silicon nitride based ( $\text{Si}_3\text{N}_4$ ).  $\text{Si}_3\text{N}_4$ -based ceramics are formed by  $\text{Si}_3\text{N}_4$  crystals with the intergranular  $\text{SiO}_2$  phase, sintered with alumina. [2]. Compared to the  $\text{Al}_2\text{O}_3$  class,  $\text{Si}_3\text{N}_4$  based ceramics have higher toughness (except for whiskey  $\text{Al}_2\text{O}_3$  reinforced ceramics), greater hardness, increased thermal shock resistance, and good chemical stability.

Ceramic cutting tool wear behavior must be properly understood for effective use in hard machining of materials. Several studies have been conducted focusing on ceramic cutting tool materials for machining different working materials.[3] Studied the fabrication of materials and the performance of ceramic cutting tools based on  $\text{Al}_2\text{O}_3$  materials /TiC, El-Wardany et al. observed that plastic deformation of ceramic cutting edges, triggered damage to surface roughness, and finally, edge fractures, while machining steel was hardened using ceramic cutting tools.[4]. Chakraborty et al conducted an experiment with cast iron machining using several types of ceramic and carbide cutting tools. Their results show that the dominant wear mechanism that occurs in ceramic-based carbide cutting tools is abrasion, whereas for silicon-based silicon cutting ceramic cutting tools the basic wear mechanism is diffusion.[5].

In metal cutting, the interactions among tool, chip, and workpiece always cause tool wear and other damages to the tool, such as plastic deformation, chipping, and thermal and mechanical cracks [6]. A comparison with tool life and surface roughness of the workpiece produced, with the aim of understanding the wear mechanism that occurs in ceramic cutting tools based on silicon nitride materials and layered carbide cutting tools in the formation of cast iron materials has been pointed by others [7].

Low and high temperatures during the machining process can affect the life of cutting tools [8]. Wear of cutting tools certainly also affect the performance of the tool which has an impact on the value of the resulting surface roughness. [9].

The type of damage that occurs in the cutting tool is plastic deformation caused by high temperature pressure in the active area of the cutting tool so that the hardness and strength of the cutting tool decrease with increasing cutting temperature. An increase in temperature at the cutting tool can occur in the area of the chip or in the main area of the cutting tool. Because of that the shape and location that wear out on the chip area are called crater wear, and wear on the main area of the cutting tool is called edge wear. The type of wear on the cutting tool is shown in Figure 1



**Figure 1.** Types of cutting tools wear

The flank wear was noticed to be lower than 0.3 mm for both tools. Abrasion and adhesion are most acting wear mechanisms for coated carbide whereas abrasion is most dominant for the ceramic tool. For both tools, speed is the major dominating character for wear at the flank surface [1,10].

## 2. Methodology

The CNC lathe "Mazak Mazatec Quick Turn 8N" was used in this study. The workpiece material that is cut is gray cast iron with a diameter size: 50 mm, length: 150 mm. The tool used is the ceramic cutting tool type TNMG 160404



**Figure 2.** Ceramic cutting tool

Observations and measurements of cutting tool wear were carried out using the Jenco Digital Microscope and surface tester are presented on Fig. 3 and Fig. 4 respectively.



**Figure 3.** Jenco Computer and Digital Microscopes.

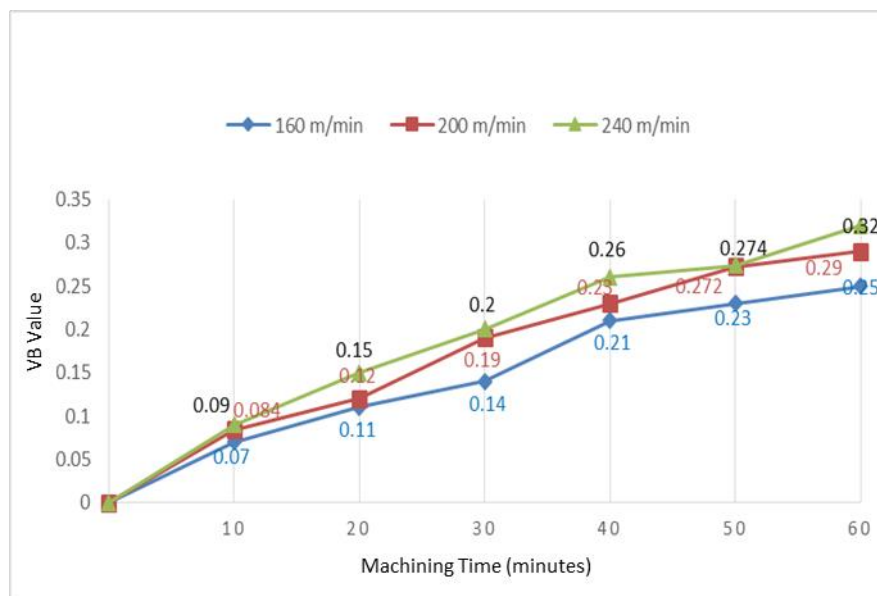


**Figure 4.** Surface Tester

The first step in this experiment is to determine the cutting parameters used. The cutting parameters include cutting, feeding depth and cutting speed. Three cutting speed variations are 160, 200 and 240 m / min with a feeding rate of 0.05 mm / rev, cutting depth of 0.5 mm. The machining process is carried out without using coolant. Then move the cutting tool to the surface of the workpiece. Cutting tool then cuts metal. Machining is stopped for each 10 minute span to see and measure the cutting tool's wear, the edge wear criteria are set at 0.3 mm. If the cutting tool has experienced edge wear, which can be observed and measured using a digital microscope, the cutting tool can no longer be used for metal cutting. However, if the wear value set at 0.3 mm has not been achieved, then the cutting tool can continue the machining process. Besides that, the symptoms of wear / damage of the cutting tool can be known by the vibrations generated on the machine tool or the condition of the work piece surface produced.

### 3. Results and discussion

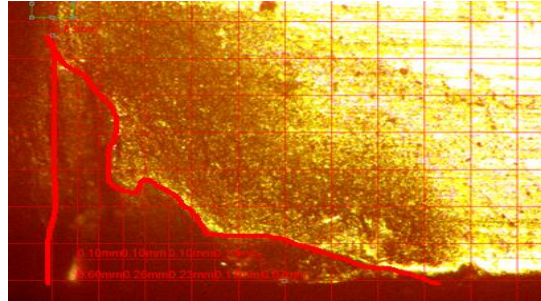
The observations and experimental measurements of the machining process on the effect of cutting speed on the wear of ceramic cutting tools are presented in the following figure



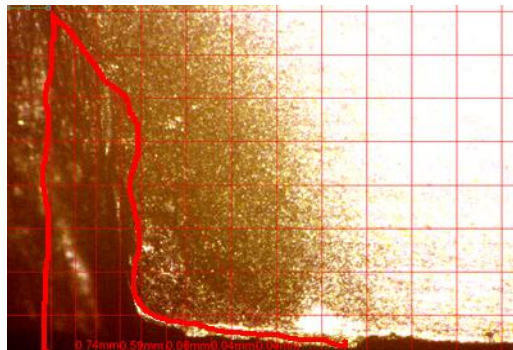
**Figure 5.** Ceramic cutting tool wear

Based on the graph above it can be seen that continuously there is an increase in the value of cutting tool wear so that it reaches the set limit as a limit to the wear of VB cutting tools by 0.3 mm. This happens at the time of machining 60 minutes. Wear occurs of course because of the friction in the contact area of the cutting tool and the workpiece causing thermal on the surface of the cutting tool, the longer, the heat that occurs in the cutting tool contact area has increased. This certainly affects the crystal structure of the cutting tool material until it finally undergoes abrasive and wear on the edge of the cutting tool. This happens as an effect of increasing cutting speed ( $V_c$ ). Can be seen from the graph at the cutting speed of 160 m / min at 60 minutes the wear growth that occurs is very slow compared to the cutting speed of 200 m / min and 240 m / min to 60 minutes, this is because the cutting speed value used is low so the heat that occurs is not affect the overall contact area of the cutting tool, however fine erosion has also occurred due to the cutting force that occurs when the cutting tool cuts the metal workpiece.

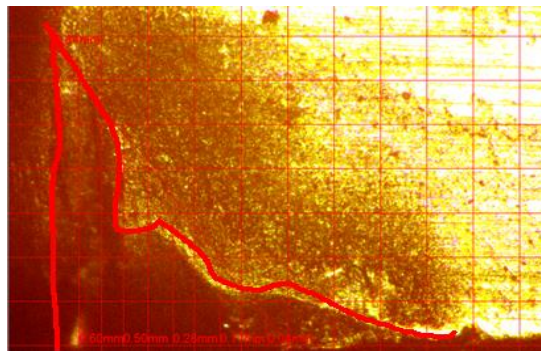
Topography of ceramic cutting tool edge wear at 60th minute machining with cutting speed variation ( $V_c$ ) is presented on Fig. 6 to Fig. 8 respectively.



**Figure 6.** Flank wear at cutting speed 160 m / min



**Figure 7.** Flank wear at cutting speed 200 m/min

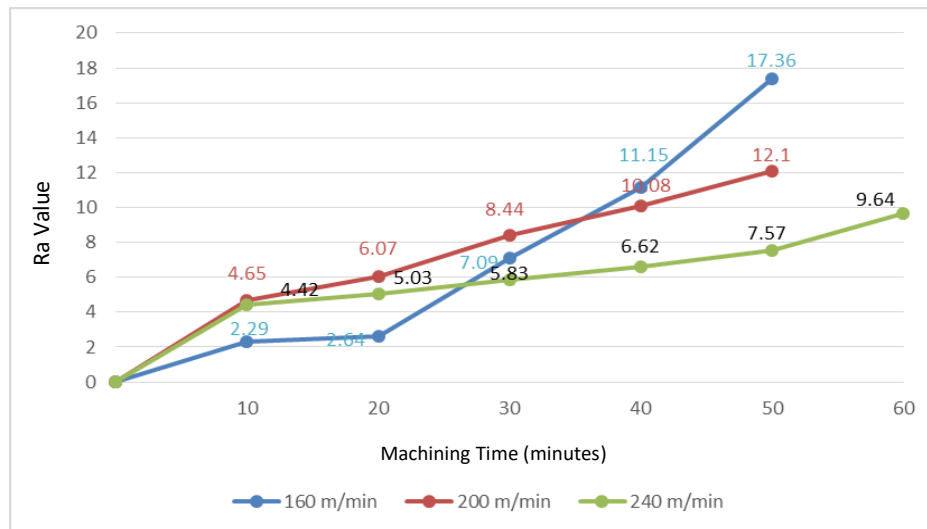


**Figure 8.** Flank wear at cutting speed 240 m/min

During the machining process is carried out by using a cutting speed of 160 m / min minutes, observations on the wear of the cutting tool are carried out, and the wear value is obtained (VB) in the 60th minute. main cutting tool. The abrasive wear continues to rise in the main areas of the cutting tool. Whereas in the main field of the cutting tool, this abrasive process causes the formation of edge wear, as a result the work surface surface roughness increases, and in the machining process, there is increasing noise. Wear due to this abrasive process continues to grow to reach the cutting edge of the cutting tool. When the cutting speed is increased by 200 m / min, the wear of the cutting tool starts to increase in the 60th minute. This is due to high friction due to increased cutting speed causing higher heat, so that the heat distribution at the cutting tool contact angle occurs faster which causes abrasive and in the end part of the chisel is eroded, wear and tear occurs. Is BUE (build up edge) which is a buildup of material layers in the chip area near the cutting tool.

The accumulation of layers of material that has just formed is attached to around the main field. This wear mechanism is due to the relatively high pressure and speed that causes the newly formed workpiece surface to stick with the cutting tool's angle to come off with the chip.

The use of cutting speed 240 m / min, wear that occurs in the 60th minute. The type of wear that occurs is plastic deformation. This mechanism occurs because the cutting tool is deformed plastic due to compressive load and deformation due to the high shear load in the main cutting tool causing edge wear. This is due to increasing cutting times and high cutting speeds so that the power of the cutting tool decreases.



**Figure 9.** Surface roughness of workpiece

Comparative analysis of work piece surface roughness values is seen based on the comparison of workpiece surface roughness value at 60 minutes, because at that minute the cutting tool has experienced wear and tear. Based on the surface roughness graph it is seen that along with the increase of the cutting tool wear rate, there is an increase in the value of surface roughness. This happens because the wear tip of the cutting tool can no longer perform its function of cutting metal with the sharpness of the cutting angle, but what happens is that the friction between the surface of the cutting tool is blunted against the surface of the workpiece, splitting occurs due to friction that causes heat high in the cutting tool and workpiece contact area, due to a decrease in material quality, the debris is formed due to the push of the cutting tool [10-11].

From the observations it can be seen that the greater wear of the cutting tool is directly proportional to the increase in the value of the surface roughness of the workpiece. This is because when cutting, the cutting tool's corners are no longer cutting, but rather because of cutting caused by friction from the worn cutting tool. This shows that the effect of the wear of the cutting tool causes damage to the surface of the workpiece.

#### 4. Conclusion

From the results of testing and analysis carried out, it can be concluded that Increasing the cutting speed has an effect on wear on the edge of the cutting tool, so the cutting tool becomes shorter. The roughness of the workpiece (Ra) is directly proportional to the value of the cutting tool (VB) wear, because in the cutting process, the cutting tool's cutting edge is no longer cutting, but because of cutting caused by friction from the worn cutting tool. The more worn the cutting tool and the lower cutting speed, the

higher the work piece surface roughness produced. Wear that occurs in the cutting tool is an abrasive. The wear of the cutting tool in the cast iron machining process takes place in the 60th minute

## References

- [1] Panda A, Sahoo A K, Rout A K, Kumar R and Das R K 2018 Investigation of Flank Wear in Hard Turning of AISI 52100 Grade Steel Using Multilayer Coated Carbide and Mixed Ceramic Inserts *J. Procedia Manufacturing*. **20** 365-371.
- [2] Yeckley R 2005 *Ceramic Grade Design* in: Kennametal Comprehensive Application Engineering Guide Kennametal University Latrobe PA 12 2–12
- [3] Xu CH, Ai X and Huang C Z 2001 Fabrication and Performance of an Advanced Ceramic Tool Material *J. Wear*. **249** 503-508
- [4] El-Wardany T I, Mohamed E, Elbestawi M A, 1993 *Material Side Flow in Finish Turning of Hardened Steel with Ceramic Tools, Contact Problems and Surface Interactions in Manufacturing and Tribological systems* New York: ASME PED 67 159–170.
- [5] Chakraborty J A, Bhaduri S B and Mahajan Y R 1990 Performance of Ceramic Cutting Tools in Machining Cast Iron. *Powder Metal Int* 22
- [6] Lubis S, Rosehan, Darmawan S and Adianto Malik R 2019 The Influence of Cutting Speed Variation in Turning of AISI 304 Materials on Wear and Tool Life Coated Carbide Cutting Tools. *Int. J. of Mechanical Engineering and Technology (IJMET)* **10** 203-210
- [7] Diniz A E and Ferrer J A G 2008 A Comparison between Silicon Nitride-Based Ceramic and Coated Carbide Tools in the Face Milling of Irregular Surfaces. *J. of Materials Processing Technology*. **206** 294–304.
- [8] Kalpakjian S 1991 *Manufacturing Processes for Engineering Materials* 2<sup>nd</sup> ed (Chicago: Addison-Wesley Publishing Company Inc)
- [9] Sobron M L, Darmawan S and Adianto Ericson 2019 Effect of Cutting Speed on Temperature Cutting Tools and Surface Roughness of AISI 4340 Steel IOP Conf. Series: *Materials Science and Engineering* **508** 012053
- [10] ASM Handbook 1989 *Metallography and Microstructures* 16 Machining 27–31.
- [11] Mrihnenaningtyas and Prayadi R 2015 Analisis Umur Pahat dengan Variasi Sudut Geram, Kecepatan dengan dan Tanpa Pendingin. *Pros. Seminar Nasional Sains dan Teknologi Terapan III* (Teknologi Adhi Tama Surabaya)
- [12] Rochim T 1985 *Teori dan Teknologi Proses Pemesinan* (Bandung: Jurusan Teknik Mesin, Fakultas Teknik Industri - Institut Teknologi Bandung)