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Wear Analysis of Coated Carbide Cutting Tools in The Turning Process Nodular Cast Iron Effect of Cutting Speed

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Abstract. *When the machining process takes place, several cutting parameters such as cutting speed will determine the effectiveness of the machining process. Determining the correct combination of cutting parameters will increase the effectiveness of the machining process. Therefore, to increase the effectiveness of machining, a method is needed to determine suitable machining parameters in order to reduce excessive wear of cutting tools. By finding the effective cutting parameters, the machining process will be more efficient and effective without using unnecessary resources. Based on this, this study was conducted to analyze the wear and tear that occurs on cutting tools when turning cast iron using coated carbide chisels. the turning process is done using a CNC lathe. In this study, variations in cutting speed were used ranging from 160 m / minute, 210 m / minute, 260 m / minute, 310 m / minute and 360 m / minute. Cutting is done in a span of 10 minutes to observe and measure the wear on the cutting tool. Observations and measurements are carried out using a digital microscope. The results showed that the increase in cutting speed applied to machining resulted in increased wear of the cutting tool. This can be proven by cutting speed of 160 m / minute in 25 minutes and cutting speed of 260 m / minute it takes 15 minutes. The wear that occurs on the cutting tool is wear on the flank that occurs as a result of the abrasive process.*

INTRODUCTION

Engineering materials have developed in terms of hardness and strength. cast iron is one of these engineering materials. Nodular Cast Iron or Ductile Cast Iron are two types of cast iron. Nodular cast iron has superior advantages over gray cast iron and in applications nodular cast iron is widely used in constructions that require high strength and durability at high speeds. For example, nodular cast iron applications are used in the automotive industry for fuel pumps and lubricating pumps, crankshafts, differential housings and engine cylinders and other applications in the wind power industry, such as joints. -connection and structure of machine frames (structural parts machine frames). This nodular cast iron has a large potential according to good mechanical characteristics, is easy to mold and the cost is relatively low. [1] The application of nodular cast iron, in terms of surface contouring, is carried out by means of a turning machining process. As in the manufacture of the crankshaft. The turning process is a machining process to form a workpiece surface that is cylindrical. In the turning process, it takes the right parameters to get good quality and the right machining time. Many factors of machining parameters affect the quality of the product. If one of the parameters is incorrect, for example the cutting speed is too high, it can increase the wear and tear on the cutting tool. As wear and tear from cutting tools increases, tool life is also reduced. Research conducted by Venkatesh. (1980) note that the tool life of cutting tool carbide has decreased sharply along with the increase in cutting speed. [2] Cutting tool wear is caused by the large pressure of the cutting force and the high temperature in the active area of the cutting tool. There are 2 types of cutting tool wear, namely crater wear and flank wear. [3] A cutting tool has reached a specified wear limit with criteria such as an increase in cutting force, vibration, an increase in machined surface roughness and a product geometry that is not as planned. [4].

The time of contact between the chip/workpiece and the tool is low due to the high relative speeds. However, diffusion may occur due to the seizure zones between the chip and the tool rake face and, occasion-ally, between the workpiece and the tool flank face. Because these zones are renewed periodically, saturation is avoided,and consequently, the diffusive flow is maintained during the process. This wear mechanism is responsible mainly for crater wear at high cutting speeds because the rake face is the area in which the necessary conditions for diffusion are more prone to occur.[6]

The dimensions of wear cutting tools determine the limits of tool life. Thus, the growth of cutting tools' wear determines the end of performance cutting tools. The growth of flank wear begins with relatively fast growth shortly after the cutting of the workpiece, and then rapid growth occurs again when the cutting speed increases as the workpiece diameter have decreased. When the wear growth begins to recur quickly, it is considered a tool life

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limit.[10]
Based on this, this research aims to analyze the effect of cutting speed on the wear and tear of coated carbide cutting tools in the turning process of nodular cast iron.

METHODOLOGY

To achieve the objectives of this research, experimental methods were used. The experimental procedure performed is shown in Figure 1.

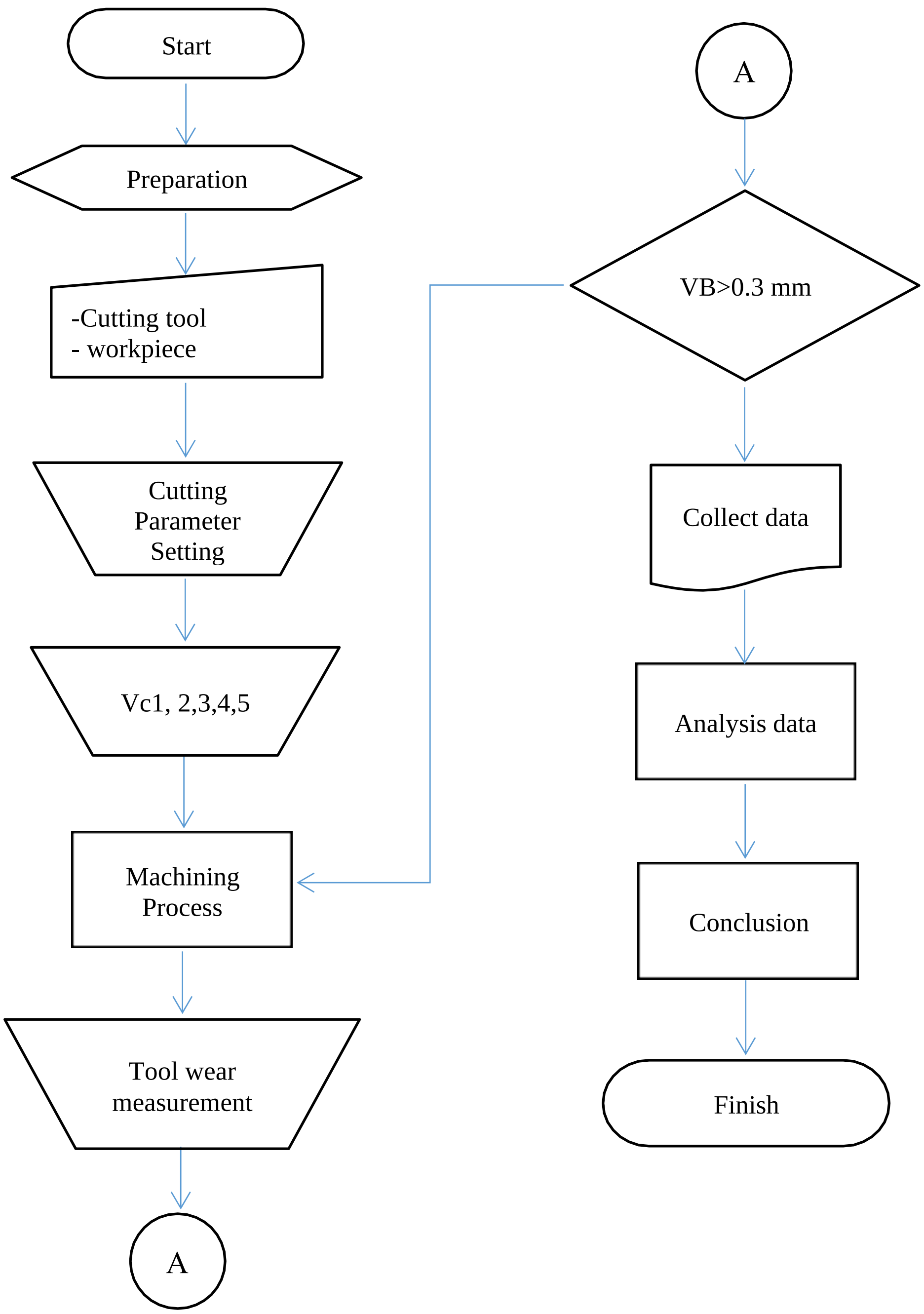
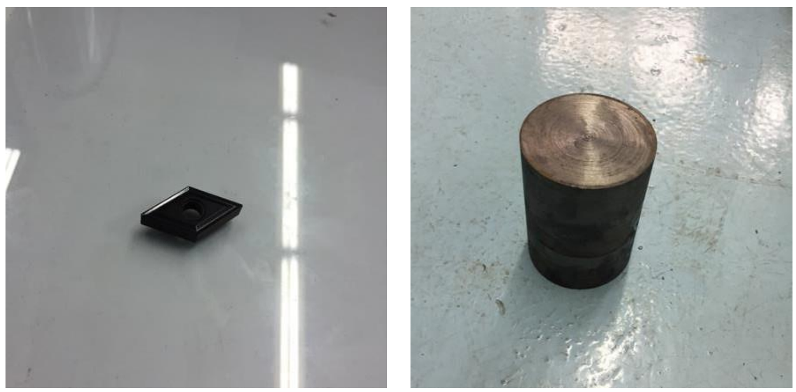


FIGURE 1. Flow chart diagram of experimental

Equipment, materials and characteristics This research was conducted using a CNC lathe, and the observation of cutting tool wear was carried out using a digital microscope as shown in Figure.2

(a) (b) (c)
FIGURE 2. Equipment (a) CNC Lathe (b) Microscope *Digital Jenco* dan Computer (c) *Toolholder*

The type of cutting tool material is carbide coated and the workpiece that is cut is nodular cast iron as shown in Figure 3.



(a) (b)
FIGURE 3. Material (a) *Coated Carbide* DNMG150404 (b) *Nodular Cast Iron*

TABLE 1. Mechanical Characteristics of Coated Carbide DNMG150404 [5]

Nose Radius R ε	Coated Composition	Hardness of Substrate	Fracture Toughness	Transverse Strength
0.4	Micro columnar TiCN + Al_2O_3	1.570 HV	12 $MPa.m^{0,5}$	2.78 GPa

TABLE 2. Composition of Nodular Cast Iron [1]

Percentage Element (%)										
C	**Si**	**S**	**P**	**Mn**	**Ni**	**Cr**	**Cu**	**Mg**	**Al**	**Co**
2.77	1.26	0.11	0.036	1.24	0.26	0.27	0.18	0.127	0.063	0.073

TABLE 3. Physical and Mechanical Characteristics of Nodular Cast Iron Material [7]

Properties	Metric
Density	7.1 g/cm^3
Tensile Strength	530 MPa
Yield Stress	455 MPa
Elongation (%)	7-18
Brinell Hardness (HB)	160-220

The machining process begins with determining the cutting parameters. The wear characteristics of the cutting tool are determined by the V_B value, based on the reference obtained from the ISO 3685 standard for cutting tools, [8] which is V_B = 0.3 mm. [8] If the V_B value has reached 0.3 mm, the cutting tool is declared worn out and can no longer be used. The variation of cutting speed used is V_{C1} = 160 m / min, V_{C2} = 210 m / min, V_{C3} = 260 m / min, V_{C4} = 310 m / min, and V_{C5} = 360 m / min which are determined based on the specifications of the cutting tool used and pay attention to the capacity of the CNC turning machine in supporting high rotation speeds. The feed speed value used is V_f = 241 mm / min and a constant feeding depth of 1 mm for all variations in cutting speed. Observation and measurement of cutting tool wear were carried out in the first 10 minutes, and then observations and measurements were made every 5 minutes until it reached the specified V_B value. Observation and measurement of cutting tool wear values were carried out using a digital microscope.

RESULT AND DISCUSSION

The workpieces and cutting tools that have been used in the machining process are presented in Figure 4.

.

(a) (b)

FIGURE 4. (a) Nodular Cast Iron Workpiece after machining (b) Carbide Cutting tool

The value of cutting tool wear resulting from the process of cutting a cast iron workpiece is presented in the following table:

TABLE 4. Wear values of cutting tools at cutting speed, Vc = 160 m / min

Time (minute)	Tool wear (mm)				
	Grid 1	**Grid 2**	**Grid 3**	**Grid 4**	**V_B**
10	0.11	0.14	0.13	0.13	0.1275
15	0.18	0.22	0.2	0.22	0.205
20	0.27	0.26	0.23	0.27	0.2575
25	0.27	0.3	0.32	0.36	0.3125

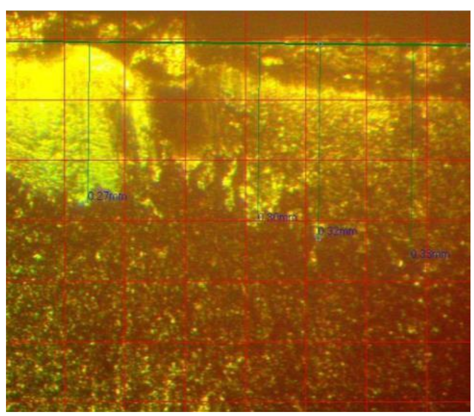


FIGURE 5. The wear of the cutting tool at a cutting speed of 160 m / min (magnification 50 x)

TABLE 5. Wear values of cutting tools at cutting speed, Vc = 210 m / min

Time (minute)	Tool wear (mm)				
	Grid 1	**Grid 2**	**Grid 3**	**Grid 4**	**V_B**
10	0.13	0.13	0.18	0.19	0.1575
15	0.16	0.24	0.23	0.24	0.2175
20	0.26	0.3	0.5	0.31	0.3425

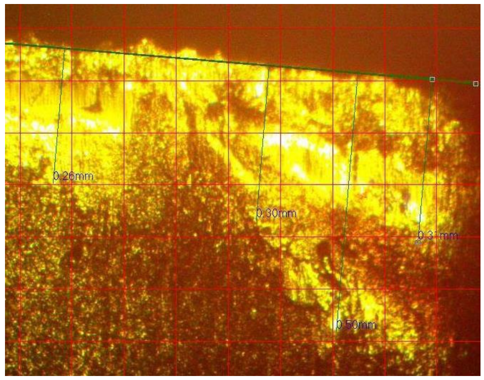


FIGURE 6. The wear of the cutting tool at a cutting speed of 210 m / min (magnification 50 x)

TABLE 6. Wear values of cutting tools at cutting speed, Vc = 260 m / min

Time (minute)	Tool wear (mm)				
	Grid 1	**Grid 2**	**Grid 3**	**Grid 4**	V_B
10	0.2	0.2	0.21	0.22	0.2075
15	0.28	0.29	0.31	0.33	0.3025

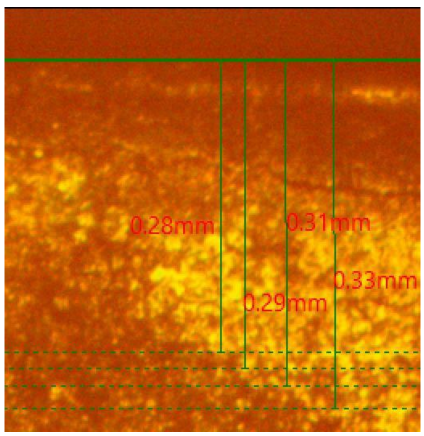


FIGURE 7. The wear of the cutting tool at a cutting speed of 310 m / min (magnification 50 x)

TABLE 7. Wear values of cutting tools at cutting speed, Vc = 310 m / min

Time (minute)	Tool wear (mm)				
	Grid 1	**Grid 2**	**Grid 3**	**Grid 4**	V_B
10	0.22	0.24	0.22	0.21	0.2225
15	0.26	0.28	0.34	0.4	0.32

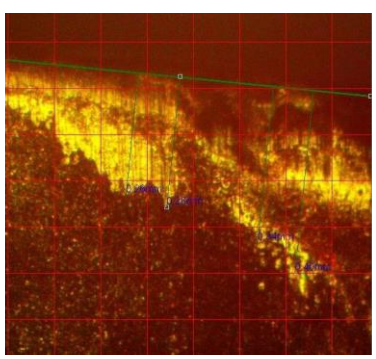


FIGURE 8. The wear of the cutting tool at a cutting speed of 160 m / min (magnification 50 x)

TABLE 8. Wear values of cutting tools at cutting speed, Vc = 360 m / min

Time (minute)	Tool wear (mm)				
	Grid 1	**Grid 2**	**Grid 3**	**Grid 4**	V_B
10	0.21	0.23	0.28	0.24	0.24
15	0.32	0.34	0.36	0.38	0.35

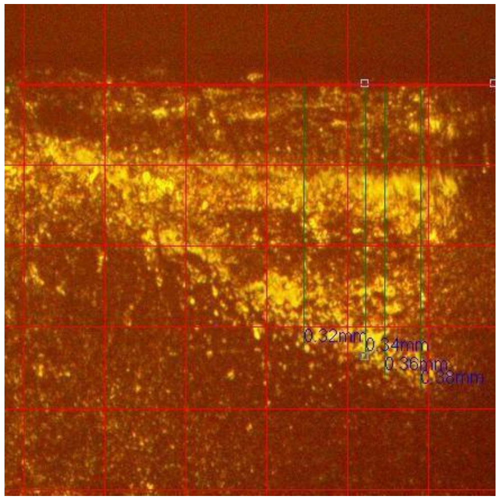


FIGURE 9. The wear of the cutting tool at a cutting speed of 360 m / min (magnification 50 x)

ANALYSIS OF CUTTING TOOL WEAR

At cutting speed, Vc 160 m / min, cutting tool wear occurs in 23 minutes 52 seconds. The wear growth of cutting tools is slow moving. When cutting lasts for 10 minutes, the wear value on the cutting tool is visible. At this cutting speed, the wear growth occurs longer than other cutting speeds. The wear that occurs is abrasive wear and adhesion. The abrasive process occurs due to friction originating from the grinding plane with the cutting tool plane, while the adhesion process is caused by the accumulation of material at the end of the cutting tool or what is known as BUE (Built-Up Edge). The cutting tool experiences a significant increase in wear value from the 10th to the 15th minute and the cutting tool exceeds its wear limit by the 25th minute.

The cutting process uses a cutting speed, Vc 210 m / min, wear and tear on the cutting tool at 18 minutes 18 seconds. At this cutting speed, the growth of cutting tool wear is faster than the cutting speed, Vc 160 m / min. At this cutting speed, when the cutting process is running for 10 minutes, the wear value has reached half of the specified wear value. The wear that occurs in cutting tools is abrasive wear and adhesion. The BUE process that is formed at this cutting speed is less than the cutting speed, Vc 160 m / min. Cutting tool wear increased significantly in value in the 15th to 20th minutes and the cutting tools exceeded the tool wear limit at the end of the 20th minute.

The cutting process uses a cutting speed, Vc 260 m / min, and wear occurs on the cutting tool at 14 minutes 52 seconds. At this cutting speed, the wear that occurs is the same as at the cutting speed, Vc 210 m / min, namely abrasive wear, adhesion and plastic deformation. But wear growth is mostly due to the abrasion process. The plastic deformation process occurs due to the compressive load and deformation due to high shear loads in the rivet area which results in crater wear and the plastic deformation process is influenced by temperature. At this cutting speed, BUE does not occur too much so that it affects the faster growth of cutting tool wear. And the plastic deformation process does not occur too much, this is evidenced by the emergence of sparks that are not too large, such as the cutting speed of Vc 310 m / min and Vc 360 m / min. At this cutting speed, after observation and measurement, there was a significant increase in the wear value at 10 minutes when compared to the cutting speed, Vc 210 m / min. At 15 minutes, there is a noise that is not too big because the cutting tool has reached its wear point. The cutting tool is over the wear limit at the end of the 15th minute.

The cutting process with a cutting speed of 310 m / min, the cutting tool wears out at 13 minutes 58 seconds. The wear growth that occurs is not much different as in the cutting speed, Vc 260 m / min. The wear that occurs is abrasive wear and plastic deformation. The occurrence of the plastic deformation process is evidenced in the 10th minute by the occurrence of sparks during friction between the cutting tool and the workpiece. At this cutting speed, the plastic deformation process that occurs is quite large when compared to the cutting speed, Vc 260 m / min, the resulting spark is greater. And at minute 15, there is also a noise because the cutting tool has reached its wear point. Cutting tool wear limits occur at the end of the 15th minute.

At the cutting speed, Vc 360 m / min, wear occurs on the cutting tool at 12 minutes 44 seconds. At this cutting speed, the wear growth is not much different as that of the cutting speed, Vc 310 m / min and also the cutting speed, Vc 260 m / min. In the last three cutting speeds, the tool life is not much different. The wear that occurs is abrasive wear and plastic deformation. At this cutting speed, when cutting the 10th minute, there is already a spark and when compared to the cutting speed, Vc 310 m / min the resulting spark is faster and also bigger. In the 15th minute cutting process, the noise is greater than at the cutting speed, Vc 310 m / min because the cutting tool has reached the point of wear and the resulting wear is greater. The cutting tool exceeds the set wear limit at the end of the 15th minute.
Using the interpolation method between the wear times, the tool life of the carbide is obtained as follows:

TABLE 9. Tool life of coated carbide

Cutting speed $\mathbf{V_c}$ **($^{m}/_{min}$)**	**Time (minute)**
160	23’52”
210	18’18”
260	14’52’’
310	13’58’’
360	12’44’’

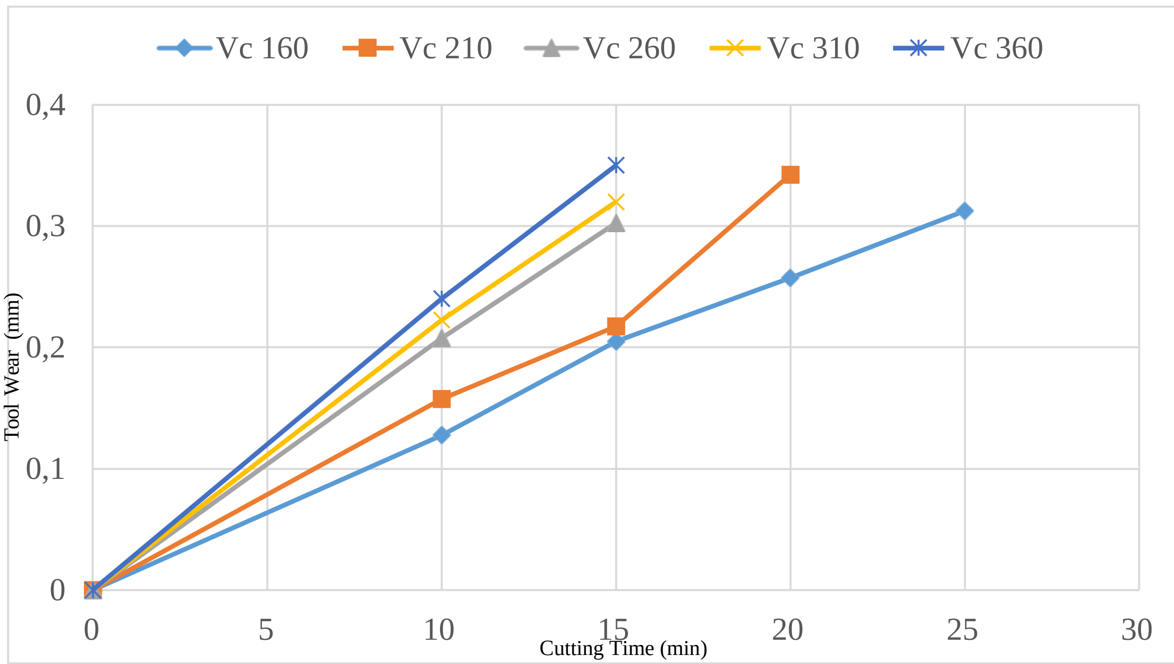


FIGURE 10. Cutting tool wear growth

When the cutting speed used is higher, the less time it takes to reach the V_B = 0.3 mm value. This increase occurs due to the friction of the cutting tool against the workpiece surface. And the wear that occurs in the cutting tool lies in the wear on the edges, it can be seen from this wear starting from the cutting edge and continuing to widen. This incident makes the cutting tool wear out quickly and results in the machining process resulting in the contour of the workpiece surface that is not what we want. According to Andri's research (2018) on the growth of carbide cutting tool wear on gray cast iron, states that high cutting speed affects the wear value of the cutting tool. This increase occurs due to cutting tool friction against the workpiece which results in the spread of heat on the cutting tool which results in abrasion on the cutting tool. [11]

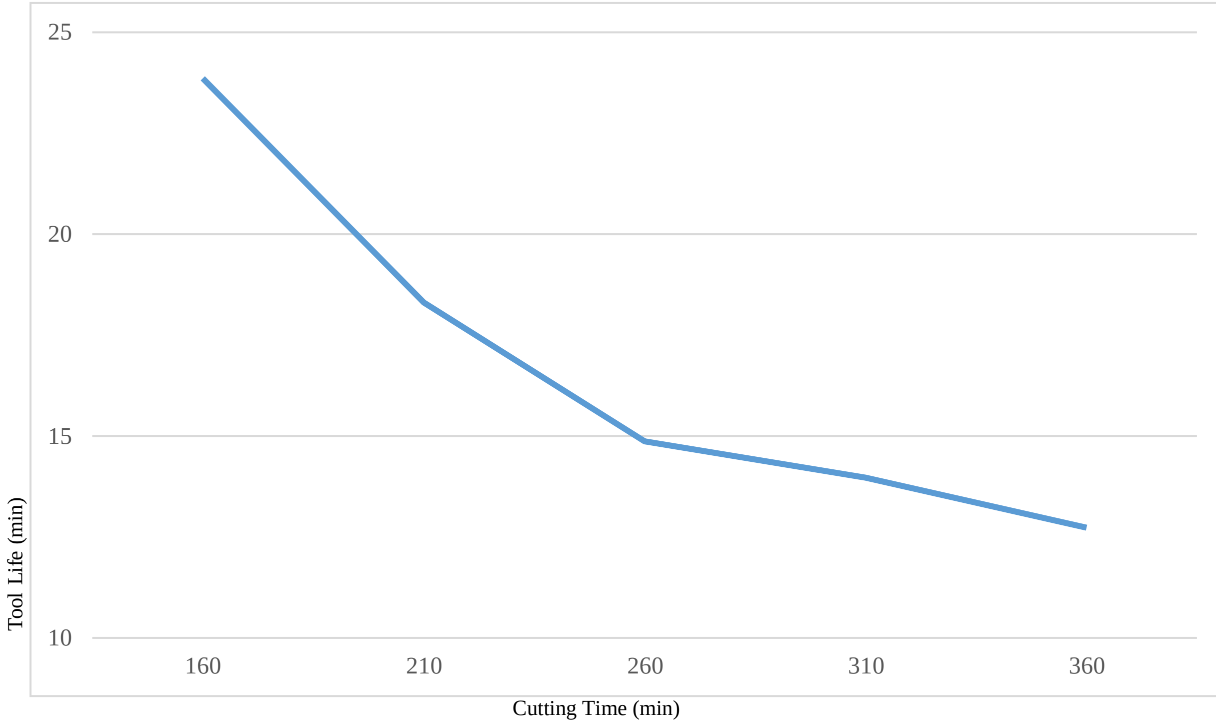


FIGURE 11. Graphic Cutting Speed Vs Tool Life

Based on the graph presented in Figure 11, it can be seen that the higher the cutting speed used, the tool life decreases rapidly. This occurs due to friction between 2 areas, namely the cutting tool and the workpiece. The resulting friction causes the surface of the cutting tool to experience an abrasive process and so that the cutting tool experiences a decrease in function (wear). based on research by Hendri Budiman and Richard (2007) on "Analysis of tool life and wear of cutting tool Carbide for Turning Alloy Steel (ASSAB 760) with the Variable Speed Machining Test Method", it is said that certain feeding movements with the addition of cutting speed also result in an increase in edge wear. cutting tools so that tool life will decrease. The increase in cutting speed (Vc) will accelerate the wear and tear of the cutting tool (V_B), so that the tool life will decrease. And at the same cutting speed, the growth of edge wear (VB) will increase with increasing cutting time. [4] And according to research by W. Grzesik (2012) on "Nodular Cast Iron Machining Process Using CBN (cubic boron nitride) cutting tools", states that the machining process of nodular cast iron uses lower cutting speeds at 100 or 160 m / min extends tool life up to 5 times with a ratio of cutting speeds of about 400 m / min. [9]. Reference cutting tool at 15 minutes is obtained at a cutting speed of 240 m / min. [10]

CONCLUSION

Based on the results of the research discussion, it can be concluded that the time to achieve cutting tool wear is directly proportional to the cutting speed. The higher the cutting speed, the faster the time to achieve wear on the cutting tool, this can be proven at a cutting speed of 160 m / min which takes 25 minutes and at a cutting speed of 260 m / min it takes 15 minutes. And the tool life of the cutting tool is inversely proportional to the cutting speed. The higher the cutting speed, the shorter the tool life of the machining results, this can be proven by the cutting speed of 210 m / min has a tool life of 18 minutes 18 seconds and at a cutting speed of 360 m / min it has a tool life of 12 minutes 44 seconds.

At cutting speeds of 160 m / min and 210 m / min, abrasive and adhesion occurs. This can be seen in the cutting tool, the result of the machining process, there is an accumulation of material in the cutting tool. Meanwhile, at a cutting speed of 260 m / min, there is a wear process that occurs abrasive, adhesion and plastic deformation. And at the cutting speed of 310 m / min and 360 m / min, abrasive wear and plastic deformation occur. This can be seen in the machining process of the spark. Cutting tools experience wear on the cutting tool edges which is called flank wear.

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