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The Influence of Variation in Cutting Speed on Wear Rate of Uncoated and Coated Carbide Cutting Tools

Sobron lubis[1], Alfred Briantio[3] , John Michel[4], Benaya Halomoan Wijaksono[5]
[1,3,4,5]Mechanical Engineering – Engineering Faculty Universitas Tarumanagara Jakarta Indonesia

Aghastya Wiyoso [2]
[2].FSRD Faculty-Universitas Tarumanagara Jakarta Indonesia

Silvi Ariyanti[6]
[6]Industrial Engineering- Engineering Faculty Mercubuana University Jakarta Indonesia

Abstract:- Based on the research conducted using a lathe, it was found that the use of cutting tools made of carbide, both coated and uncoated, is essential for the machining process. The friction that arises during machining causes heat in the contact area of the cutting tools, leading to wear and tear, and ultimately damage to the tools. Therefore, it is crucial to determine the good cutting speed and effective machining time to ensure the quality of the surface of the object being worked on. The research also revealed that cutting speed is one of the factors that influence the wear on cutting tools. The study used AISI 1045 steel as the workpiece material and varied the Cutting parameters, such as cutting speed and spindle rotation, to evaluate the wear growth rate on the cutting tools. The results showed that TiAlN coating has a significant impact on the surface quality of the workpiece and the life of the cutting tool. Cutting tools with TiAlN coating take longer to wear than those without coating.

Keywords:- *Wear rate, Carbide Cutting Edge, Cutting Speed. Tool Wear.*

I. INTRODUCTION

When it comes to cutting a workpiece, machine tools are typically used for the task. One such machine tool is the lathe, which works by removing part of the workpiece through cutting as the object rotates. In this process, choosing the right cutting tools is crucial and should be based on the type of workpiece to be cut. Cutting tools must have high hardness, strength, and resistance to high temperatures so they can operate at high cutting speeds. It's important to select appropriate cutting parameters to ensure optimal metal cutting. With the right cutting tools and cutting parameters, you'll achieve good workpiece surface conditions and significantly extend the cutting tool's lifespan. completely agree. When it comes to cutting a workpiece, using a machine tool like a lathe is the way to go. It's interesting to learn that cutting tools play an important role in the turning process and that their choice must be appropriate for the type of workpiece being cut. I also didn't know that cutting tools have to be hard, strong, and resistant to high temperatures. It makes sense though, as they need to operate at high cutting speeds. And of course, using appropriate cutting parameters is crucial in metal cutting. It's fascinating how choosing the right cutting tools and parameters can result in good workpiece surface conditions and significant cutting tool life. Increasing cutting speed appears to shorten machining time, but it can also cause cutting tools to wear out more quickly. This can ultimately shorten the life of the equipment used. I have read that tool wear, cutting forces, and vibration are factors that can affect the quality and efficiency of machine tools, and there has been a lot of research done on this. [1].The contact time between the chip/workpiece and the tool is low due to its high relative speed. However, diffusion can occur due to the presence of hot zones between the chip and the rake surface of the cutting tool and, sometimes, between the workpiece and the tool flank. This wear mechanism mainly occurs in crater wear at high cutting speeds because the surface of the back rake angle cutting tools is an area where the conditions required for diffusion are more prone to occur.[2]. In metal cutting, the interactiON BETWEEN THE TOOL BIT, CHIPS, and the workpiece always causes tool bit wear and other damage to the tool bit, such as plastic deformation, chipping, and thermal and mechanical cracks. Mechanisms that cause wear or damage to the tool tip include friction, particularly in the presence of a built-up edge (BUE); abrasion; diffusion; oxidation; and variations in thermal and/or mechanical loads.[3]. Research conducted by Diniz et al., with a higher cutting speed of 200 m/min, diffusion occurred when machining S41000 martensitic stainless steel, and friction was dominant in machining S41426 super martensitic stainless steel. In PH stainless steel milling operations, friction is the main factor in wear on cutting tools used for dry cutting, MQL, and abundant emulsion cooling/lubrication systems. The use of a cooling medium with a low flow rate can reduce the adhesion of the workpiece material to the tool and, as a result, reduce frictional action [3]. In a low-carbon manufacturing environment. The results obtained were that (i) optimal cutting parameters change along with the wear conditions of cutting tools; (ii) For the same type of cutting tools with different wear conditions, the optimal values of production carbon emissions, costs, and time increase as the wear conditions of the cutting tools increase; (iii) For various types of cutting tools available with different cutting tool wear conditions, it is necessary to apply a multi-objective optimization method to determine carbon emissions, costs and optimal production time [4]. Wear is a phenomenon that often occurs in machining processes. Wear is not just a single process, but several different processes that can occur independently or simultaneously. Each cutting tool has a wear limit value which is presented in Table 1.

Table 1: m Maximum Wear Limits for Tool Life [5][9].

Cutting tools materials	Workpiece	Tool Wear, V_B(mm)
HSS	Steel and Cast Iron	0,3-0,8
Carbide	Steel	0,2-0,6
Carbide	Cast Iron and Non Ferrous	0,4-0,6
Ceramic	Steel and Cast Iron	0,3

Then wear caused by mechanical behavior is classified into abrasive and adhesive.

Abrasive wear is wear that occurs when hard particles or rough hard surfaces erode and cut the surface, resulting in material on the surface being lost (earth moving equipment).[7].

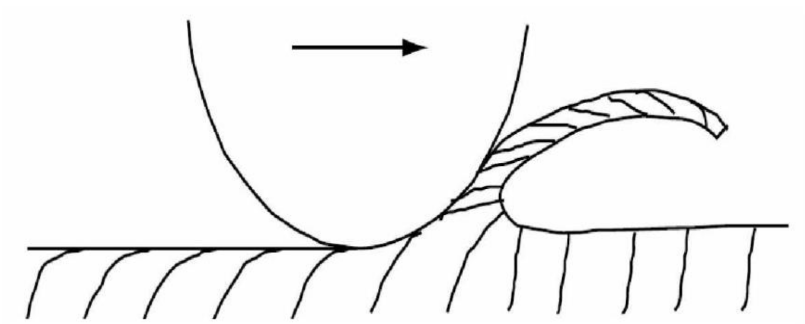

Fig. 1: Abrasive Wear By Microcutting

Adhesive wear, is wear that occurs if softer surface particles stick or adhere to a harder contact opponent.

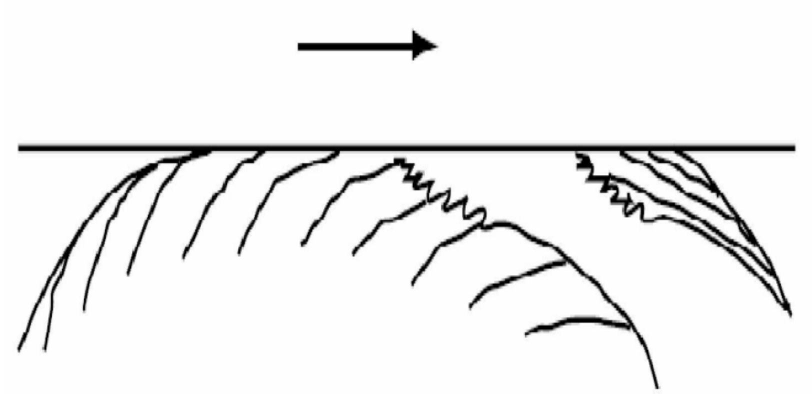

Fig. 2: Adhesive Wear Due To Adhesive Shear And Transfer

From the results of experiments conducted by Park et al., surprisingly, dry and wet machining outperformed MQL and MQL with nanoparticles in terms of cutting tool wear. Cryogenically treated tools showed stable cutting tool wear without severe edge fracture due to cryogenic hardening of cutting tools, while MQL and Nano-MQL experienced severe cracking, and uncoated carbide cutting tools performed better than treated cutting tools. coated.[5] [11].

The issue of reliability and lifespan of cutting tools is currently very topical. Many cutting tool manufacturers determine the durability of cutting tools based only on assumptions or suppositions. The issue of durability of cutting tools and their service life is specified in the ISO 3685 standard. This standard describes how to determine the dependence of time and cutting speed (T-Vc) for different cutting materials through machining long-term test methods.[8][10].

Based on the above, this research was conducted to analyze the wear rate that occurs on coated and uncoated carbide cutting tools due to an increase in the use of cutting speed. This research is also to determine the type of wear that occurs on the cutting tools and how long the two types of cutting tools can carry out their functions when cutting AISI 1045 steel.

II. RESEARCH METHODS

Experimental research using a lathe. The workpiece material used is AISI 1045 steel which has dimensions of length 150 mm and, a diameter of 100 mm

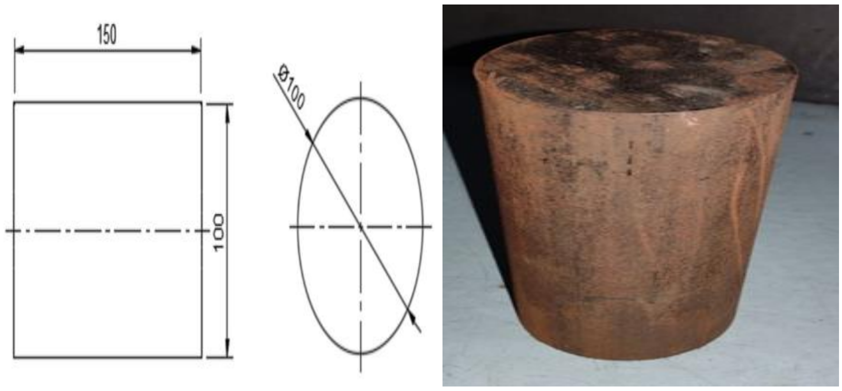

Fig. 3: AISI 1045 Steel Workpiece

A. *Carbide cutting tools uncoating*

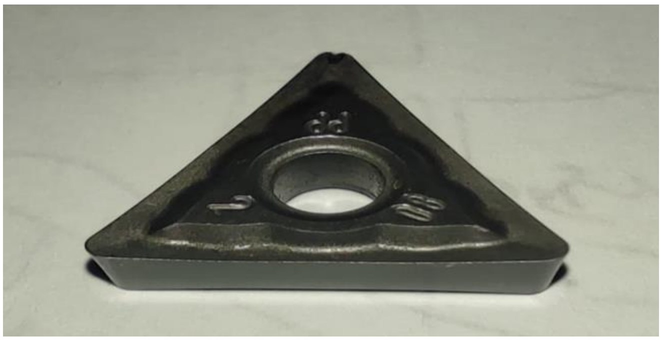

Fig. 4: Uncoated Carbide Cutting Tools

B. *Carbide cutting tools with TiAlN*

CoatingTitanium Aluminum Nitride (TiAlN) is a hard coating that solves many tribological problems with components that can be coated at temperatures of 450°C - 475°C. TiAlN is often applied to steel, hardened steel, and stainless steel materials that require high wear resistance and lubricity. The TiAlN coating provides exceptional oxidation resistance and extreme hardness. That is the reason why this coating performs well in very demanding cutting tool applications, especially when the tool is pushed to its maximum. The advantages of using TiAlN coating on cutting tools are extreme hardness, excellent abrasive wear resistance, higher reliability in dry operations, reduced lubricant, heat resistance, and hard machining.

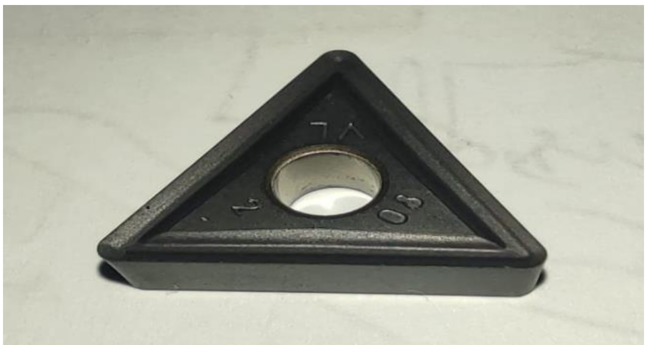

Fig. 5: Carbide Coating Cutting Tools

The equipment used in the research is:

- CNC Lathe
- Digital microscope

The machining process parameters are:

- Cutting speed (Vc) = 150, 200, 250 m/min
- Spindle speed (n) = 500, 670, 840 r/min
- Depth of cut (a) = 0.5 mm
- Feeding speed (f) = 0.1 mm/put

C. *Experimental Procedures*

The turning process is carried out using variations in cutting speed parameters. Before the turning process is carried out, a cutting tools wear (VB) wear limit is first set at 0.3 mm. The turning process was carried out for 5 minutes, then stopped, and the cutting tools were removed from the tool holder and then placed under the surface of the microscope to observe and measure the wear value that occurred. If the measurement results obtained are below the VB value, then the machining process continues for 5 minutes. Thus the machining process is carried out repeatedly so that wear occurs on the cutting tools with a

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value of 0.3 mm. The next process uses different cutting parameters using new cutting tools. The results of measuring the roughness values are then input into a table and created in a graph of speed vs. tool bit wear. Based on the data and the results of wear observations using a microscope, wear analysis was carried out on the two types of cutting tools.

III. RESULTS AND DISCUSSION

Wear values for uncoated carbide cutting tools are presented in Table 2, Table 3, and Table 4.

Table 2: Cutting Tools Wear Values at a Cutting Speed of 150 m/min

Spindle speed (n): 500 rpm feeding (f): 0.1 mm/rev Depth of cut (a): 0.5 mm		
No.	Time, (t,second)	Tool Wear (V_B mm)
1	290	0.1
2	580	0.15
3	870	0.2
4	1160	0.25
5	1450	0.32

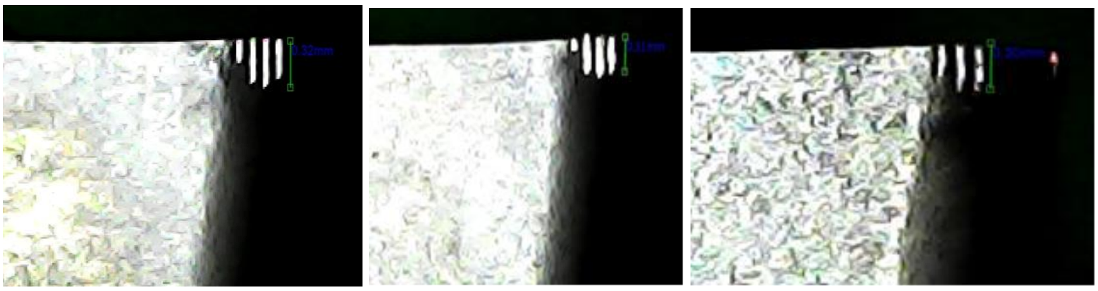
Table 3: Cutting Tools Wear Values at a Cutting Speed of 200 m/min

Spindle speed (n): 670 rpm feeding (f): 0.1 mm/rev Depth of cut (a): 0.5 mm		
No.	Time, (t, second)	Tool Wear (V_B mm)
1	320	0.14
2	640	0.23
3	960	0.31

Table 4: Cutting Tools Wear Values at a Cutting Speed of 250 m/min

Spindle speed (n): 840 rpm feeding (f): 0.1 mm/rev Depth of cut (a): 0.5 mm		
No.	Time, (t, second)	Tool Wear (V_B mm)
1	340	0.15
2	680	0.30

Based on Table 2, Table 3, and Table 4, it can be seen that cutting tools reach wear at around 1450 seconds, 960 seconds, and 680 seconds with VB values of 0.32 mm, 0.31 mm, and 0.30 mm. Apart from cutting speed, turning time also influences cutting tool wear. The form of wear that occurs on cutting tools can be seen in Figure 6 (a), (b), and (c).



(a) (b) (c)

Fig. 6: Wear of Cutting Tools at a Cutting Speed (a) 150 m/min,(b) 200 m/min, (c) 250 m/min

The value of cutting tool wear that occurs at a cutting speed of 150 m/min is 0.32 mm, at a cutting speed of 200 m/min is 0.31 mm, and at a cutting speed of 250 m/min is 0.30 mm.

Wear values for carbide coated cutting tools are presented in Table 5, Table 6, and Table 7.

Table 5: Cutting Tools Wear Values at a Cutting Speed of 150 m/min

Spindle speed (n): 500 rpm feeding (f): 0.1 mm/rev Depth of cut (a): 0.5 mm		
No.	Time, (t, second)	Tool Wear (V_B mm)
1	290	-
2	580	-
3	870	0.05
4	1160	0.09
5	1450	0.12
6	1740	0.15
7	2030	0.19
8	2320	0.24
9	2610	0.30

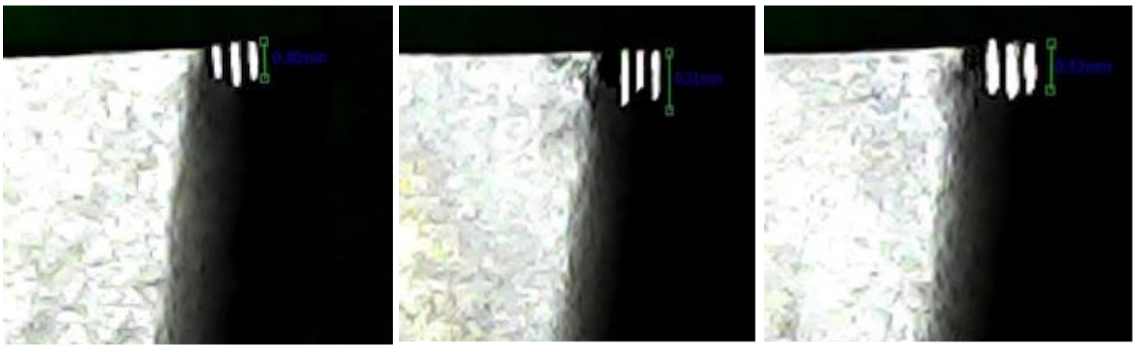
Table 6: Cutting Tools Wear Values at a Cutting Speed of 200 m/min

Spindle speed (n): 670 rpm feeding (f): 0.1 mm/rev Depth of cut (a): 0.5 mm		
No.	Time, (t, second)	Tool Wear (V_B mm)
1	320	-
2	640	0.07
3	960	0.12
4	1280	0.18
5	1600	0.25
6	1920	0.31

Table 7: Cutting Tools Wear Values at a Cutting Speed of 250 m/min

Spindle speed (n): 840 rpm feeding (f): 0.1 mm/rev Depth of cut (a): 0.5 mm		
No.	Time, (t, second)	Tool Wear (V_B mm)
1	340	0.07
2	680	0.16
3	1020	0.24
4	1360	0.32

Based on Table 5, Table 6, and Table 7, it can be seen that cutting tools reach wear at around 2160 seconds, 2160 seconds, and 1360 seconds with VB values of 0.30 mm, 0.31 mm, and 0.32 mm. Apart from cutting speed, turning time also influences cutting tool wear. The form of wear that occurs on cutting tools can be seen in Figure 10, (a), (b) and (c).



(a) (b) (c)

Fig. 7: Wear of Cutting Tools at a Cutting Speed (a) 150 m/min,(b) 200 m/min, (c) 250 m/min.

Wear that occurs in the friction area between the edges of the cutting tool surfaces. In the image (c) you can see the friction area experiencing greater wear compared to the previous cutting speed.

The value of cutting tool wear that occurs at a cutting speed of 150 m/min is 0.30 mm, at a cutting speed of 200 m/min is 0.31 mm, and at a cutting speed of 250 m/min is 0.32 mm.

When cutting tools carry out the metal cutting process, a frictional force occurs between the cutting tools and the workpiece. High cutting speeds will produce greater friction forces. If the speed is increased further, excessive friction forces between the cutting tools and the material will result in higher wear on the cutting tools. During the cutting process, the heat generated by the interaction between the cutting tools and the workpiece can affect the wear rate. High cutting speeds cause heat to be generated in a shorter time. If the heat produced exceeds the cutting tool's tolerance limits, the cutting tool material can experience deformation, lose sharpness, or even break. This accelerates the rate of wear on cutting tools.

The Effect of Variations in Cutting Speed on the Wear Rate of Uncoated Carbide and Coated Carbide cutting tools

A comparison of wear rates between uncoated carbide and coated carbide cutting tools is presented in Figure 8, Figure 9, and Figure 10.

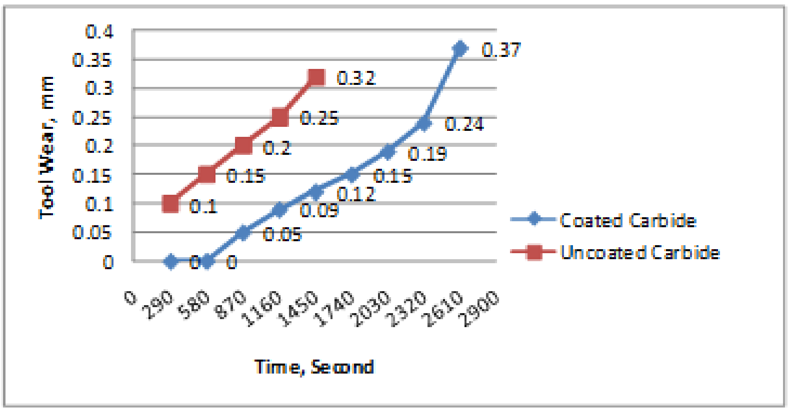


Fig. 8: Comparison of Wear Rates of Uncoated Carbide and Coated Carbide cutting tools at a cutting speed of 150 m/minute

Based on Figure 8, it is found that the wear rate of uncoated carbide and coated carbide cutting tools at the same cutting speed, wear of coated carbide cutting tools is longer compared to uncoated carbide. This can be seen in the graph above which shows that coated carbide cutting tools experienced wear in the 2610th second of 0.3 mm, and uncoated carbide cutting tools wear in the 1450th second of 0.32 mm.

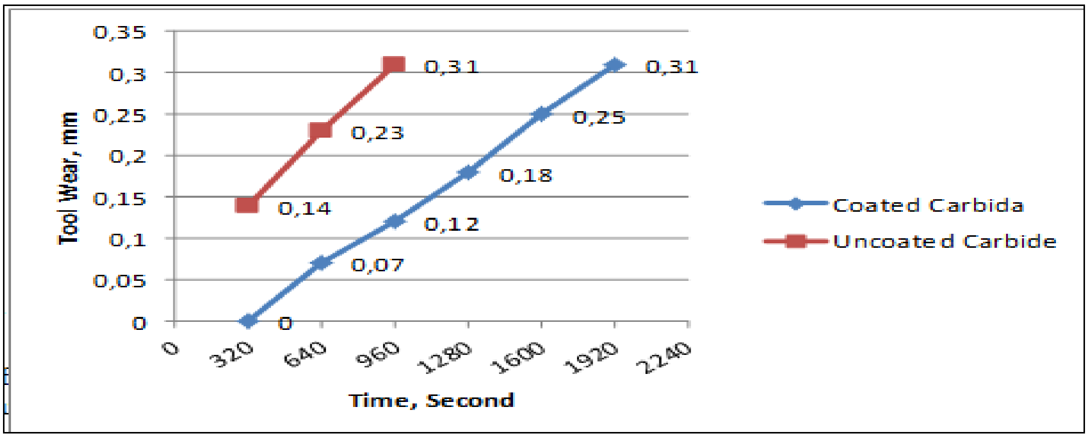


Fig. 9: Comparison of Wear Rates of Uncoated Carbide and Coated Carbide Cutting Tools at a Cutting Speed of 200 m/minute

Based on Figure 9., it is found that the wear rate of uncoated carbide and coated carbide cutting tools at the same cutting speed, wear of coated carbide cutting tools is longer compared to uncoated carbide. This can be seen in the graph above which shows that coated carbide cutting tools experienced wear in the 1920th second of 0.31 mm. Meanwhile, for uncoated carbide cutting tools, wear was 0.31 mm in the 920th second.

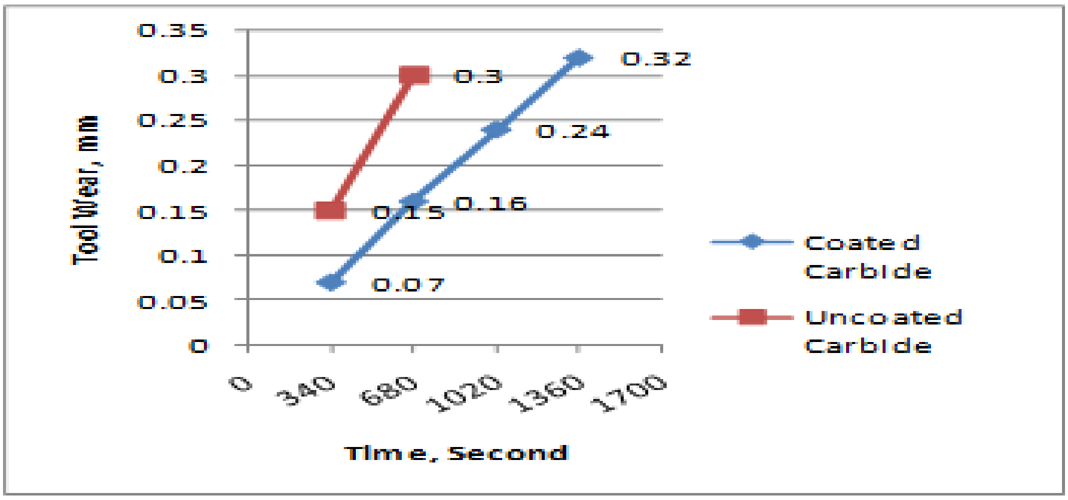


Fig. 10: Comparison of Wear Rates of Uncoated Carbide and Coated Carbide Cutting Tools at a Cutting Speed of 200 m/minute

It is evident from the data shown in Figure 10 that the wear rate of coated carbide cutting tools is lower as compared to uncoated carbide cutting tools at the same cutting speed. The graph clearly illustrates that coated carbide cutting tools experience wear at a much later stage, around the 1360th second, with a wear of 0.32 mm. On the other hand, uncoated carbide cutting tools show wear of 0.30 mm at the 680th second.

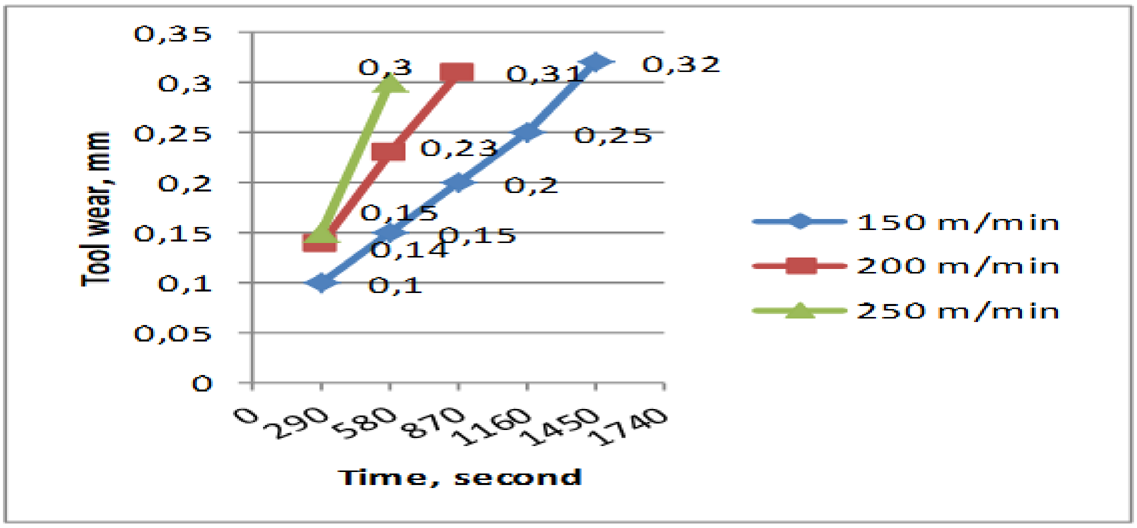


Fig. 11: Comparison of Wear Rates of Uncoated Carbide Cutting Tools at Varying Cutting Speeds

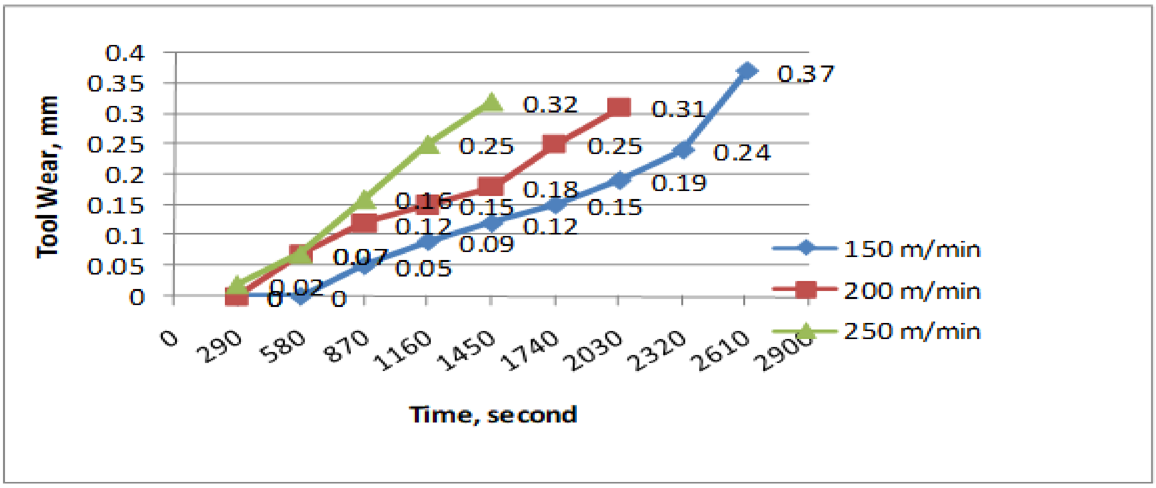


Fig. 12: Comparison of Wear Rates of Coated Carbide Cutting Tools at Varying Cutting Speeds

Based on Figure 12, it shows a comparison of the wear rate between the two cutting tools. Cutting speed influences the wear rate of each cutting tool. The wear that occurs on uncoated carbide and coated carbide cutting tools at a cutting speed of 150 m/minute increases from VB 0.1 mm to 0.32 mm. This is because coated carbide cutting tools have a TiAlN coating which gives the cutting tools increased resistance to wear. It can be seen in the wear rate comparison graph that the increase in wear on coated carbide cutting tools is longer than on uncoated carbide with an average increase in wear of 0.12 mm, while on uncoated carbide cutting tools, the average increase in wear is 0.20 mm, so the cutting tools are uncoated. carbide wears out more quickly. Apart from that, cutting tools with coatings are found to be more resistant to wear. Cutting tool coating is more resistant to wear due to the use of TiAlN coating. The addition of coating can increase the hardness of cutting tools, making them more wear-resistant than cutting tools without coating.

The wear rate that occurs on coated and uncoated carbide-cutting tools is significantly different. Carbide-cutting tools with a protective coating are more resistant to wear than without a coating. The coating on carbide cutting tools helps reduce friction and heat, thereby reducing stress and wear on the cutting tool. In incomparable use, carbide-cutting tools with a protective coating tend to have a longer service life than those without a coating. Cutting tools without coating will be subject to abrasion and wear more quickly, which in turn requires more frequent replacement.

The coating on the cutting tool generally has a higher hardness than the cutting tool material itself, so it can reduce direct friction between the cutting tool and the workpiece. The coating can protect the cutting tool from the heat generated during the cutting process. Because high heat can cause faster wear and the coating functions as a barrier to this heat. Coatings can also offer chemical reactions that can damage cutting tools.

IV. CONCLUSION

Based on the observation data that has been obtained and the discussion that has been presented, the conclusions obtained include:

- Increasing cutting speed affects the rate of wear on cutting tools.
- TiAlN coating has a significant influence on the surface quality of the workpiece and the service life of cutting tools, where cutting tools with TiAlN coating wear longer on cutting tools than cutting tools without coating.
- The coating on carbide cutting tools helps reduce friction and heat, thereby reducing pressure and wear on the cutting tool
- The cutting length for uncoated carbide cutting tools at a cutting speed (Vc) of 150 m/minute is 1200 mm while the cutting length for coated carbide cutting tools at vc 150 m/minute is 2160 mm.

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