PERFORMANCE EVALUATION OF TiN COATED AND UNCOATED CARBIDE TOOLS IN TURNING

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Abstract: Hard coatings are well known to improve the performance of cutting tools in high-speed machining. The development of cutting tool for high-speed machining of hard and difficult-to-cut material has remain a problem for quality and economy of production. The present work studies the performance of various coated tools in machining of hardened steel under turning and compared with that of uncoated tool. The effect of cutting speed and feed rate on tool wear (tool life) and surface roughness of the TiN (Titanium Nitride) coated carbide inserts was experimented. For coated tools the tool life obtained was relatively higher values as compared to uncoated tool in similar cutting conditions. It has also been found that the machining of hard materials at higher speeds and lower feeds is improved by using coated tools as compared to uncoated tools.

Keywords: TiN coated; uncoated; tool life; surface roughness.

Introduction: Surfaces of cemented carbide cutting tools need to be abrasion resistant, hard and chemically inert to prevent the tool and the work material from interacting chemically with each other during machining. In order to accomplish these objectives, coated carbide tools were developed around 1970. This development was regarded as a significant advance in cutting tool technology. Coated carbides are basically a cemented carbide insert coated with one or more thin layers of wear-resistant material, such as Titanium Carbide (TiC), Titanium Nitride (TiN), Aluminium Oxide (Al_2O_3) and/or Titanium Aluminium Nitride (TiAlN) [1]. When turning AISI 4340 steel using low feed rates and depths of cut, the cutting forces required were higher [2]. The combination of low feed rate and high cutting speed is necessary for minimizing the surface roughness [3].

The crater wear of the TiN coated inserts is less than that of the PCBN inserts because of the lubricity of TiN capping layer on the TiN coating [4]. Samir K. Khrais [5] did a detailed study on the tribological influences of TiAlN coatings on the wear of cemented carbide inserts. The cutting speed significantly affects the machined surface roughness values. With increasing cutting speed, the surface roughness values decreased [6]. Cutting speed plays a dominant role in determining the tool performance in terms of tool life, followed by feed and depth of cut [7]. Low cutting speed and low feed produces the longest tool life. The combination of high cutting speed and high feed was found to be unfavorable for hard turning of stainless steel [8].

In this paper, the experimental results of an investigation on the effect of cutting speed and feed rate on tool wear and surface roughness to optimize the machining conditions for turning applications using the TiN coated carbide inserts are presented.

In addition, a comparison is made between TiN coated carbide inserts and uncoated carbide inserts in terms of tool wear and surface roughness for the same machining conditions.

Experimental details:

Workpiece material:

The workpiece material used in this study was thoroughly hardened AISI 4340 steel (~58 HRC), which typically has a chemical composition of 0.4% carbon, 1.85% nickel, 0.8% chromium, 0.25% molybdenum, 0.68% manganese, and 0.25% silicon. The solid bars have a diameter of 65mm and a length of 200 mm.

Cutting inserts: Coated and uncoated carbide inserts were used for turning tests. The inserts used were DNMG 432 EUP EH10Z (55º diamond with chipbreaker) coated carbide inserts and DNMG 431 C520 uncoated carbide inserts. DNMG 432 is coated with TiN outer layer. The inserts were rigidly mounted on a tool holder with an ISO designation of MDJNR20-4D.

Experimental techniques: Cutting tests were carried out on a Type R5 Gottwaldov Precision Capstan lathe. While the surface roughness was measured by Taylor Hobson (Surtronic 25) Tester. Turning experiments were carried out at two different cutting speeds. The coated carbide tools and the uncoated carbide tools were tested at following cutting speeds: 80 and 130 m/min. Five different feeds (f) were used as follows: 0.1, 0.15, 0.2, 0.25, and 0.3 mm/rev. Three different depths of cuts were used as follows: 0.2, 0.5 and 1 mm. Some preliminary trials were also conducted to establish the tool wear criterion. The observations and measurements obtained from these preliminary trials showed that flank face of coated and uncoated carbide tools was regularly worn in zone C and therefore, VBmax of 0.6mm was taken as wear limit to determine tool life. Flank wear was observed and measured at various cutting intervals throughout the experiments.

Results and discussions:

Tool wear: The significant decrease in tool life for coated as well as uncoated carbide tools at higher depth of cut can be attributed to the temperature increase. The flank wear values of the coated carbide tools for different cutting speeds were presented in Fig. 1 and 2 respectively. Figures indicate that tool life is significantly affected by cutting speed and feed rate. Tool life decreases as cutting speed increases from 80 to 130 m/min. This decrease in tool life is mainly due to significantly increased heat involved in the cutting process, leading to rapid tool wear.

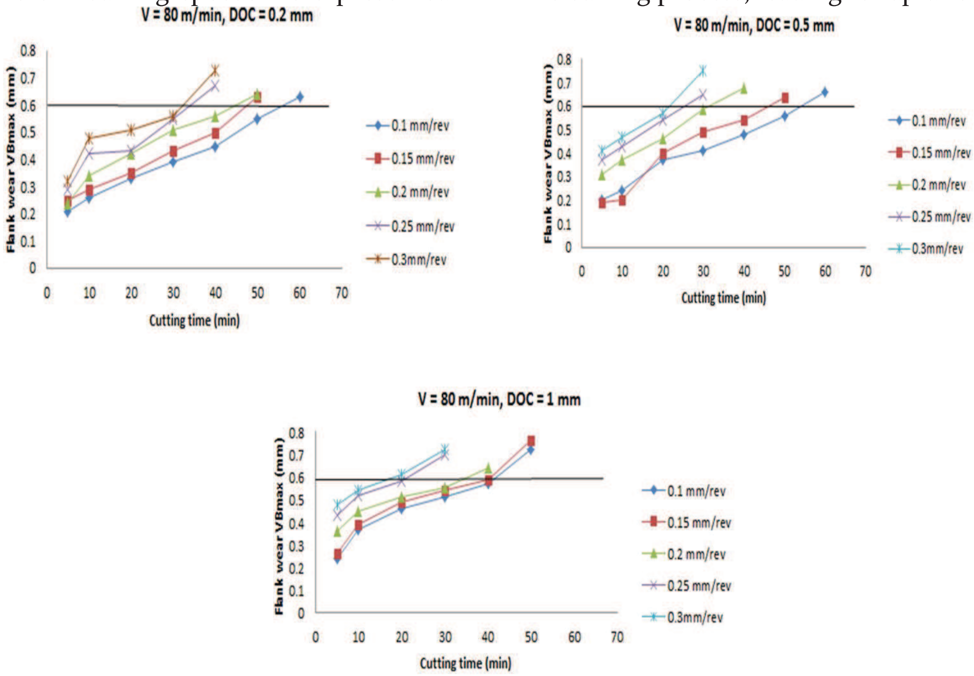

Fig 1: Flank wear v/s Cutting time (Tool life for coated tool, V= 80 m/min)

Figure 1 shows the graph for tool life of TiN coated carbide insert when the cutting speed V= 80 m/min. The cutting speed is kept constant and tool life for various feeds is found by varying the depth of cuts.

The TiN coated inserts exhibited a maximum tool life of 59 minutes at cutting speed V= 80 m/min, depth of cut (d) = 0.2 mm and feed (f) = 0.1 mm/rev. Figure 2 shows the graph for tool life of TiN coated carbide insert when the cutting speed V= 130 m/min.

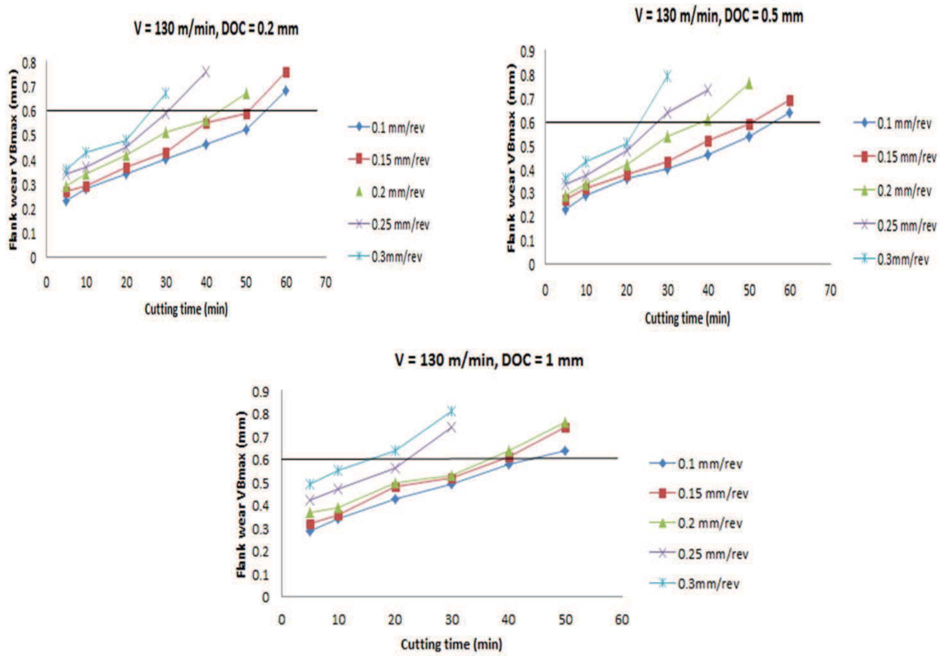

Fig 2: Flank wear v/s Cutting time (Tool life for coated tool, V= 130 m/min)

The TiN coated inserts exhibited a maximum tool life of 51 minutes at cutting speed V= 130 m/min, depth of cut (d) = 0.2 mm and feed (f) = 0.1 mm/rev. As the depth of cut was increased to 1mm, the tool life was also decreased to 13 minutes.

Now, the flank wear values of the uncoated carbide tools for different cutting speeds were presented in Fig. 3 and 4 respectively. The same tests were done on uncoated tip inserts as on coated carbide inserts.

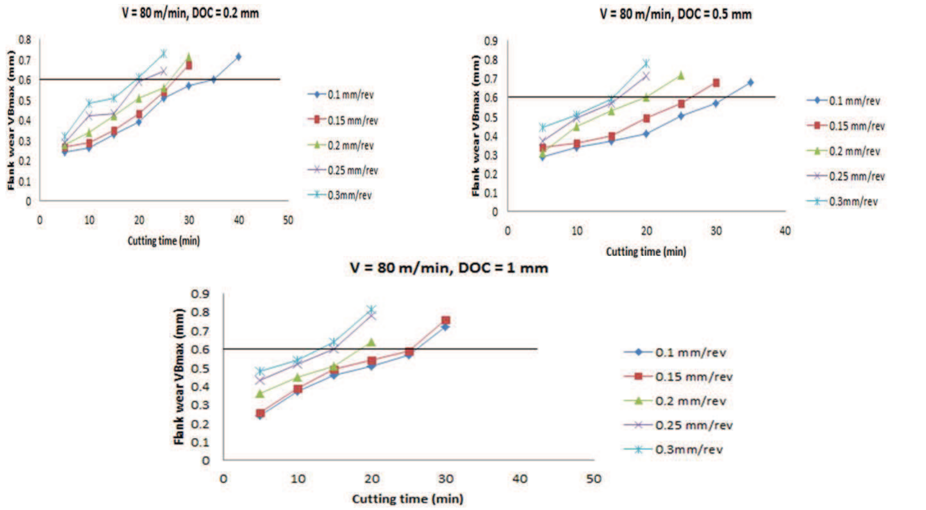

Fig 3: Flank wear v/s Cutting time (Tool life for uncoated tool, V= 80 m/min)

Figure 3 shows the graph for tool life of uncoated carbide insert when the cutting speed V= 80 m/min. The tool life starts a gradual decrease as the depth of cut increases. A minimum tool life of about 12 min was observed for f = 0.3 mm/rev and d = 1 mm. Figure 4 shows the graph for tool life of uncoated carbide insert when the cutting speed V= 130 m/min.

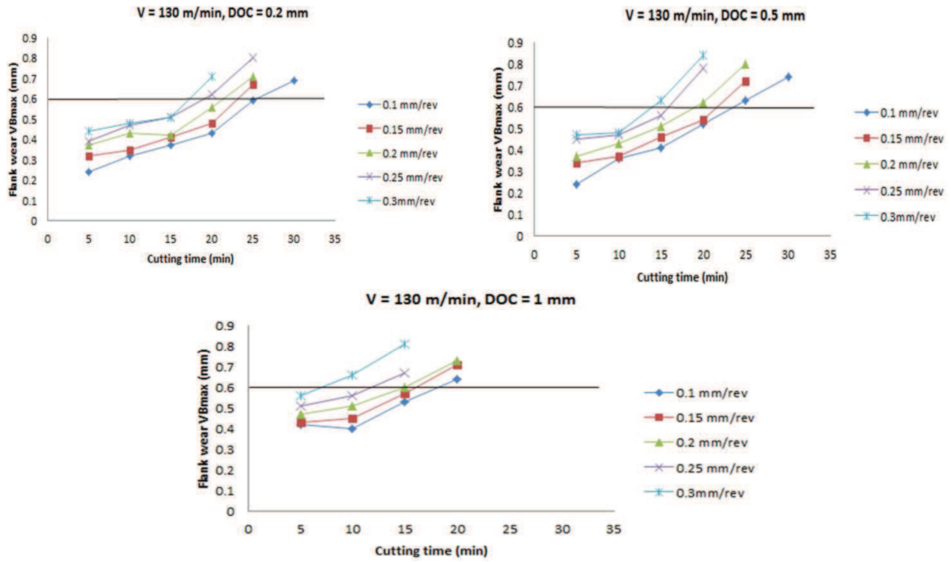

Fig 4: Flank wear v/s Cutting time (Tool life for uncoated tool, V= 130 m/min)

The uncoated inserts exhibited a maximum tool life of 25 minutes at cutting speed V= 130 m/min, depth of cut (d) = 0.2 mm and feed (f) = 0.1 mm/rev. While the tool life was reduced to 7 minutes at V= 130 m/min, depth of cut (d) = 1 mm.

Surface roughness: Surface roughness is one of the important indicators of the surface integrity of machined parts. Surface finish in turning has been found to be influenced by a number of factors such as cutting speed, feed rate and depth of cut. Surface roughness influences not only dimensional accuracy of machined parts but also their properties. Surface roughness is an important parameter to evaluate the performance of the cutting tools. The Fig. 5 shows the graphical representation of cutting speed, feed rate and depth of cut v/s surface roughness at cutting speeds of 80 and 130 m/min feed of 0.1, 0.15, 0.2, 0.25, 0.3 mm/rev and depth of cut of 0.2, 0.5 and 1 mm.

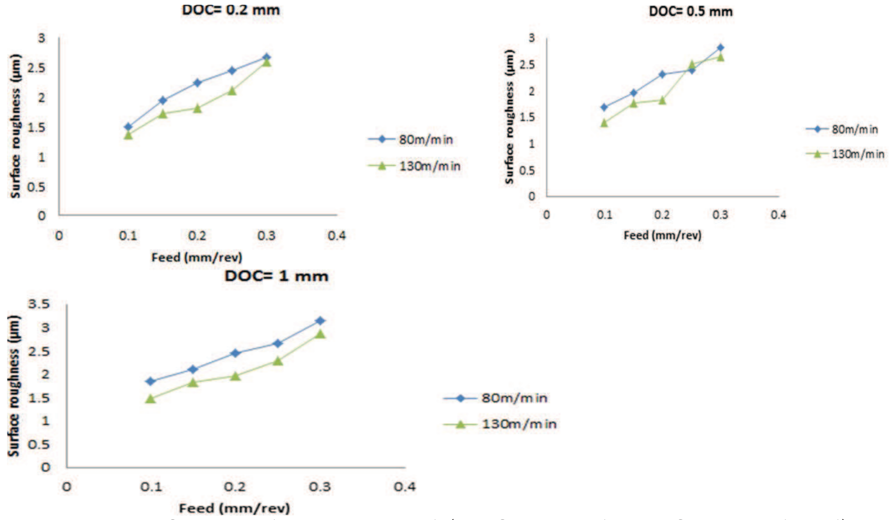

Fig 5: Surface roughness v/s Feed (Surface roughness for coated tool)

For cutting speed V= 80 m/min, depth of cut (d) = 1 mm and feed (f) = 0.3 mm/rev, the surface roughness comes out to be 3.15 μm. But as the cutting speed increases to 130 m/min then for depth of cut (d) = 1 mm and feed (f) = 0.3 mm/rev the surface roughness is 2.8 μm. The figure indicates that as the cutting speed increases, the surface roughness decreases.

Now, Fig 6 shows the graph of surface roughness values for the uncoated inserts.

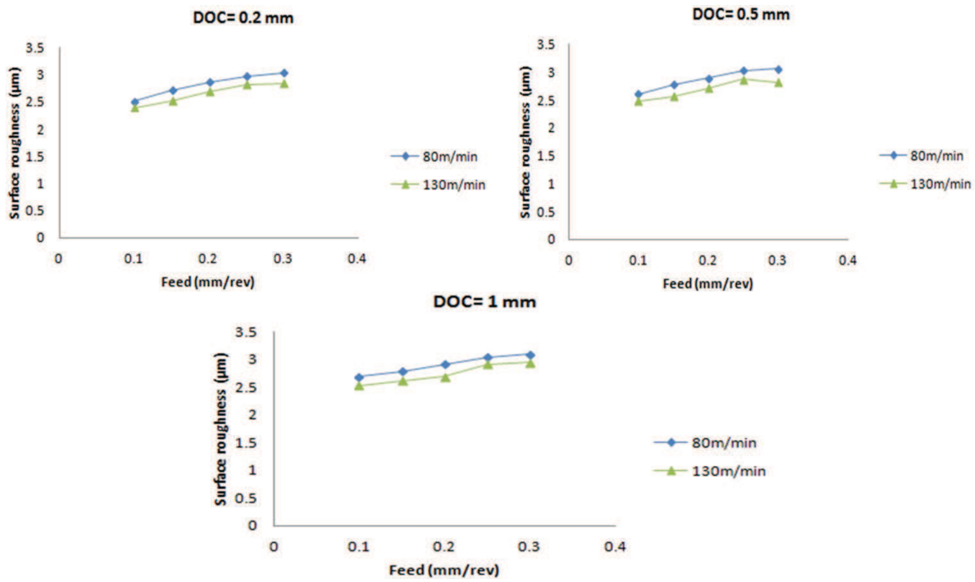

Fig 6: Surface roughness v/s Feed (Surface roughness for uncoated tool)

The values for surface roughness of uncoated inserts are greater than the values of the coated inserts. As machining time increases, tool sharpness deteriorates and leads to a degraded surface roughness. The amount of heat generation increases with increase in feed rate, because the cutting tool has to remove more volume of material from the work piece.

Conclusion: Based on the experimental results presented and discussed, the following conclusions are drawn on the effect of cutting speed and feed on the performance of TiN coated and uncoated carbide tools when turning AISI 4340 steel.

- Coated carbide tools perform better than uncoated carbide tools as far as tool life is concerned. Tool life obtained with coated carbide tool was higher than those obtained with uncoated carbide tools under experimental conditions.
- This study concluded that the TiN coated carbide tool produce better surface roughness with respect to high speed and low feed rate. But the depth of cut has minimum effect on surface roughness. The combination of low feed rate and high cutting speed is necessary for minimizing the surface roughness.
- Results show that, the machining of hard materials at higher speed is improved by using coated tools. From the experimental investigation

it is observed that coated tools give better results as compared to uncoated tools in turning.

- Coated carbide tools are superior to uncoated carbide tools and its flank wear grows smoothly than uncoated carbide tools.
- The feed rate has highest influence on surface roughness, cutting speed and followed by depth of cut. The surface finish was improved as cutting speed was increased and deteriorated with feed rate. The optimum parameter setting for better surface finish is obtained at a higher cutting speed with low feed rate.

Acknowledgment: I wish to express my gratitude to Dr. A. V. Kale, Department of Mechanical Engineering, YCCE, Nagpur for all technical support.

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