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Research Article

EXPERINMENTAL INVESTIGATION OF TOOL BEHAVIOR OF Al-Ti-N COATED CARBIDE INSERT IN HARD TURNING PROCESS

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ABSTRACT

Tool wear analysis became a vital area of research in the current scenario of mass machining or mass production in industries especially in the event of machining of hard materials. The applications where hard steel replaces the less hard materials, multilayer coated carbide inserts have shown better results in comparison with single layer coated carbide inserts. In this paper, a study has been carried out to report the tool wear behavior of multilayer coated carbide inserts while machining hard steel of 55 HRC in dry cutting conditions. The objective of this study is on the effect of coating on tool to determine its various parameters such as interface temperature, tool wear and surface roughness. Machining of hardened steels has become an important manufacturing process, particularly in the automotive and bearing industries.

INTRODUCTION

Machining of hardened steel especially known as hard turning has attracted many industries for mass machining or for mass production because it mostly found applications in making of bearing, gears, shafts etc. and offers an alternative to grinding operation. Multilayer coated carbide inserts are normally used for machining of hardened steel at or above 50 HRC. Extensive study has been performed by researchers for the selection of tool material to investigate its wear behavior. The primary reason being that the machining of hardened steel usually requires advanced or harder cutting tool. Different studies utilized different tool inserts made up of ceramic, CBN, diamond and carbides etc. But from the economic point of view, researchers as well as industries have started concentrating on cheaper tool material like carbide. From the production point of view, uncoated or single-layer carbide inserts have not turned out to be efficient in increasing tool life. On the other hand, use of multi-layer coated carbide inserts have not turned out to be efficient behavior because of their wear resistant and lubricious property, it also provides the economical beneficial aspect especially in terms of tool life, surface finishing, balanced edge sharpness and high toughness when compared with uncoated or a single-layer coated insert in machining. Therefore in order to cater the need of mass production and the machining of hard materials, multi-layer coated carbide inserts were investigated. Chen and Chen (1999) have proposed a methodology for online detection of cutting tool failure based on cutting frequency. At low frequencies, frequency domain presents two important peaks which are compared to find the ratio that could be an indicator for monitoring tool breakage. When compared with other in-process method such as 3-axis sensor and acoustic emission sensor, their system was found to be advantages in terms of mechanism and is reliable with less cost. Sick (2002) has proposed a technique which involves a physical process model with an ANN in turning process. This physical wear model describes the influence of cutting conditions on measured force signals. The ANN model describes the relationship between the force signal and the cutting tool state. The performance of the best model was 99.4% for the learning step and 70% for the testing step. Caken *et al*. (2008) has described the behavior of tool wear on TiN and CrN coated insert. The study involves a dynamometer and opto-electronic sensor that monitors the

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change of tool state behavior without interrupting machining process. Their study involves the indirect measurement of tool wear by correlating it with the dimension of work piece; they verified the results with the change of cutting force during machining. Results showed that TiN coated had higher wear resistance than Cr-N coated insert. Trejo-Hernandez *et al.* (2010) has developed a fused smart sensor based on Field Programmable Gate Array to improve the online quantitative estimation of flank wear for coated carbide CNMG 433Ma in a CNC machine. Measurement involved two primary sensors: cutting force sensors and current output of servo amplifier. Experimentation has showed that fusion of both signals makes 3 times better accuracy as compared with individual sensor signal. Sahoo and Sahoo (2012) have done a comparative study to determine the cutting tool state, surface roughness, chip morphology and cutting force in finish hard turning of AISI 4340 steel using uncoated and multi-layer TiN and ZrCN coated carbide inserts at higher cutting speed range. Experimental results showed that the abrasion, chipping and catastrophic failure are the principal wear mechanism. The turning forces were observed to be lower using multi-layer coated carbide insert than that of uncoated carbide insert. Choudhury *et al*. (2001) have developed a non-contact displacement optical fibre transducer to monitor the tool wear. The result shows that the dimensional inaccuracy of the machined surface can be maintained below 0.03 mm using the newly developed sensor. Reliable and sensitive techniques to detect tool wear and breakage during cutting have indicated that the force dynamometer signals, i.e., cutting force signals works more efficiently than any other sensors. According to Kinnander (1981), the cutting force is the parameter which seems most likely to provide a solution to monitor flank and crater wear, being the most appropriate criterion to determine the exact time to replace worn out tool. Park and Kwon (2011) have measured the flank wear and surface roughness on turning AISI 1045 steel using multi-layer TiCN/Al2O3/TiCN coated insert. They found that multilayer coating did not prove to be much effective in showing the tool state conditions because of the hardness of the coating layer which unable to resist the abrasion wear in their cases and followed by adhesion due to the expose of substrate material on the cutting insert. This reason may be the possibility of selecting cutting parameter away from the permissible limit and the tribological behavior between the matting surfaces. Noordin *et al.* (2007) have observed that the multi-layer TiCN/Al2O3/TiN coated carbide have shown better performance as compared with TiCN coated cermet. It was also concluded that the longest tool life for cermet insert was found during machining at low speed and feed at side cutting edge angle of -50. However, in all other instances multi-layer coated carbide inserts performed better.

In this paper, a study has been carried out to report the tool wear behavior of multi-layered coated carbide inserts while machining hard steel of 50 HRC in a dry cutting environment. The outputs have been compared analyzed to investigate the behavior of cutting tool in a real life situation for precision machining.

MATERIALS AND METHODS

Cutting Condition

Turning process for number of passes was taken on the Horizontal Machining Centre lathe with fresh coated carbide inserts in the dry cutting environment. Experiments were carried out at constant values of cutting parameters viz. cutting speed, feed and depth of cut. According to literature review, capability of the machine and recommendation from insert manufacturer, the values provided in Table 1 were used as cutting parameters for the experimentations.

Table 1 Cutting Parameters

Parameters	Values
Cutting Speed, V(m/min)	100
Feed, f(mm/rev)	0.15
Depth of Cut, d(mm)	0.25

Work piece material and Cutting Insert

In this study, 50 HRC EN8 hardened steel of diameter 70 mm was used for turning operation. The hardness was assured to be constant (± 2 HRC) throughout its cross section by uniform hardening and tempering process. The length of the work piece was 150 mm. The chemical composition of EN8 is given in Table 2.

Table 2 Chemical Composition of EN8 Steel

C	Si	Mn	Cr	Mo	V	Fe
1.1	0.9	0.4	8.3	2.1	0.5	Balance

The turning operation has been carried out using multi-layer Al-Ti-N coated carbide insert using Physical Vapor Deposition-Thermal Evaporation Technique with specification as DNMG with 0.4 mm nose radius. Fig. 1 shows the schematic of multi-layer coated Carbide insert. A Right hand side tool holder designated by ISO as PCLNR 2020 K12 was used for mounting the insert.

Coated carbide insert

Figure 1 Multi-layer Al-Ti-N coated carbide insert using Thermal Evaporation Technique

Experimental Procedure

Experiments were carried out at prescribed cutting conditions as given in Table 1. Tool makers microscope (Make-Opto Mechatronics Ltd and model-HO-TTM-01)was used to identify the amount of wear produced on inserts. Infrared pyrometer

(Make-Keller and Model-cellaport PT) was used to monitor the temperature generating at the chip tool interface. The surface roughness values of the turned part were measured by portable roughness tester (Qualitest TR 100). The figure 2 shows the tool wear, interface temperature and Surface roughness measuring arrangement.

Figure 2 Tool Wear, Interface Temperature and Surface Roughness measuring setup

RESULTS AND DISCUSSIONS

The table 3 shows the output values of machining of EN8 steel using a multilayer Al-Ti-N coated insert.

Table 3 output values (multilayer Al-Ti-N coated insert)

Passes	Temperature (^{0}C)	Surface Roughness (microns)	Tool Wear (mm)
1	53	0.41	0
2	72	0.43	0.004
3	81	0.47	0.005
4	84	0.49	0.007
5	86	0.52	0.012
6	85	0.3	0.013
7	88	0.32	0.015
8	92	0.38	0.021
9	91	0.43	0.027
10	93	0.54	0.032
11	94	0.63	0.038
12	92	0.69	0.043
13	94	0.75	0.046
14	113	0.83	0.054
15	116	0.89	0.067
16	118	0.92	0.072
17	120	0.84	0.083
18	121	0.78	0.091
19	123	0.75	0.094
20	123	0.75	0.102
21	125	0.76	0.113
22	129	0.72	0.115
23	138	0.72	0.127
24	145	0.73	0.132
25	172	0.71	0.133
26	228	0.77	0.137
27	231	0.81	0.145

In this section, the experimental observations are summarized. The relationship between passes and the chip-tool interface temperature at the constant parameters is shown in fig 3. The trend clearly shows that as passes increases, chip-tool interface temperature increases gradually. In the beginning up to 24 passes of machining, the temperature remains almost constant. This is happened because in the initial stage of machining the coating tends to delaminate without affecting the carbide substrate which ultimately did not change the temperature range drastically. After 24 passes, the graph shows a sudden increase in temperature as the coating had worn out completely and the substrate performed the machining operation.

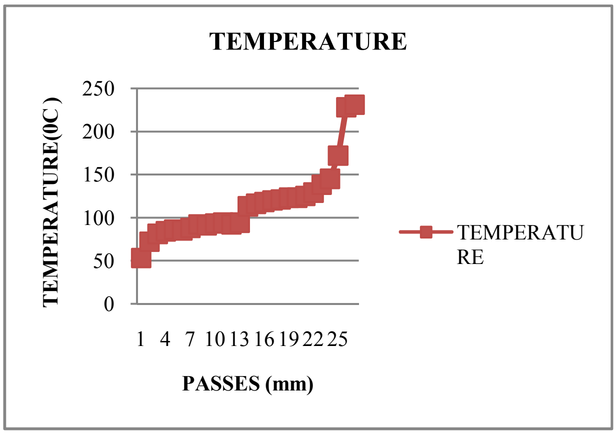

Figure 3 Relationship between number of passes and chip-tool interface temperature on machining with multi-layer Al-Ti-N coated carbide insert

Such behavior of surface roughness occurred due to chip-in of insert. As the number of passes increases the surface roughness tends to decrease because of the chipping-in take place. This stables the nose radius and tool cutting edge becomes blunt, which further improves the surface finish. Later increase in passes increases the surface roughness because of the gradual wearing of tool and high chip-tool interface temperature. This further leads to the occurrence of diffusion wear at the cutting edge of the insert.

Interface Temperature

It has been observed that overall the surface roughness increases with the increases in number of passes is shown in fig 4. It has also been observed that, initial surface roughness increases up to 16 passes and then it shows an improvement in surface finish.

Surface Roughness

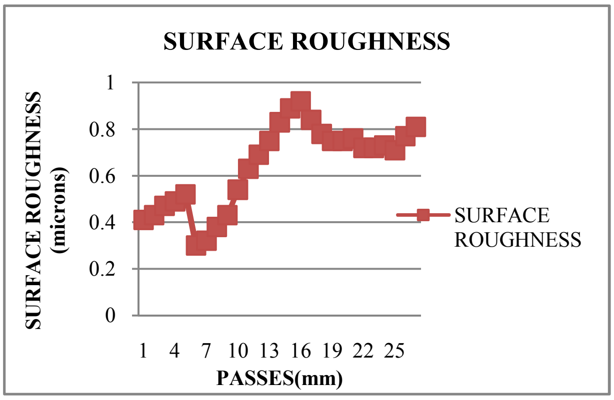

Figure 4 Relationship between pass length and average surface roughness.

Tool Wear

Fig 5 shows the relationship between passes and tool wear at constant parameter. The graph clearly shows that, as pass length increases tool wear also increases.

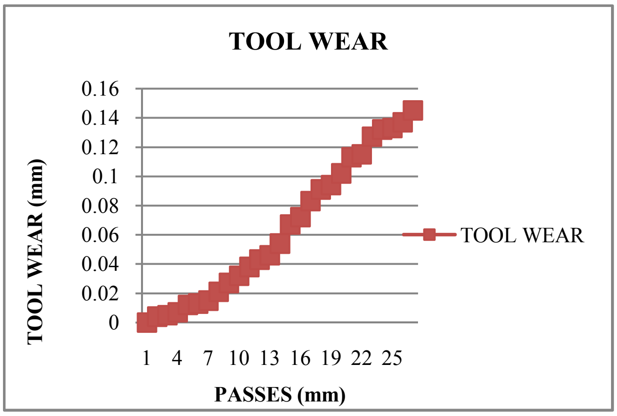

Figure 5 Relationship between tool wear and number of passes

Assuming 0.2 mm limiting criterion for tool wear for this experimentation, the maximum tool life of cutting tool was approximately found to be more than 27 passes.

CONCLUSION

Based on the results and analysis from the experimentation of hard turning (50 ± 2 HRC) in a dry cutting environment. It is evident from this study that multi-layer Al-Ti-N coated carbide insert have shown economical beneficial aspect in terms of tool life, surface finish and lesser chip-tool interface temperature due to lubricious properties present in the cutting inset. From the experimental investigation, following findings and conclusions can be reported.

Output response such as temperature, average surface roughness and flank wear width with respect to the number of passes were monitored and found that the multilayer Al-Ti-N coated carbide insert can increase tool wear twice the times when compared to single layer coated carbide insert.

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