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"STUDY AND ANALYSIS OF EFFECT OF COATING ON CERMET CUTTING TOOL"

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Abstract

Coatings, over the cutting tools, are very much useful for enhancing their performance in high-speed machining such as CNC Dry turning. Automobile industries use a number of coated tools for producing the various parts. Titanium nitride (TiN) and Titanium carbide (TiC) and Titanium oxide (TiO) has been used for the coating of tool steels since the sixties. Coatings of different materials are provided on the cutting tools to increase life of tool, to enhance the surface quality of the product, and to increase the rate of production. The coating of the tools with the hard materials such as TiN, TiC, TiO and Al2O3improves the cutting capabilities. This paper shows the study of the performance of coated tools during dry turning conditions. This paper involves the machining of hardened steel using T(C,N,O) coated cermet tools. The objective of this study is to analyze the effect of different coatings on tool so as to determine its various parameters such as temperature, spindle speed, feed and depth of cut in machining of hardened steel.

Key Words: Cermet Inserts, Titanium nitride (TiN), Titanium carbide (TiC), Titanium Oxide (TiO), Coated tools

1. Introduction

Metal Cutting Processes are involved directly or indirectly of almost every product of modern civilization. To realize and understand the full potential of the metal cutting processes, one of the most important element that has to be taken care of is cutting tool. Regular and continuous efforts has been made by manufacturing industry to minimize the cost cutting during the process and to enhance the product quality. High cutting temperature during the process and its adverse effects are reduced or eliminated by the use of tools having high wear and heat resistant properties like Coated or Multilayer Coated Tools. Existing tool materials can be improvised by using various types of coating materials. By providing these coatings on the tools, it makes the machining quite easy as these coated tools can offer greater wear resistance and deformation under high speed machining.

1.1 Recent Advancements in Coated Cutting Tools

Soderberget al.[1] in 1969, the first coated cemented carbide inserts for turning process was introduced and had quite influential effect on the different cutting industries. D’Erricoet al.[2] developed the cermet inserts using a rich binder component having high toughness such as Ti(C,N) and TiN by the technique of PVD coating. The Uncoated and Coated type of cermet inserts were used in the continuous and interrupted type of turning tests. Positive results have been found in Continuous turning process in which the tools are coated by the use of PVD technique without a chamfer. Watmonet al.[3] the coating of the tools with the hard materials such as TiN, TiC and Al_2O_3 improves the cutting capabilities. Therefore, these types of tools can cut at higher speeds for the improved productivity with very less power requirements.

Konyashinet al.[4] studies that conventional processes for depositing the coatings have not much effect on the improvement of tool life for the TiCN and TiC based cermet al.ong with the Ni-Mo as the binder. Therefore, for depositing the chromium carbide based coatings on the cermet tool a new technique has been developed and in this technique a substrate is treated in vacuum environment and this will results in the coating of chromium carbide on the outer layer and interlayer will consists of Ni between the substrate and the carbide and hence, this type of coated cermet tools shows an enhancement in the wear rate of the tool. D'Erricoet al. [5] carried out the effect of PVD type of coatings to check the performance of a cermet inserts used for milling operations. Two cermet inserts having two mono-layers of TiN,Ti_2N and multi-layer of TiCN+TiCN, TiCN+TI_2N and TiN+TiCN obtained by PVD coating are used. The experiments shows that the tool which have the coating of TiN layer have an increased tool life. This may be due to the higher resistance property of TiN to the oxidation. While the other coatings such as Ti_2N, TiCN+TiCN, TiCN+TI_2N has been responsible for tool life decrements.

Ming et al. [6] studied finish-turning of NiCr20TiAl nickel-based alloy by using Al_2O_3/TiN-coated carbide tools. They investigated the effect on cutting forces, surface integrity, and tool wear. They found that the cutting forces decreased slightly with an increase of the cutting speed and increased with feed and depth of cut and plastic flow of the machined surface was produced at a low cutting speed. In view of surface quality and tool wear, they recommended the parameters as cutting speed of 60 m/min and feed of 0.15 mm/r were, and depth of cut not exceeding 0.4 mm. Selvarajet al. [7] during the dry turning studied the Influence of bulk texture, cutting speed and feed rate on the surface finish of Nitrogen Alloyed Duplex Stainless Steels. They carried out the experimental work by using TiC and TiCN coated cemented carbide cutting tools. They conducted the tests at five different cutting speeds) and three different feed rates with a constant depth of cut (0.5 mm). They found that, till a particular point, the increasing cutting speed decreases the surface roughness and then increases and with the decreasing feed rate the surface roughness value decreases.

Ghani et al. [8] investigated the wear mechanism of uncoated cermet tools and TiN coated carbide inserts for the different machining parameters for the AISI H13 steel on the milling machine. SEM has been used to investigate the tool wear rate. From the results of SEM it has found that time taken by the carbide tool coated with TiN for initiation of cracking and fracturing was much more than that of uncoated cermet inserts at high speed, docand feed. The results also shows that at low feed, speed and doc, the uncoated cermet tool have more uniform and gradual wear rate as compared to the TiN coated carbide tools for the same milling conditions. Alexandre et al.[9] carried out the performance of carbide tool coated with TiN while turning AISI 8620 steel. It has been found that this methodology is realistic alternative to study the crater wear as compared to the ISO 3685/93. Different tests were performed under different machining conditions and it was observed that coated carbide tool was much more effective as compared to the tools those were uncoated. Kumbharet al.[10] optimized the surface roughness and tool life of multi-layer coated carbide inserts having coating of TiALN/TiN material by the PVD technique of hardened EN31 alloy steel during the semi-hard dry turning conditions and experiments were performed statistically based on Taguchi method by using L9 orthogonal arrays. It has been found that the feed was the most effective factor that affects the surface roughness and life of tool and doc, speed were the least significant parameters. Schulz et al.[11] studied the different cutting edges of cutting tools which are coated with the TiC, TiN materials have ten times enhancement in the life of tool when compared to the tools which are uncoated.

Hocineet al. [12] studied the tribological behaviour of coated carbide tools during turning of steels. The friction coefficient has been identified by the use of tribometer in difficult cutting conditions and (42CrMo4, 27MnCr5) steels, TiN, AlTiN coated carbide tools in the experimental work. It has been noted that, at a speed of 60 m/min, the coefficient of friction between TiN and 42CrMo4 alloy was better than that between AlTiN and 42CrMo4 alloy. They observed from the system set-up that by increasing the cutting speed the apparent friction coefficient decreases. It has been also found that the heat flow transmitted to the TiN pin at high pressure is more important for TiN pin as compared to AlTiN pin. Arshiet al. [13] the tool life of the tools coated with TiN increased by a factor of four than the tool life of uncoated HSS tools. Lim et al. [14] studied the wear rate of TiC coated tools during the dry turning machining. Cracking, discrete plastic deformation and abrasion were the factors which leads to the wear of the TiC coating. Wear maps of the coated tools were compared with the similar wear maps for uncoated carbide tools. Speed and feed were presented, which clearly demonstrate that by the application of TiC coatings resistance to wear capability of tools tends to increase dramatically.

Sani et al. [15] studied the microstructure and investigated the cutting ability of Ti(C, N) based cermet inserts which contains different types of secondary carbides. Number of alloys having different amount of Mo2C, WC and Ta0.7Nb0.3C were added and after the continuous turning operation, they were studied by using the SEM technique, Vickers hardness testing and by Transverse rupture strength. It has been found that the alloys which contains Mo2C and WC type additives have finer carbonitride grain structure and it also shows an increment in the resistance to wear properties. Basuet al. [16] studied the mechanism for the material removal rate of TiCN-Ni based cermet inserts. The TiCN based cermet which contains the carbides as considered as cutting inserts with high potential due to their excellent properties like wear resistance having high chemical stability and high hardness with improved toughness. This paper provides the investigation of the wear properties of TiCN-Ni based cermets and having four different secondary carbides such as (WC, NbC, TaC or HfC) against the steel at 5500C by fretting test. It has been found that wear rate in the cermets were found to be in the order of 10-6 mm3/Nm and it has been also found that resistance to wear property of the tool decreases with the addition of WC or NbC whereas TaC or HfC has very less impact when compared with that of the TiCN-20Ni cermets. Yigitet al.[17] evaluated the performance of multilayer coated carbide tools when turning cast iron. The tool life performance of multilayer hard coatings for machining of spheroidal graphite cast iron with fabricating (TiCN + TiC + Al2O3 + TiN) multilayer coatings with different thicknesses on WC substrates using (HTCVD) has been evaluated and it was observed that the TiN coated carbide tools generated less force components (the main cutting force, feed force, and radial force) than those generated by the uncoated carbide tool at all cutting speeds. Thus indicating that turning with the former tools was more economical than the latter in terms of energy and power requirements and similar study is concluded, to determine tool life, optimum cutting parameters, suitable tool grades, and their geometry, can be carried out.

Suresh et al. [18] studied on hard turning of AISI 4340 steel by using multilayer coated carbide tool. A correlation between different parameters such as rate of feed, speed and doc with machining power, force, wear rate of tool and surface roughness of work piece has been established and the accomplishment of multi-layer hard coatings (TiC/TiCN/Al2O3) on carbide inserts for the machining of hardened AISI 4340 steel with the help of Taguchi Method. The experiments shows that for reducing machine force combination of low feed rate and low doc with high cutting speed is beneficial and it was found that to minimize the specific cutting force larger values of feed rates are necessary. Tool wear of cutting tool increases nearly linear with increase in feed rate and cutting speed and for minimizing the surface roughness combination of high cutting speed and low feed rate is necessary. Aurichaet al. [19] evaluated the effect of coating system on tool performance during turning of heat treated AISI 4140 steel. Four differently coated cemented carbide inserts (TiN, TiN + TiCN + Al2O3,TiN + TiAlN + TiN,, TiN + TiCN + Al2O3 + TiN) and uncoated cemented carbide tools has been used. It was observed that all coating systems enhance the cutting tool performance. C.H. CheHaronet al.[20] investigated the performance of alloyed uncoated ((W–Ti/Ta/Nb)C–Co) and CVD-coated carbide (W–Ti/Ta/Nb)C–Co + (TiC+ Ti/CN + /TiN) tools in the dry milling of titanium alloy Ti-6242S. They observed from their study that there good possibility of the alloyed uncoated carbide and alloyed CVD-coated carbide to be used in end milling of titanium alloy Ti-6242S even under extreme dry (green) cutting condition. They observed the plastic deformation and brittle fracture such as rake face flaking, cracking, chipping and fracturing are the other failure modes on both tools. They observed that adhesion (attrition) and dissolution-diffusion were responsible for the tool failure modes. They concluded that the best performance of the tools was observed at Vcof 100–110 m/min, fz 0.15–0.185 mm/tooth and a 2–2.25mm where tool life was ranging from T of 5–15 min. Kumar et al. [21] studied that hard coatings improve the performance of cutting tools during the aggressive machining and they have also found that the life of tool was improved upto 50% for the Si content in work piece. Sahooet al. [22] experimentally investigated the machining aspects of AISI 4340 in finish hard turning with the use of uncoated and multilayer coated carbide inserts. Performance parameters like surface roughness, flank wear, cutting forces and chip morphology in finish hard turning of AISI 4340 steel, at higher cutting speed range by TiN and ZrCN coated carbide inserts and it has been found after the experimentation that the multilayer coated inserts having layers of TiN/TiCN/Al2O3/TiN coated insert performed much better as compared to uncoated tools. Tool life for the inserts having coatings of TiN and ZrCN was approximately 19 min and 8 min respectively at the extreme cutting conditions tested and found that uncoated carbide insert fractured prematurely when used to cut hardened steel.

Noordinet al. [23] evaluated the performance of cemented carbide tools while turning AISI 1010 Steel. Three cemented carbide tools; two coated tungsten based cemented carbide tools (one Al2O3 (black) outer layer, second TiN (golden layer)) and uncoated titanium based cemented carbide (silver grey layer). With Cutting forces and surface roughness measurements it was observed that tool having the CVD coating of TiCN/TiC and PVD coating of TiN performed best under conditions having lower forces with little variations, good surface finish, chips with minimum SSZ thickness were produced. Surface finish was more with increasing cutting speed. Stanford et al.[24] investigated the Tool wear during turning of BS970-080A15 carbon steel by using the coatings TiCN-Al2O3coated on carbide tool in gaseous and liquid nitrogen environments. A No. of cutting trials has been performed for a range of cutting environments. Experiments shows that the liquid nitrogen can act as a "liquid inert barrier" under the chip within the tool/chip interface as tighter chip curl, shorter contact lengths, reduced adhesion and lower feed forces were observed.

Das et al.[25] studied the effect of different machining parameters on surface roughness during machining of hardened AISI 4340 steel using coated carbide inserts. Different machining parameters were cutting speed, feed and doc. The tools were coated with CVD technique and having coatings of (TiN+TiCN+Al2O3+ZrCN) material. Full factorial DOE and ANOVA has been used and observed that feed is the most important parameter followed by speed. It has been found from the experimentation that the depth of cut did not impact the surface roughness significantly. The most optimum parameters for surface roughness were speed 150m/min and feed 0.05mm/rev. Chen et al. [26] investigated the wear characteristics and cutting performance for the Ti (C,N) based cermet tools during the turning of hardened steel. Multi-layer Cemented carbide tool having coatings of TiN/Al2O3/ Ti(C,N) was used for the comparison. The results shows that the Cermet tools having longer life during when doc is less and its life is shorten if doc is increase due to the chipping caused by an increase in cutting force. High thermal conductivity and low cutting forces tends to enhance the crater wear resistance ability of the cermet tool but due to the adhesion and diffusion wear mechanisms a very severe crater wear was found in the carbide tool. The Chips formed during the machining with cermet tools shows less severely curled and adhesive due to the low cutting temperature during the process.

2. Conclusion

In the present study performance of coated and multi-layer coated tools during the machining of hardened steel under dry conditions has been studied. The machining of hard materials at higher speeds is improved by using coated tools. From the investigation it is observed that coated tools give better results as compared to uncoated tools in turning. The uncoated tools has been successfully employed for machining of soft ductile material like Al and for the soft and abrasive materials like Al-Si alloy. The surface finish obtained under dry machining has been found to be acceptable. However, the surface finish produced for Al-Si alloy is not acceptable. Hence, this better surface can be achieved by use of coated or multilayer coated on cermet tools having coatings of Ti(C,N,O). The experimental results shows that by the selection of proper cutting parameters the multilayer coated tools are best suitable to produce superior surface finished products.

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