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# A REVIEW OF LATEST INNOVATIONS IN COATED CUTTING TOOLS

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## ABSTRACT

*This paper presents the information mainly on coatings applied to various types of cutting tools such as carbides, ceramics and cermets. Production costs can be reduced by enhancing the performance of cutting tools. Coatings, over the different types of cutting tools, are very much useful for enhancing their performance in high-speed machining such as CNC Dry turning. Automobile industries uses different types of coated or multilayer coated cutting tools for producing the various types of parts. Titanium nitride (TiN) and Titanium carbide (TiC) and Titanium Aluminum Nitrides (TiAlN) and Titanium oxide (TiO) has been used for the coating the tool steels since the sixties either in terms of single layer or multilayer. Coatings of different materials are provided on the various cutting tools like carbides, ceramics and cermets to increase life of these tools, to enhance the products surface quality, and therefore, subsequently to increase the rate of production. This paper shows the study of the performance of coated carbide, ceramic and cermet tools during the dry turning conditions. The objective of this study is to analyze the effect of different coatings on various types of tools so as to determine its various parameters such as temperature, spindle speed, feed and depth of cut in machining of hardened steel. This study reviews the literature on the performance for the coated carbide, ceramic and cermet tools.*

***Keywords***

***Coated Cutting tools, Cemented Carbide, Ceramics, Cermets, Dry Turning, Titanium nitride (TiN), Titanium carbide (TiC), Titanium Aluminum Nitrides (TiAlN), Titanium oxide (TiO) etc.***

## INTRODUCTION

Metal cutting is a process which involved in the manufacturing process either directly or indirectly for making every product in modern civilization. In every metal cutting operation, the most vital element is cutting tool materials that are selected carefully. So, main concentration is to reduce cost of the cutting tool material and simultaneously improve the quality of the machined parts. The major objective of the every manufacturing process is to produce the high quality product at a minimum cost. In the modern civilization, to meet the increasing demand, overall production and productivity the major force on the industry is to developing a new and good quality tool material.

The purpose of developing a new cutting tool material has following advantages like lead time reduces, manufacturing cost has been reduced, difficult and hard materials are easily machined, improve surface roughness and material removal rates (MRR) increases. The heat resisted and wear resisted tools materials like carbides, cermet and ceramics coated tools reduces the effect of temperature and high wear. Existing tool materials can be improvised by using various types of coating materials. By providing these coatings on the tools, it makes the machining easy as these tools can offer greater wear resistance and deformation under high speed machining. In 1969, first index able coated cemented carbide inserts for turning process were introduced and had an instant impact on the metal cutting industry [1].The coating on the cutting tools with the hard constituents like TiN, TiC and $Al_2O_3$ improves the cutting tool capabilities. Hence, the tools can be used to cut a material at higher cutting speeds for better productivity with less power requirements [2].

Chattopadhyay et al. found that, a secondary coating of TiN over TiC has improved the crater resistance at the expanse of flank wear, and the performance of coated carbide tools was found be efficient as compared to ceramic tools [3]. Schulz et al. found that the cutting edges of cemented carbide tools coated with TiC, TiN can show an increase of service lifetime of tools by a factor of ten compared to the uncoated tools [4].

Carbides were introduced in the 1930s. Because of their more hot hardness and resistant to wear properties, these are the most important tool materials. Ceramics were introduced in the 1940s. Ceramic cutting tools in recent years have been sought in many applications due to their enhanced properties such as improved thermal shock resistance, good high-temperature strength. Cermets were introduced in 1960s. These materials are the composite materials in which the ceramic materials and the metals are combined together in order to provide something having high temperature resistance of ceramic material and high electrical conductivity and flexibility of the metal.

**ADVANCEMENTS IN COATED CUTTING TOOLS.**

D'Erricoet al. 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. Theexperiments reveal that the tools which are coated with 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 [5]. Konyashin et al. studied that conventional processes for depositing the coatings have not much effect on the improvement of tool life for the TiCN and TiC based cermet along 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 [6]. Kumar et al. observed that coated tools give better results as compared to uncoated tools in turning. The uncoated tools have 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) [7]. Chen et al. experimented 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/$Al_2O_3$/ 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 [8].Canteli J.A. et al. studied the cutting performance when new cermet based on high speed steel (M2+50% TiCN) is produced by the powder metallurgy and during the study chipping wear, flank wear were the dominant wear pattern. In which orthogonal test were performed at the constant speed and a constant feed rate when both M2 and M2+50% TiCN materials were used. After experimentation results shows that there is an improvement in wear resistance and tool life [9].

Prengel H.G. et al experimented that the PVD TiAlN coating deposited by highly ionization sputtering process on the cermet and carbide cutting tools. The results show that the coating generated by this process is highly dense and has greater adhesion properties. After experiment performed on various machines like turning, drilling and milling shows that the advanced highly ionization sputtering process is more superior to the conventional sputtering process and it improves the productivity in machining operation [10]. Ghani et al. 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, doc and 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 [11].

Wang J et al. studied that the effect of multilayer hard surface coating on the carbide inserts to check the cutting forces during the tuning and the various experiments were done for different parameters. The results were compared both qualitatively and quantitatively with those of the uncoated inserts [12]. Ming et al. 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 tends to decrease slightly with an raise in the cutting speed and increased with feed and depth of cut and at a low cutting speed plastic flow of the machined surface was produced. 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 [13]. Suresh et al. studied the hard turning of AISI 4340 steel by using multilayer coated carbide tool. A correlation between machining parameters like speed, feed and depth of cut with machining force, wear rate of tool and surface roughness on work piece has been established and the performance of multilayer hard coatings (TiCN/TiC/Al2O3) on cemented carbide substrate using CVD coating technique for machining of hardened AISI 4340 steel by using Taguchi Method. The experiments shows that the optimal combination of low feed rate and low doc with high cutting speed is valuable for reducing machining force and was found that to lessen the specific cutting force higher values of feeds are necessary. Tool wear of cutting tool increases nearly linear with increase in feed rate and cutting speed and for minimizing the roughness of surface to minimum combination of high cutting speed and low feed rate is necessary [14].

Sahoo et al. experimentally investigated the machinability affects in finish hard turning of AISI 4340 steel using 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, using uncoated and multilayer TiN and ZrCN coated carbide inserts and it has been observed form the experimental results that multilayer TiN/TiCN/Al2O3/TiN coated insert performed better than uncoated and growth of flank wear and surface roughness in TiN/TiCN/Al2O3/ZrCN coated carbide insert being balanced. Life of tool for TiN and ZrCN coated carbide inserts 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 [15].

Krishankant et al. applied the Taguchi Method for Optimizing Turning Process by the effects of Machining Parameters. EN24 as the work material has been used and designed the Taguchi orthogonal array, with three levels of turning parameters, with the help of software Minitab 15. Experiments were repeated twice and material removal rate (MRR) was calculated and it has been predicted that Taguchi method, as it reduces the number of experiments, is a good method for optimization of various machining parameters. Optimum parameter (Spindle Speed, Feed Rate & Depth of Cut) for the machining of EN24 Steel for higher Material Removal Rate has been calculated [16].Kumbhar et al. optimized the tool life and surface roughness of PVD TiALN/TiN multilayer coated carbide inserts during the semi-hard turning of hardened EN31 alloy steel under dry cutting conditions and performed statistically designed experiments based on Taguchi methods using L9 orthogonal arrays to analyze the tool wear and surface roughness. It has been found that the feed rate was the most influential factor affecting the surface roughness and the tool life and the cutting speed and depth of cut are the least significant parameters [17].

Hazzaa et al. studied the flank wear in High Speed Turning of Stainless Steel AISI 304. Coated carbide tool is used for the machining of steel and found that the cutting speed was the most effective factor on the flank wear i.e. when the cutting speed was kept low the flank wear decreases and the chip shape was continuous and this causes some problems [18].

Das et al. studied the effect of machining parameters on surface roughness in machining of hardened AISI 4340 steel by using coated carbide inserts. Different machining parameters were cutting speed, feed and depth of cut with CVD (TiN+TiCN+$Al_2O_3$+ZrCN) multilayer coated carbide inserts. Full factorial design of experiment and the analysis of variance (ANOVA) has been used and observed that feed is the most influencing parameter followed by cutting speed. It has been found from the experimentation that the depth of cut did not impact the surface roughness drastically. The most optimal conditions for surface roughness, when cutting speed was set at 150 m/min and feed of 0.05 mm/rev and CVD coated tool was more useful in dry turning [19].Kadirgamaet. al. have investigated the wear mechanism and tool life during machining of Hastelloy C-22HS with coated carbide tools under wet conditions. The results obtained indicated that under selected parameters; PVD cutting tools performed better than CVD cutting tools, as far as tool life is concerned [20].

Chakraborty et al. carried out some experiments on cast iron using various types of ceramic and carbide tools. Their results showed that the foremost wear mechanism for aluminum oxide based ceramics was found to be because of abrasion, whereas for silicon nitride-based ceramics the basic mechanism was diffusion [21]. Wardany et al. experimented that the surface roughness was triggered due to plastic deformation of cutting edge of the ceramic tool and ultimately, edge fractured during machining hardened steel using ceramic cutting tool materials [22]. Paiva et al. experimentally investigated that the turning with TiN coated (A12O3+TiC) wiper mixed ceramic inserts by using Multivariate Robust Parameter Design on the hardened steel (AISI 52100). The new optimization approach has following characteristics variable of hard turning consists of controllable (xi) and noise (zi) to find out the parameter levels that decrease the distance of each response (yi) from its respective targets (Ti) and each variance due to noise variables as low as possible [23]. Long ying et al. investigated that the effect on cutting performance and the wear mechanism of the silicon nitride ceramic inserts when Ti-Al-N and Al-Cr-O coatings were deposited on it. After experimentation it has been observed that the cutting performance, hardness and wear resistance can improve during the machining process. During uncoated inserts abrasive wear and where as in case of coated inserts abrasive wear has the most dominant factor [24]. Yeckley et al. studied the machining process on austempered ductile iron (ADI), the most broadly used ceramic class is the alumina-based class. There are different classes of ceramic materials for cutting tools, each one along with different properties. The two major classes of ceramic for cutting tools are aluminum oxide (Al2O3)-based, and silicon nitride-based (Si3N4). The Si3N4-based ceramics are produced by crystals of Si3N4 with inter granular phase of SiO2, sintered with alumina [25].

## CONCLUSION

In the present study performance of various coated and multi-layer coated tools such as carbide, ceramic and cermet tools during the machining of hardened steel under dry conditions has been reviewed. The machining of hard materials at higher speeds is improved by using coated tools. From the investigation it is observed that coated tools give superior results as compared to uncoated tools in dry turning. In some cases TiN coated cermet tools have an increased tool life. This may be due to the higher resistance of TiN to oxidation. While the other coatings such as $Ti_2N$, TiCN+TiCN, TiCN+$TI_2N$ has found to be responsible for tool life decrements. In case of carbide inserts it was observed that tools with CVD of TiCN/TiC and PVD of TiN coating layer sequence performed best under conditions as lower forces with little variations, good surface finish. Whereas for the ceramic inserts it has been observed that the cutting performance, hardness and wear resistance may improve during the machining process for the coated tools. For uncoated & coated inserts abrasive wear was found to be the most dominant factor.

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