"REDUCING WEAR RATE OF CUTTING TOOL" - A REVIEW

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ABSTRACT

The use of coated cutting tools in machining of various materials now represents the state of art technology. The cutting tool life plays a major role in increasing the productivity and consequently is an important economic factor. Thus, the need of the hour is focusing research on innovative techniques for prolonging the life of the tool. Developments in coating equipment and process now enable us to produce a wide range of different hard nitride, carbide and oxide films to deposit them on various tool substrates as monolayer, multilayer or composite coatings. The challenge of machining industries in this modern world is mainly focused on achieving high quality, in terms of work piece dimensional accuracy, increased production rate, less wear of the cutting tools, economy of machining in terms of cost saving, surface finish and increased performance of the product with reduced environmental impact. This assessment paper is aimed to review various coatings that lowers tool friction coefficient and reduces wear rate.

Keywords: Coating material, wear, Tool life

INTRODUCTION

Since the demand for the high tolerance goods are rapidly increasing, most of the manufacturing industries are striving for the development of new techniques to increase the quality of the machined parts with decrease in its cutting costs. The main driving force behind the development of various cutting tools is the urge in every industry to increase the productivity with combined improvement in quality in high volume. Carbon steel was developed nearly a century ago, but many cutting tools have emerged since the use of cutting tool in metal cutting. Recently the use of Cemented carbides is most common in production tool material. The enhancement in the productivity of the manufacturing process is due to the improvement in the cutting tools towards the wear resistance. This results in the development of hard coatings for the cutting tools with thin films of one layer to hundreds of layers. These hard coatings slow down the wear rate thereby increasing the tool life. This helps in the reduction of frequent tool changes and also allows more improved and consistent surface roughness of the machined work piece. The rate of wear can also be reduced by changing the geometry of the cutting tool which slows down the wear process and produces better surface finish. The need for high wear resistance tools is essential in a metal machining environment to help keep replacement and tool replacement costs low. Most metal cutting people know that it is wear resistance of substrate and not the inherent wear resistance of the coating that matters. Rather, the coating should be able to yield maximum protection in the critical contact point between the tools and the work piece in order to enhance the wear resistance capability. Vapor deposition techniques such as PVD or CVD are employed to most of the carbide cutting tools for hard coatings. The coating process under CVD takes place at higher temperature when compared with PVD which causes deformation and softening of many cutting tools especially High Speed Steel (HSS). Carbides are susceptible to high damage by cracking if sudden loads are applied to their edge due to their inherent brittleness. This fact is the reason why PVD is becoming increasingly favorable over CVD in hard coating process for cutting tools.

LITERATURE REVIEW

Suraj R and **Jadhav** reported a case study on AISI 4340 alloy steel of 50 mm diameter cylindrical work pieces with coated tungsten carbide tool and the performance of the coated cutting tool and their parameters were studied at different cutting conditions. And it was found that tool coating improves chemical stability, surface roughness, anti-welding and anti-diffusivity. And also the coating thickness of about 3-10 µm is generally appropriate which increases the cutting rate 3 to 5 times faster than conventional cutting tools.

A.A.Vereschaka, A.S.Vereschaka and **A.D.Batakoc** proposed that the results of carbide inserts with newly developed coatings for heavy duty machining using Filtered Cathodic Vacuum Arc Deposition(FCVAD) increases the cutting tool parameters.Also it was found that increased tool life was achieved when carbide inserts with nano-structured multilayer composite coatings based on Ti-TiN-TiALCrN compound were used.

Satish Chinchanikara and **S.K.Choudhuryb** evaluated the cutting tool performance parameters of PVD applied single layer TiAlN and CVD applied multi layer TiN/Al2O3/TiCN during the turning operation of haredened steel.And the result obtained was that, lower interface temperature was observed for PVD coated tool in comaprision to CVD coated tool.Depth of cut having small influence on chip-tool interface temperature was observed for both the coated tools.

Sergej N Grigorieva and **A.A.Kutind** in their paper proposed that the layered composite material build up on a carbide substrate, a ceramic layer and a nano-scale multilayered caoting provides raised toughness and strength for the tool material.Also, the ceramic layer provides resistance for the tool material against oxidation, corrsion and high –temperature waekening at elevated temperatures.

Haruki Tanaka and **Enomoto** experimented on PCBN coated cutting tool especially in high speed machining of Inconel 718 at a cutting speeds ranging from 20m/min - 300m/min and the wear behaviours of the cutting tool was evaluated.The results of the turning experiment showed that the PCBN tool life significantly depends on the cutting speed and material structures on PCBN tools.

A.Thakur et al proposed that the coated tool on the other hand helps to prevent severe built up in temperature, but consequently results in a thermally dominated layer(due to lower thermal conductivity of Al_2O_3 coating) possessing less hardness.Therefore, it may be concluded that CVD multilayered caoting has synergetic improvement on the machined surface integrity based super alloy (Inconel 825).

Youqiang Xing et al proposed that the cutting performance of WS_2/Zr coated nano-textured tools is significantly improved compared with the conventional Al_2O_3/TiC ceramic cutting tools.The nano-textured TiC/ Al_2O_3 ceramic cutting tools deposited with WS_2/Zr composite soft coatings are more effective for the process of reducing the cutting force,cutting temperature,friction co-efficient and tool wear compared to WS_2/Zr caoted tool without nano-textures on its rake face.

Yin-Yu Chang et al found that the Si containing TiAlSiN coatings have better oxidation resistance when compared to TiAlN coatings. All the coatings which are deposited, exhibit good adhesion strength on tungsten carbide tools. It is confirmed that the multi component coatings are useful at high speed machining of the Ti-6Al-4V alloys which possessed high thermal satbility.

G.K.Dosbaeva studied the cutting temperature of the tool workpiece thermocouple on wear characteristics of carbide device with CVD multilayer TiCN with Al2O3 coating, along with low element Polycrystalline Cubic Boron Nitiride utensils in turning toughened D2 instrument steel. When growing cutting speed to 175m/min and consequently the cutting heat over 1100^0 C, these tribo films develop into unsucessful and PBCN has extended instrument living due to its higher hot rigidity.

W.Henderer et al proposed that TiSiN+CrCx/C coated tools have better wear resistance than C/TiN+CrC and DLC coatings. Higher level of hardness can be achieved with Ti targets containing 15% Si. The optimum cutting tool wear rseistance was achieved at 5% Si targets.

Further work is required to improve the surface finish by means of the cathodic arc deposition process for Si-Ti-N coatings.

Federico M. Aneiro and **Reginaldo T. Coelho** made observations in the turning of AISI 4340 with 48-50HRC at high speed cutting using the PCBN coating on the cutting tool shows results which were economical, mainly for the reason that it yielded good tool life. The tool life was found out to be longer for coated carbide, which yielded nearly 7000mm of the cutting length with low flank wear relatively.

Anand Kumar, Pardeep Kumar and Anuj Kumar made study that presents the influence of parameters such as surface roughness during the machining of AISI 1045 steel with carbide tool with TiN hard coating. The control factors had varying effects with the feed rate of the TiN coated carbide insert having the highest effects. This study concludes the best optimum speed, feed and depth of cutting for the TiN coated carbide insert.

Frank Barthelmäa made studies about the effect of oxygen-improved coating systems which show a better thermal and chemical stability under higher loads of the cutting tool. The combined effect of the oxidic and oxynitridic structures with the hard coating improves stability. The improvement of coating properties like hardness and elasticity are due to these structural elements which also optimizes thermodynamic properties. Thus the efficiency of cutting processes is improved by the development of these oxynitridic coating systems which allows high performance of the cutting process.

K. Gołombek and L.A. Dobrzański made studies related to the structure and properties of cemented carbide tools with PVD and CVD coating processes. The cathodic deposition of TiN and multi (Ti,Al,Si)N+TiN system with PVD coating process reveal better working properties in comparison to other uncoated tools. These hard coating on the cutting tool reveals that there is high influence of coating in tool life extension and surface finish with reduction in wear reduction.

Mohamed Handawi Saad Elmunafi proposed that the use of minimal amount of cutting fluid for lubrication is also an alternative for the reduction in the tool wear. This study evaluates the increase in the performance of the carbide cutting tool by the usage of castor oil as the cutting fluid. The experiments conducted with different cutting parameters shows that the tool life is inversely proportional to both cutting speed and feed, with much greater impact due to the cutting speed.

Miroslav Piska and Petra Sliwkova made studies related with the performance of PVD coated HSS taps with parameters such as Coulomb's coefficient of friction when carbon C45 is machined with cutting tool with hard coating combination of TiN and DLC. The machining showed premature fractures when uncoated tool was used which also showed poor quality of thread surfaces. With TiN/DLC coating on HSSE, the results showed safe and stabilized cutting and forming with excellent quality.

A.Thakur and S.Gangopadhyay made study that deals with the effect of cutting speed and CVD on machined surface integrity of Inconel 825 in dry turning. The effect of coated tool results in the reduction of microhardness in the surface and therefore leads to the elimination of thermal softening of the work peice which was observed in machining usin uncoated tool.

Naumov Alexander G.A and Vereschaka Alexey A.B made studies that deal with the effectiveness of machining process using microcapsules and nano-scale composite coating on the HSS and carbide tools. The nano-scale composite coating is evaluated as cutting fluid medium which increases the efficiency of the machining and was found out to be as good as the cutting process with other standard fluids.

H. Sert and F. Okay observed that minimum tool wear was achieved from TiN coated at highest speed of cutting at V=250 m/min. The biggest value of wear rate ranging from V=100 to 250 m/min was found out for Cermet cutting tools. TiN coated carbide tools are more suitable than TiAlN coated tools at higher speed of cutting. At a speed of 100 m/min, TiAlN coated carbide tool achieves maximum tool life, similarly TiN coated tool achieves maximum tool life at a cutting speed of 250 m/min.

N. Balasubramanyam observed that TiN and TiC coated tools are compared with uncoated tungsten carbide cutting tool. This study will help in finding the tool life and wear behaviour of each coated tool and also help in finding the best coating for the cutting tool. Observations were made which revealed AlCrN-T coating on the carbide tool shows the best acceptable levels of productivity in machining.

Ping Chuan Siowa investigated the ball on disk test to determine the mechanical properties of TiCN and

TiCN/ZrN. These coating significantly reduce the coefficient of friction and improves the abrasive wear resistance of carbide inserts. Titanium based hard coatings show improvement in surface hardness and it was also observed that TiCN coatings show results higher than that of TiN coating.

Jaimin P.Prajapati1 made comparisons of TiAlN and CrN coated tool with that of the uncoated tool. These hard coatings on the cutting tool show reduction in the wear and tear of the tool tip and hence increased tool life. Thus the study conclude the performance of the coated tool is higher than that of the uncoated tools.

Andrey Karaseva and Pär Göran Jönssona made study reports related to hard part turning of carburised steels in fine machining using PCBN cutting tools. Various machining experiments were conducted to examine the flank and crater wear which showed the longest tool life using Ca-treated steel. A protective layer of slag was found on rake face of the tool during machining. This Ca-treatment is aimed at increasing the fatigue resistance and impact toughness.

Ahmet Cakan investigated the experiments conducted on the prenitrided substrate and surface treatment on the adhesion and cutting performance of TiN and CrN coated tools. The experiments revealed that the prenitrided substrate and surface treatment enhances the turning performance of the TiN coated cutting inserts.

M. Narasimha and R. Reiji Kumar investigated that the coated tool shows higher life than the uncoated tool. Observations were made on the TiC/A12O3/TiN in the case of coated and uncoated tool which showed higher wear reduction in the coated tool. These coated tools produced the lowest surhace roughness of the entire tested tool. Multi layers offer high hardness, strength, heat resistance, and greatly enhance the performance of the cutting tools.

Table 1

Life increase of TiN-coated tools [3,7]

Tool name	Substrate	Workpiece	Life increase (%)
END MILL	M7	1022 STEEL, RC35	269
END MILL	M7	6061-T6 Al-alloy	804
END MILL	M3	7075T Al-alloy	489
GEAR HOB	M2	8620 Steel	100
BROACH	M3	303 Stainless steel	200
BROACH	M2	48 % Nickel alloy	1600
BROACH	M2	410 Stainless steel	158–210
PIPE TAP	M2	Gray iron	200
TAP	M2	1050 Steel, RC30-33	971–1233
FORM TOOL	T15	303 Stainless steel	220
DRILL		12L14 Steel	275
DRILL		304 Stainless steel	2067
DRILL		316 Stainless steel	2357
DRILL		4140 Steel	714
DRILL		Alloy steels	200–400
DRILL		Aluminum bronze	2850
DRILL		Carbon steels	300–500
DRILL		Cast irons	600–800
DRILL		Copper alloys	1900
DRILL		H-13 Tool steel	300
DRILL		Hastelloy	417
DRILL		Stainless steel	400–1100
DRILL		Ti alloy	856
DRILL		Tool steels	400–600

CONCLUSION

Based on studies related to tool life, it was observed that tool wear is a major phenomenon which affects the cutting tool life and surface finish of the work piece. The introduction of TiC coating for tungsten tool by PVD process in the early 1980s were followed by hard coating substances like TiN, TiC and Al_20_3 which improved the cutting tool capabilities.

Also, studies revealed that the performance and life of the cutting tool is high in case of coated tool when compared to the uncoated tool. The recent studies and researches focus on the development of cost effective coatings on the cutting tool by conducting various turning experiments.

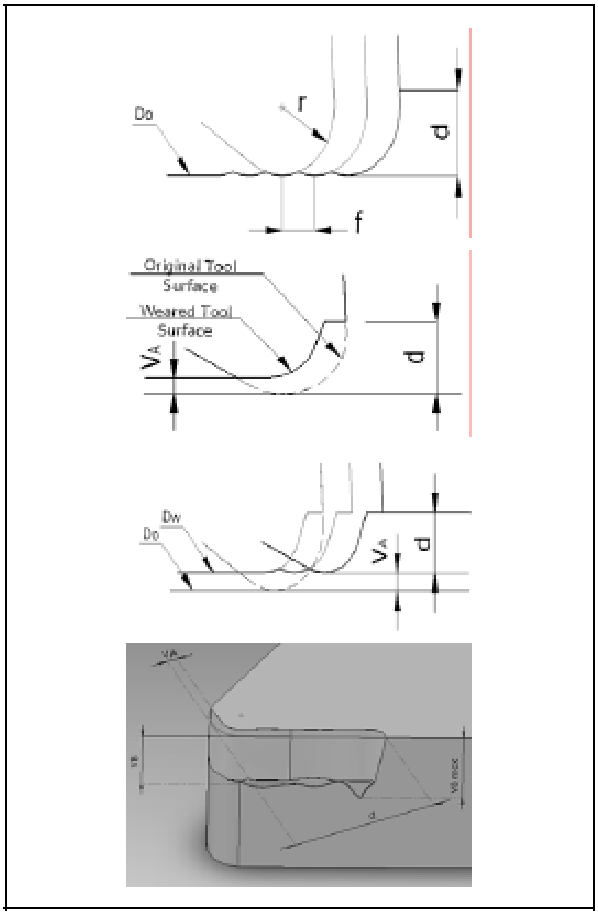

Figure 1: (a). The formation of the surface roughness with no wear sharp cutting tool (b) Tool Wear (c), Change of surface roughness and dimensional deviation after the tool wear propagate. (d) Simple wear propagation on single point cutting edge.

Following the experiments made in the past TiAlN and CrN coated tool performs better and reduces wear thereby increasing the tool life to greater extent. These hard coating enable high speed accurate machining and reduces the tool wear on the surface of the cutting tool which increases the tool life. Thus coating on cutting tool improves the surface roughness, chemical stability, and tool life.

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