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Charaterization of Coatings on Tool: A review

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ABSTRACT

Improvement in performance of cutting tool for high-speed machining of hard and difficult-to-cut material has remained a problem for quality and economy of production. Hard coatings are well known to improve the performance of cutting tools in machining applications. Physical and chemical vapour deposition techniques have found increasingly wider use in such applications in recent years. To improve the lifetime of a tool for which it functions properly, the cutting tool has to be protected, often by coatings that are specifically designed to prevent certain damage modes that occur in particular applications. In fact, over 90% of all cemented carbide inserts are currently coated using chemical vapor deposition, CVD, physical vapor deposition, PVD, or their combination. This paper will present coatings that are specially designed to protect the cutting tool and extend its functionality (lifetime).

Keywords: *physical vapor deposition (PVD), chemical vapor deposition (CVD), cutting tool*

1. INTRODUCTION

In any industry where Tool Performance is a major cause for the production, the durability of the tool as well as the tool failure and accuracy of while cutting and finishing operation are of great importance as any deviation in its cutting parameters may lead to tool failure or even affect the work piece. These control parameters include
(1) Cutting Speed
(2) Temperature
(3) Feed
(4) Coating
(5) Metal removal rate

The proper treatment of surface of tools can overall increase the life of tools, decrease in cycle time and improve better surface finish. Unfortunately for choosing the right coating to be applied on the cutting tool plays a vital role in manufacturing. Each of them has an advantages and disadvantages. A wrong selection can be lead to less tool life and tool failure than an uncoated tool. **[1]**

The ever-increasing demands of design and production engineers have led to the search for new materials with significantly improved properties. In recent years many new materials have been synthesized, characterized and put into use. Among these materials, composites and surface-engineered materials deserve special mention. Surface-engineered materials generally have their surfaces modified, e.g. by infusion of C and/or N, or coated with some other material(s) so that their resistance to wear, corrosion or fatigue is improved. [**2**]

In turning, catastrophic tool failure is to be avoided since it can damage the component, the tool and/or the machine tool and thus interrupt the machining process substantially. Instead, the useful life of a tool can be defined in terms of the progressive wear that occurs on the tool rake face (crater wear) and/or clearance face (flank wear). Of these two, flank wear is often used to define the end of effective tool life. The different types of wear can take place which are shown below in fig 1 [**3**]

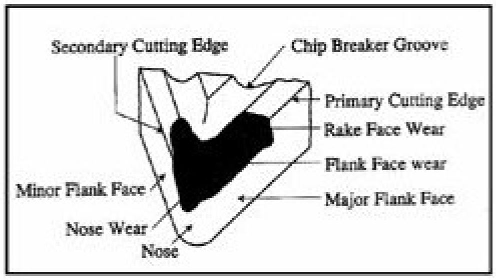

Fig 1: Different types of wear on tool

Different kinds of coating—physical vapour depositing (PVD) or chemical vapour depositing (CVD)—and different coated material (e.g. TiC, TiN, TiCN, Al2O3, HfN) have led to specialises areas of use. With PVD the sharpness of cutting edge is greater, making cutting forces smaller and lengthening tool life. Production costs are closely linked with the use of cutting tools. In Fig. 2 we can see that this is the case for only a small part of the costs of cutting tools (3%), but these are permanent costs, which accrue throughout the use of the equipment. From supply and demand and the situation of cutting tools and materials in the world market, it is evident that where cutting tools are concerned, a considerable amount of money can be either spent or saved. [**4**]

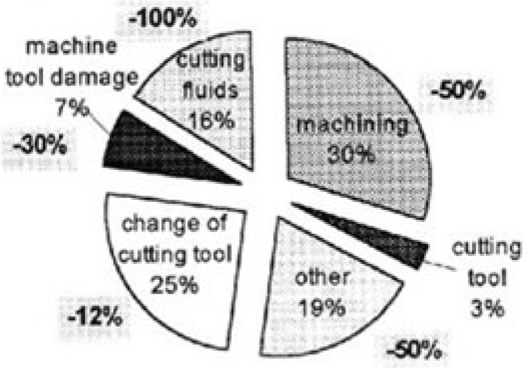

Fig 2: Division of production costs

This paper will focus on the role of coatings for metal cutting applications. Specifically, physical vapor deposition (PVD) coatings as applied to inserts made of cemented carbide, WC/Co. The paper will conclude with a summary and outlook on the development of new PVD coatings for cutting tools.

2. LITERATURE REVIEW

J.A. Ghani et al. [**5**] stated that the time taken for the cutting edge of TiN-coated carbide tools during machining of hardened AISI H13 tool steel to initiate crack and fracture is longer than that of uncoated cermets tools, especially at the combinations of high cutting speed, feed rate, and depth of cut and at the combinations of low cutting speed, feed rate, and depth of cut, the uncoated cermets performance is better.

Yong Huang et al. [6] Reported that flank wear of tool depend upon the cutting conditions, that is, cutting speed, feed, and depth of cut. According to results of Analysis of Variance cutting speed plays a dominant role in determining the tool performance in CBN hard turning of hardened 52100 bearing steel, followed by feed and depth of cut. These tendencies agree with predictions from the general Taylor tool life equation as well as experimental observations.

Schulz et al. [7] stated that cemented carbide tools coated with TiC, TiN or (Ti, Al)N by chemical vapor deposition (CVD) and or by physical vapor deposition (PVD) technology can show an increase of the service lifetime of tools by a factor of ten compared to uncoated tools.

It is found by **F Akbar et al.** [**8**] they investigated heat partition into the cutting tool for high-speed machining of AISI/SAE 4140 high-strength alloy steel with uncoated and TiN-coated tools. According to reported results, the use of TiN coating on tools causes about 17 percent reduction in heat partition into the cutting tool compared with the uncoated tools at ordinary cutting speed and 60 percent in the HSM region.

According to **RAMAMOORTHY et al.** [**9**] according to them even in such an advanced vacuum coating techniques, the failure is not due to the wear of the coating but rather due to the lack of coating adhesion to the substrate. The sputter deposition conditions for DLC/TiN/ Ti/Cu/Ni multilayer coatings are identified to achieve improved quality with particular reference to adhesion and surface finish.

K. Subramanyam et al. [10] studied the performance of coated tools in machining hardening steel under dry conditions. The experimental results showed with increase in feed the surface roughness observed is very poor. The effect of cutting velocity on surface roughness is relatively low when compared to feed rate. With increase in depth of cut the surface roughness is increased. According to experimental results by selecting the proper cutting parameters the coated tools are suitable to produce fine surface finished components.

Nouari et al. [11] stated that the selecting optimized tool geometry and the cutting conditions entails a high surface quality. Use of diamond as coating material allowed to extend the tool life.

J.-E. Sundgren et al. [12] studied the present state of art in hard coatings grown from the vapor phase. They studied some commonly used coatings of these, carbides and nitrides are the most important, but other refractory compounds such as oxides and borides are also studied. According to them Voided or weak boundaries decrease the hardness of coatings below bulk values. Weak boundaries are, for example, promoted by low substrate temperatures; small grain size will lead to high hardnesses of the coatings. Process conditions such as high growth rates and energetic particle bombardment can give rise to extended solubilities and non equilibrium phase compositions. These coatings are highly stressed and have hardness values far above that for the corresponding equilibrium structure. In particular, the incorporation of noble gases during growth of coating using plasma or ion-assisted techniques has been shown to generate high compressive stress levels in the deposited coatings.

A.A. Vereschakaa et al. [13] studied Nano-scale multilayered composite coatings for cutting tools operating under heavy cutting conditions. A new process called Filtered Cathodic Vacuum Arc Deposition (FCVAD) was used to deposit coating on a set of carbide inserts. An increased tool life was achieved using carbide inserts with nanostructured multilayer composite coatings based on the Ti-TiN-TiAlCrN compound. The comparative experimental study in roughing re-profile machining in heavy duty conditions with depth of cut of 4-8 mm showed that the inserts with the new coatings had substantially higher wear-resistance than commercial ones. There was no chipping, no micro/macro spalling of contact areas and tool cutting edge. The experimental result showed that that the operational life of the inserts with the elaborated coating exceeded by a factor of more than two the lifetime of commercially coated inserts.

Yunsong Lian et al. [14] studied WS_2/Zr self-lubricating soft coatings in dry sliding against 40Cr hardened steel balls. The results showed that the specimen with WS2/Zr composite coating has higher hardness and coating/substrate critical load compared with that of the specimen only with WS_2 coating. The coefficient of friction for WS2/Zr self-lubricating soft coatings in dry sliding is small as compared to all specimens tested under same conditions.

Reginaldo T. Coelho et al. [15] studied turning hardened AISI 4340 with coated PCBN tools using finishing cutting conditions. Three different coatings TiAlN, TiAlN-nanocoating and AlCrN were tested using finishing conditions. Finite element method (FEM) simulations indicated that temperature at the chip–tool interface was around 800 ^{0}C in absence of flank wear, independently of coating. In that range only the TiAlN coating oxidize since AlCrN needs higher than 1000 ^{0}C. Therefore, due to a combination of high hardness in the cutting temperature range and the presence of an oxidizing layer, TiAlN-nanocoating performed better in terms of tool wear and surface roughness.

CONCLUSION

Literature underlines the long list of coating-products, i.e., coatings that are already in-use; Following Conclusions can be drawn from different types of coatings deposited on tools.

- It is observed that the cutting operation and its parameters affect the cutting tool and its durability. The coating applied on the cutting tool plays a vital role while performing the operation due to its cutting speed and hardness of the cutting tool also the surface hardness of coated cutting tool is more compared to the uncoated cutting tool.
- Also it should be taken in mind that not every coating is possible in any of the cutting tool. It varies from work-piece material to cutting tool material. The composite material has the more strength than an individual material.
- In PVD systems where the coating formation and properties are affected by the local plasma conditions and by the configuration of the deposition chamber. Good understanding and precise control of the plasma are essential for further commercialization of new PVD coatings.
- Since today’s requirement for metal cutting industry is dry machining, molybdenum disulfide

(MoS2), graphite(C) and boron nitride (BN) coatings will play important role in dry machining.

- For the coated tools selecting the proper cutting parameters are suitable to produce fine surface finished components.

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