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EFFECT OF COATING ON CUTTING TOOLS

Tejas A. Firodiya,
Dept. Mechanical Engineering, Indira college Of Engineering and Management Pune,India.
tejasfirodiya1988@gmail.com
Prof. Shubhangi Manwatkar
Dept. Mechanical Engineering, Indira college Of Engineering and Management Pune,India
shubhangi.kamble@indiraicem.ac.in

Abstract—Cutting is an important process in the manufacturing industry. It is necessary to use good quality cutting tools in order to maintain the quality of a product. The coating on a cutting tool has a great impact in terms of the mechanical properties as well as the end results of the product.To improve the performance of cutting tools, various coatings have been applied to the tools, among them being single coatings, multi-layered coatings, Nano composites and superlattices.This review discusses cutting tools, their functions and coatings the effect of coating thickness and substrate roughness on the tool wear ,the performance of TiN, TiAlN and TiN+AlCrN coatings were assessed.

I. INTRODUCTION

The cutting process involves the removal of material from a workpiece to produce a specific design. The quality of the cutting process is assessed in terms of the end result of the product and the lifetime of the cutting tool itself. Cutting tools are made of various types of materials including cemented tungsten carbide, high-speed steel, diamond and boron nitride. All these materials have their own mechanical and tribological properties, but cemented tungsten carbide is the most commonly used material in the industry, especially for steel cutting applications. This is because cemented tungsten carbide is reasonably priced and has a high level of hardness and boiling point. However, the performance of a cutting tool does not depend on the material alone.
The performance of a cutting tool can be improved by applying a coating to the surface of the cutting tool. Various types of coating structures and materials can be combined to produce high-performance cutting tools. The coating not only functions to extend the lifetime of the cutting tool but it also acts as a protection against wear, especially against abrasions and adhesions, in cutting tool applications. The coating thicknesses range from microns to several millimeters.

II. LITRATURE REVIEW

G. ERKENS ,Improved Coating Properties and Optimized Substrate Data, Essential Conditions for High Performance Cutting Tools, Volume 25, No. 1&2, 2003.- **“**One of the most effective state of the art coatings is the metastable solid solution phase (Ti,Al)N in cubic B1 structure, offering superior oxidation resistance and hardness With increasing aluminum content the oxidation resistance of (Ti,Al)N coatings increases, however a barrier is set to PVD process technology by the deposition of insulating films at a film composition of approx. 65-67mol-% AlN “[3]

M.Narasimha,D.Tewodros, R.Rejikumar, Improving Wear Resistance of Cutting Tool by coating.-
“The TiN coated tool showed a slight improvement compared to the uncoated tool. The TiN/Al2O3 had the third highest flank wear. The improvement of the wear resistance compared to the TiN coating was due to the addition of the Al2O3 layer. This layer protected the TiN coating. However, the Al2O3 coating had the second highest flank wear resistance and showed an improvement in wear resistance as compared to TiN/Al2O3. Hence, using one layer of Al2O3 appears to have better wear resistance to flank wear as compared to using 2 layers of coating with TiN interlayer and Al2O3 outer layer. The TiC/Al2O3/TiN coated tool appeared to have the best wear resistance under the testing conditions used. This was as expected since the combination of TiC with high abrasive resistance, chemically stable Al2O3 with low thermal conductivity and the added wear resistance of the TiN coating improved the overall wear resistance of the cutting tool.”[10]
TiAlN-based coatings with different compositionswas investigated. The data presented in Figure 8 show that the Al/Ti ratio in SFC coatings affect the cutting performance. The tool life was longest within Al/Ti ratio 50–60%. Tool life improvement was around 60% compared to the commercial thin TiAlN coating. When the Al/Ti ratio is higher, the tool life decreases.[9]

M. Bar-hena, i. Etsionb, -Experimental study of the effect of coating thickness and substrate roughness on tool wear during turning - the tool wear resistance continually increased with increasing coating thickness. tool life was longer with thickness between 7.5 and 10.5 μm, in the flank wear resistance increased with increasing coating thickness up to 6 μm and decreased drastically at coating thickness of 10 μm. In an optimum coating thickness of 3.5 μm it was found that maximized the tool life (or wear resistance). In each of the above five studies. only a limited number of 3–5 coating thickness values was tested over the entire thicknesses range.[1]

Rogante (2008) conducted the comparative study on TiC–TiN coated and uncoated inserts when machining of normalized medium carbon steel in dry cutting process. The results revealed that coated tool produced approximately 50% longer machining time and lesser power consumption when compared to the uncoated tool.[4]

Shanyong Zhang, Weiguang Zhu, TiN coating of tool steels: a review,-“Titanium nitride as a coating for tool steels has been available widely since the last decade and is enjoying increasing attention and application in tool industries. The reasons are simple yet important: the advantages of TiN coatings of tool steelsinclude a noble appearance, excellent adhesion to substrates, high chemical inertness, resistance to elevated temperatures, hard surfaces (2400HV) to reduce abrasive wear, a low coefficient of friction with most workpiece materials which increases lubricity and results in excellent surface finish and decrease of horsepower requirements, improved ability to hold tolerances and high temperature stability and low maintenance cost and high productivity”

PVD TiN coating currently enjoys wide metal cutting application. Surface coating is an effective method to improve the durability of materials used in aggressive environments. The PVD coatings featured TiN as the hard coating and were applied in cutting processes. Hard coatings increase tool performance and longevity by arresting or slowing down the tool wear. TiN coated tool exhibited lower wear than the Al2O3 coated tool (Sahin 2005). TiN was considered as a universal coating for cutting tools and is indicated when different workpiece materials are machined with the same cutting tool (Harris et al 2001). Ghani et al (2004) studied the performance of TiN coated carbide inserts when machining of AISI H13 tool steel. The tool life results indicated that the cutting speed did not have an effect was not affected significantly by the cutting speed much contrary to the early findings [4]

Type of Coating	Functions of the Coating
TiN (TITANIUM NITRDING)	Reduces friction and prevents adhesive wear and BUE formation
Ti(C,N) (TITANIUM CROMIUM NITRIDING)	High fracture strength and excellent abrasive wear resistance
TiAlN (TITANIUM ALUMINIUM NITRDING)	Displays high thermal hardness, ductility and thermal impact resistance
Al2O3 (ALU. OXIDE)	Excellent thermal separation, and good oxidation resistance
CrN (CROMIUM NITRIDE)	Excellent wear and corrosion resistance, low friction and internal pressure resistance

I. Tool wear phenomena

Under high temperature, high pressure, high sliding velocity and mechanical or thermal shock in cutting area, cutting tool has normally complex wear appearance. This consists of some basic wear types such as crater wear, flank wear, thermal crack, brittle crack, fatigue crack, insert breakage, plastic deformation and build-up edge. The dominating basic wear types vary with the change of cutting conditions.[2]

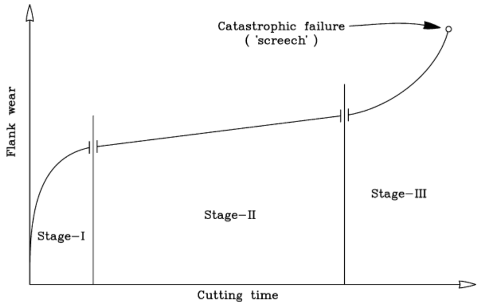

Figure 1 Tool Wear Phenomena

From above fig we can see that thereare three stages of tool ear in first stage soll wear rate is bit high it is caused by the friction between the newly machined work piece surface and the tool flank face.in Second stage slop is very low as tool lifegradually decreases and in third stage tool wear increases suddenly as tool life is almost ended

II. MODES OF TOOL WEAR OCCURRING DURING MACHINING PROCESS

Cutting tools are subject to an extremely severe rubbing process. They are in metal-to-metal contact, (between the chip and work piece) under conditions of very high stress at high temperature. This situation is further aggravated by the inducement of extreme stress and temperature gradients near the surface of the tool. During cutting, cutting tools remove the material from the component to achieve the required shape, dimension and finish. However, wears continue to occur during the cutting action, which it willresult in the failure of the cutting tool.
Tool wear is a major phenomenon that affects the cutting tool life and the surface roughness of the workpiece. Many research studies were carried out to reduce the effect of tool wear on surface roughness and to increase the tool life. The cutting tool life can be improved by of coating given on tool surface. Early research studies revealed that coated tool performed better than the uncoated tool.[2]

Crater wear:In continuous cutting, for example, in the case of a turning operation, crater wear normally forms on the rake face. It conforms to the shape of the chip underside and reaches a maximum depth at a distance away from the cutting edge where the highest temperature occurs. At high cutting speed, crater wear is often the crucial factor that determines the life of the cutting tool. This is because the tool edge is weakened by the severe cratering, eventually leading to fractures. Crater wear is improved by selecting suitable cutting parameters and by coated tool or ultra-hard material tool. A rapid cratering on the rake face of the tool can result either from high temperatures generated at cutting speeds (much higher than recommended ones) or from high chemical reactivity between the tool material and the work material[2]
.

Flank wear: Flank wear is caused by the friction between the newly machined work piece surface and the tool flank face. Flank wear results in poor surface finish decreased dimension accuracy of the tool and an increased cutting force, temperature and vibration. Hence the width of the flank wear land "VB" is usually taken as a measure of the amount of wear.[2]

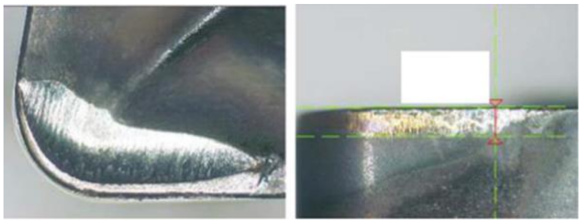

Figure 2Example of crater (left) and flank (right) wear in a cutting tool.

III. TYPES OF COATINGS FOR CUTTING TOOLS

a) Single Coating

A classic PVD layer such as TiN, Ti-C-N, CrN, Ti-Al-N is based on a single-coating architecture[1]

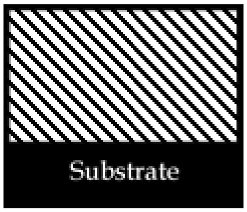

Figure 3 Single Coating

b) Multiple Layers

A multi-layered coating is made up of a lamellae structure of 2 or more materials that are uniformly layered . The advantages of using a multi-layered coating are that it is able to adapt to pressure, it promotes adhesion to the substrate and improves the resistance to crack propagation.[1】

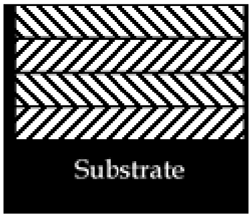

Figure 4-Multiple Layers

c) Superlattices

Nano-scale multi-layered coatings, known as superlattices, have been developed to enhance the hardness and strength of a system. A key element in the concept of superlattices is the very thin layer measuring less than 10 nm, which is said to be able to prevent the formation of dislocations, while the difference in the elastic modulus between the layers will impede the mobility of the dislocations. The weakness of superlattices is that the effect of the nano layers in the superlattices can be lost if the resultant layers do not follow the correct order[1]

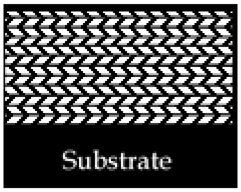

Figure 5-Superlattices

IV. CONCLUSION

In this literature studies, it was found that tool wear is a major phenomenon that affects the cutting tool life and the surface roughness of the workpiece. Many research studies were carried out to reduce the effect of tool wear on surface roughness and to increase the tool life. The cutting tool life can be improved by of coating given on tool surface. Early research studies revealed that coated tool performed better than the uncoated tool. Today, far more than half of all cutting tools with a geometrically defined cutting edge are coated. Developed back in the 1970s and 1980s, TiC, TiCN, TiN, Al2O3, and TiAIN still remain the most frequently used tool coating materials. They are still the basis for modern high-performance coatings, although there is still potential for performance improvement by adjustments of the coating architecture.

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