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Effect of cutting parameters on wear behavior of coated tool with titanium nitride

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ABSTRACT

The effect of cutting parameters on cutting force, cutting temperature, tool life, wear mechanism and surface roughness is studied and analyzed by single factor process. Experiment in high-speed high-strength steel with coated carbide tool is conducted. It is suggested that the cutting speed has the most important effect on the cutting force, cutting temperature and tool life, while the feed rate has great influence on surface roughness. The major wear mechanisms of the coated tool include abrasion, adhesion, oxidation and diffusion. In addition, the titanium oxide is present on the worn surface, which contributes to improve the hardness of the cutting zone, reduce the friction coefficient and play a role in insulation. So it reduces wear rate.

Keywords: High Speed Steel, Titanium Nitride, Physical Vapor Deposition.

INTRODUCTION

The development of modern application of high-strength steel is confronted with great challenge due to the high cutting force and heat, severe tool wear and unstable machined quality. In particular, the tool wear and machined surface quality are the most important indicators for manufacturers [1, 2], which are subjected to a thermo mechanical coupling. There are various machining parameters which have an influence on the tool wear and surface integrity, such as cutting parameters, work piece material hardness, tool material properties, cutting fluid conditions and so on. The effect of cutting conditions on cutting force and cutting temperature has been studied by many researchers. With the increase of cutting speed (vc) and decrease of depth of cut (ap) and feed rate (f), the cutting forces decrease [3]. But the magnitude of cutting force increases, as cutting speed decreases. The experimental observations indicated that the cutting force is

affected mostly by depth of cut, while turning of high-strength steel with coated tool [4]. In addition to limiting cutting speed, the minimum cutting forces can be ensured at low level of feed and depth of cut [4]. Based on the semi-artificial thermocouple, the tool temperature has a rising trend as the cutting parameters increase [5]. Moreover, the same fluctuation feature of the cutting temperature and cutting force is displayed [5]. So they can complement each other. For turning of AISI 4340 steel, the influence of coating type is also investigated. It is found that the cutting temperature of CVD-applied multi-layer TiCN/Al₂O₃/TiN is higher than that of PVD-applied single-layer TiAlN [6]. The cutting temperature gets affected mostly by cutting speed, but gets negligible influence by depth of cut [6]. In the intermittent turning process, a theoretical method is proposed for prediction of tool temperatures to reveal the influences of cutting parameters on tool temperatures [7]. It is suggested

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that relatively large feed rate and relatively small depth of cut should be adopted to acquire the lowest tool temperature.

OBJECTIVES

To make a comparative study on the performance and wear test of Titanium nitride coated HSS samples with uncoated insert tools. To study the effect of different cutting parameters on the tool life of coating insert tool (HSS and carbides) and development of tool life equations employing design of experiment (DOE) technique. To study the mechanical properties changes.

LITERATURE SURVEY

Chen Wuyi cutting force generated using CBN tools have been evaluated when cutting steel hardened to 45~55 HRC. Radial thrust cutting force was the largest among the three cutting force components and was most sensitive to the changes of cutting edge geometry and tool wear. The surface finish produced CBN tools was compatible with the results of grinding and was affected by cutting speed, tool wear and plastic behavior of the work piece material [1].

Guangming Zheng The effect of cutting parameter on cutting force, cutting temperature, tool life, wear mechanism and surface roughness is studied and analyzed. Experiments in high speed dry turning of 300M high strength steel with coated carbide tool is considered. It is suggested that the cutting speed has the most important effects on the cutting force, cutting temperature and tool life, while the feed rate has great influence on surface roughness. The major wear mechanism of the coated tool include abrasion, adhesion, oxidation and diffusion. In addition, the titanium oxide is present on the warm surface, which contributes to improve the hardness of cutting zone, reduce the friction co-efficient and play a role in insulation. So it reduce wear rate [2].

Muammer Nalbant Abdullah Altin. The effect of cutting tool coating material and cutting speed on cutting forces and surface roughness are investigated. For this purpose, nickel based Inconel 718 is machined at dry cutting conditions with three different cemented carbide tools in CNC

lathe. Metal removing process is carried out for five different cutting speeds(15,30,45,60,75 m/min.) while 2mm depth of cut and 0.20mm/rev feed rate are to be constant. main cutting force, F_c is considered to be cutting force as a criterion. In the experiments, depending on the tool coating material, lowest main cutting force is found to be 506N at 75 m/min with multi coated cemented carbide insert whose top layer is coated by Al_2O_3 , lowest average surface roughness ($0.806\mu m$) is obtained at the cutting speed of 15 m/min with single coated (TiN) cemented carbide inserts [3].

Rech.J, Kusiak.A. The study deals with the qualification of the tribological system work material coated carbide cutting tool chip. It's a aim of this paper to achieve a clearer understanding of the heat flow during the turning process in tool subtracts. Results from experiments associated with an inverse heat condition method signify the beneficial effects of upon the interactions in tool chip interface, in addition two confirming previous theoretical approaches that their thermal barrier role does not exist. This highlights the advantages offered by certain coatings which combine hardness and self lubricating properties, for example (Ti,Al)N+ MoS_2 [4].

Rech. J, Battaglia. J.L, Moisan. A The paper deals with the qualification of the thermal behavior of system work material coated carbide cutting tool chip, with the purpose of reaching a better understanding of the heat flow. Heat transfer in the deposit subsets system was analyzed for simple dip geometry. A model of heat transfer in cutting tool has been proposed. Results source that coating thermal barrier thus not exit in continuous operation but the seems to be significant in discontinuous cutting operation, especially performed with high cutting speed [5].

Tonshoff.H.K magnesium is the lightest metal used in construction and therefore offers the greatest potential for weight reduction. The automotive industries in particular has an upcoming in trust in the use of magnesium allows. To observe the interactions between work piece material and coating, respectively, turning experiment were carried out machining the alloy AZ91 HP. When machining magnesium dry, flank build-up due to adhesion between cutting tool and work piece can occur at cutting speed of $v_c=900$

m/min and more for uncoated and TiN-coated carbide tools. Tools with either polycrystalline diamond(PCD) insect or coating can be used to reduce friction and adhesion in the tool-work-piece contact resulting in low machining forces as well high cutting speeds $v_c=2400$ m/min. PCD coatings can also be applied to complex tool geometries. Excessive tool wear can be observed for TiN coated carbides even at low cutting speeds of $v_c=100$ m/min [6].

MATERIALS AND METHODS

Selection of material

HSS TOOL (High speed cutting tool)

HIGH-SPEED TOOL STEELS and their requirements are defined by The American Society for Testing and Materials in Specification A600-79 as follows: High-speed tool steels are so named primarily because of their ability to machine materials at high cutting speeds. They are complex iron-base alloys of carbon, chromium, vanadium, molybdenum, or tungsten, or combinations thereof, and in some cases substantial amounts of cobalt. The carbon and alloy contents are balanced at levels to give high attainable hardening response, high wear resistance, high resistance to the softening effect of heat, and good toughness for effective use in industrial cutting operations.

Selection coating materials

Titanium Nitride

Titanium nitride (TiN) has been widely used as a coating material, ranging from diffusion barrier in microelectronic industry, to the hard and protective coatings on mechanical tools and decorative coatings. Because of the well-established application history, TiN thin films are good choices to meet the requirements. To improve the characteristics of TiN thin film, many studies have been presented to understand the relationships between the processing parameters, the film structure and properties. The previous research shows that the mechanical properties of TiN film are strongly affected by its preferred orientation, residual stress, packing factor, and grain size. Also the resistivity of TiN thin films is correlated to the packing factor. DC magnetron

sputtering is presently used for the deposition of a wide variety of thin films, especially oxides, nitrides and carbides. The presented models do not include the effect of different reactivities of the reactive sputter process. DC magnetron sputtering from elemental targets is a suitable technique for the preparation of compounds. In the past decade, DC magnetron sputtering technique has been used especially for hard coating. Presently, semiconducting nitrides (GaN, InN) are very important. DC magnetron sputtering is a cheap and well developed deposition technique that should be applied also for the preparation of these nitrides. The reactive sputtering of nitrides, especially that of the refractory nitrides (TiN, TaN, etc.), has been investigated greatly over the past years. Hofmann was the first to make a systematic study formation of nitrides by sputtering titanium targets in Ar/N₂ mixtures. In his model he discovered a parameter that took into account the different reactivities of metals to nitrogen. But he could not find a relationship between the heat of formation of the nitrides and the discharge characteristics. Mientus and Ellmer have investigated the changes of nitrogen partial pressure for formation of the nitrides and they discovered that both the discharge voltage and the deposition rate show a significant change when the nitrogen partial pressure increased. The discharge voltage increases or decreases depending on a decreased or increased secondary electron emission coefficient of the nitride target surface. For Ti and TiN, the discharge voltage increases by about 20–30 % when nitrogen partial pressure increased from zero to 3.7×10^{-3} Torr. In addition, in this paper it was concluded that deposition rate decreases when nitrogen partial pressure increases. TiN thin films were deposited by DC magnetron sputtering method in Ar + N₂ atmosphere. The reactive sputter gas was a mixture of Ar (99.999 %) and N₂ (99.999 %) with the ratio Ar (97 %) and N₂ (3 %) by volume and effect of temperature on the structural properties of the films was investigated. Topography and atomic structure were investigated by atomic force microscopy (AFM) and X-ray diffraction (XRD), respectively. XRD showed that TiNnanocrystal is formed on these films. Average particle size nanoparticles were estimated by Scherrer formula, also we were compared.



Fig.1 Titanium nitride

Table. 1 Properties of Titanium Nitride.

Properties	Value
Density	5.24 g/cm ³
Melting point	2950°C
Molecular weight	61.874Mol

SELECTION OF COATINGS PROCESS

Physical vapor deposition

Main article: Physical vapor deposition

1. Cathodic arc deposition
2. Electron beam physical vapor deposition (EBPVD)
3. Ion plating
4. Ion beam assisted deposition (IBAD)
5. Magnetron sputtering
6. Pulsed laser deposition
7. Sputter deposition
8. Vacuum deposition
9. Vacuum evaporation, evaporation (deposition)

For the evaporation process the substance to be evaporated is heated in a dedicated container (ceramic crucible, Ta boat, W spiral wire etc.) by the introduction of energy (electrical current, electron beam, laser, arc discharger etc.) to a suitable temperature. The thermally released atoms or molecules leave the surface of the evaporated material and form a coating on the substrate or on

the surrounding walls. To guarantee well defined film properties the substrate temperature often has to be as high as some 100°C.

This can be achieved by using heating rods or quartz lamps. Employing glow electrodes allows for a cleaning of the substrate by ion or electron bombardment which is extremely important for a good coating adhesion. A suitable vacuum system equipped with gas inlets and different mechanical devices (screening arrangements, shutter, motor powered substrate movement) has to be available to perform an evaporation process.

1. So far we have seen deposition techniques that physically transport material from a condensed phase source to a substrate.
2. The material to be deposited is somehow emitted from the source already in the form that we need for the thin film (ex.: evaporation, sputtering).
3. No chemical reactions are assumed. In fact, they are generally unwanted. If there are chemical reactions (as in reactive sputtering) they are simple reactions with no by-products.
4. The critical parameters are physical (temperature, pressure, voltage applied, etc.)



Fig.2 PVD image

TEST PARAMETERS

- Load: Values of the force in Newtons at the wearing contact.
- Speed: The relative sliding speed between the contacting surfaces in metres per second.
- Distance: The accumulated sliding distance in meters.
- Temperature: The temperature of one or both specimens at locations close to the wearing contact.
- Atmosphere: The atmosphere (laboratory air, relative humidity, argon, lubricant, etc.) surrounding the wearing contact.

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CONCLUSION

In the present work the performance of coated HSS tools by using titanium nitride conditions is studied. The results show that the coated tool performs better as compared to uncoated cutting tool. The effect of cutting is to reduce wear and tear of tool tip point as well as more heat dissipation to surrounding hence the increase in tool life and surface finish of the product to be machine. With increase in depth of cut the surface roughness is increased. Here experimental results shows by selecting the proper cutting parameters the coated tools are suitable to produce fine surface finished components.