Review Of Analysis and Improvement in Tribological Properties Of Nitrided And Coated HSS Tool

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Abstract- **Depositions of surface coating materials is one of the important approaches in improving friction and wear properties of the surface, there is a growing demand for low friction coatings like are commonly used to solve tribological problems and in particular problems of fretting. Hence, the use of low friction coatings like TiN, TiAlN and AlCrN is to improve the tribological properties of tools for metal cutting, forming and machine elements e.g. sliding bearings, seals and valves etc. It is therefore of strong scientific interest to conduct fundamental tribological research on the materials that exhibits low friction and can be used for surface coating on surfaces to rub against with reduced friction and wear. The reasons to coat cutting tools in a production situation are to increase tool life, to improve the surface quality of the product, and to increase the production rate. The advantages of this coating include high hardness, good ductility, excellent lubricity, high chemical stability and tough resistance to wear, corrosion and temperature. In this paper, the principles, advantages and limitations of various coating and processes are summarized. With the growing popularity of coated tools and new development of coating process, this paper deals with the study of the performance of coated tools in machining hardening steel under dry conditions. This paper involves of machining hardened steel using Titanium nitride (TiN), TiAlN and AlCrN coated HSS tools is studied using Taguchi technique. Many parameters influence the quality of the products in turning process. The objective of this study is on the effect of coating on tool to determine its various parameters such as Sliding Speed, Load and Sliding Distance in machining hardened steel.**

Index Terms— **Surface coating, *Friction, wear,* Pin-on-disc,metal cutting.**

I.INTRODUCTION

The machining industry is constantly seeking ways to enhance performance (metal removal rate) and reduce cost of the manufactured parts. One way to enhance the machining performance is to utilize high speed machining. One of the problems associated with high speed machining is the high tool wear, leading to reduction in tool life. This is essentially due to the existence of higher cutting temperature generated between the tool tip and the component interface. Higher cutting temperature can also enhance the chemical reactivity between tool and certain work piece materials such as Titanium (Ti). This can lead to higher chemical wear thereby further reducing the tool life. Lower tool life leads to frequent tool changes resulting in increased machine down time. This in turn reduces the overall productivity. Hence, it is essential to minimize the tool wear & tear and increase the life. This is possible by controlling the cutting temperature, time of cutting, using cutting oils etc. Conventionally the cutting temperature is lowered by the use of metal-cutting fluids (coolants). One of the alternatives to satisfy the demand for cost effective machining with reduced ecological impact is to employ high speed and/or dry machining technique. However, dry machining concept is still in its infancy and until it becomes a reality we must look for alternatives that will help us find ways to protect the tool from higher cutting temperature. This can be achieved through the exploitation of advanced surface coatings on cutting tools. Hard wear resistant coatings such as TiN, TiAlN&Nitriding etc. provide overall improved tool life and better machining performance.

A. Review Stage

It is found by F Akbar in 2008[1], Weiguang Zhu [2]. that the use of TiN-coated tools causes a reduction in heat partition into the cutting tool compared with the uncoated tool about 16 percent at conventional cutting speed and 62 percent in the HSM region. It may be concluded that, compared with uncoated carbide tools, TiN coatings significantly improve the tribological phenomena by reducing the tool chip contact area, providing a lower thermal conductivity for the tooling systems, and ultimately reducing heat partition into the cutting tool. Seshadri.R. [3]. Titanium Nitride (Tin) coating improves the tool wear by increasing the wear resistance, thereby protecting the tool. Initial Flank wear is observed after machining the material continuously for 250 seconds. Specific power consumption is low at higher cutting speeds which supports that this material possess good machinability. Hardness of the material is more, hence machining at high speed is recommended.

S. PalDey [4] In this paper, deposition of (TiAlN) coatings using different PVD techniques have been reviewed. The effects of deposition variables on coating microstructure and film properties were analyzed. (TiAlN) exhibited superior performance in many applications as compared with the other commercially available Ti based coatings. Based on a simple TiN coating, various strategies were developed in order to improve or adapt hard coatings. CemKaracal et al. [5] advanced coating technology has significantly improved the tool life expectancy. Titanium Nitride (TiN), Titanium Carbo-Nitride (TiCN), Titanium Aluminum Nitride (TiAlN or AlTiN), Chromium Nitride (CrN), and Diamond coatings can increase overall tool life, decrease cycle time, and promoted better surface finish. K. Aslantas et al. [6] in coated mixed ceramic tool, the thermal conductivity value of TiN coating material increases with increases in temperature. Therefore, the heat flow to the cutting tool increases and the temperature at the tool–chip interface decreases. The temperature difference between the upper and lower sides of the chip decreases and the chip up-curl radius increases. J. Nickel et al.[7] The nature and the underlying wear mechanisms of TiN-coated tools and the role of TiN in improving wear resistance and increasing tool life have been the subject of many investigations. For example, the wear modes of TiN-coated HSS, from the results of sliding pin-on-disc wear tests, were found to include adhesive and abrasive wear of the coating w12,13x. TiN-coating fragments were found to be the dominant wear mechanisms in actual machining tests w8x. The latter wear mechanism was attributed to insufficient adhesion. Abdul Kareem Jaleel et al. [8] Hard coating such as TiN, TiC and AL2O3 have been used. High-speed machining is constantly increasing in importance. These new techniques can be applied in place of conventional machining methods for manufacturing of various components at low cost or even making entirely new type products, e. g. machined from brittle materials.

B. RAMAMOORTHY et al.[6] 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. The stable and protective oxide surface layer on AlTiN and AlTiON coatings provide an enhanced resistance to high temperature wear. Force difference is observed when using the same type of tools, but with different thermal properties. For example, under the same cutting condition there is force difference between using low CBN content tools coated with TiAIN and CBN-Low coated with TiN/AI2O3/TiCN. This was the case when turning with uncoated CBN-High and CBN-High coated with TiN/AI2O3/TiCN.

Y. C. Chim1 et al. [5] TiN, CrN, TiAlN and AlCrN coatings were deposited by vacuum arc. Their thermal stability and oxidation resistance were investigated after annealing in air at different temperatures (500°C-1000°C). TiAlN and AlCrN showed better oxidation resistance than their binary counter parts TiN and CrN. Cr-based coatings exhibited much better oxidation resistance than Ti-based coatings.

In results of investigations gives that it is beneficial to do heat treatment which helps to increase tool life and other things. But along with heat treatment some Thermochemical processes and PVD or other hard material coating processes also plays much more important role in determination of tool life of tools made of High Speed steel [3,4]. Heat treatments are need to carried out properly for steel, it should be ensured that tempered martensite structure along with dispersive precipitation secures maximum secondary hardness. If tempering is done slightly above this formation of maximum secondary hardness helps to significant increase in ductility. In Thermochemical treatments nitriding in dissolved ammonia shows good improvement in tool life compared to heat treatments. Application of Hard Coatings such as Ti or Cr based such as TiN, TiCN, AlCrN and TiAlN, etc has very high demands as they shows better results in improvement tool life. Also some of the coatings Ti based has good thermal stability such as TiAlSiN, TiAlN, TiN, etc. AlCrN coating has good sliding wear resistance. In such way there are many types of coatings developed nowadays and every coating has his own area of application.

In present paper Tribological analysis of different tool coatings such as TiN, AlTiN and AlCrNis compared with performance of bare HSS material.

II.EXPERIMENTAL APPROACH TRIBOLOGICAL TESTING MACHINE

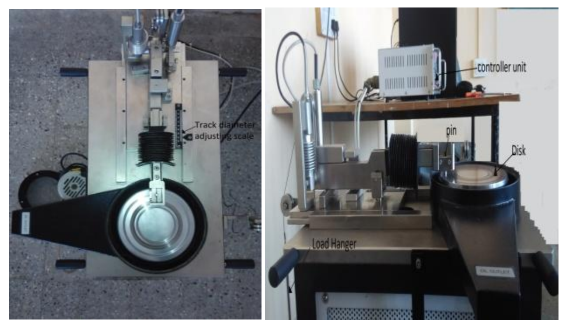
1. PIN-ON-DISC MACHINE

A pin on disc tribometer is the standard equipment used to determine the sliding friction coefficient and wear resistance of surfaces. The tester consists of a stationary "pin" under an applied load in contact with a rotating disc. Either the pin or the disc can be wear- and friction-tested using the pin on disc tester. The pin is usually a sphere however it may be any geometry that simulates the actual application counter surface. A load cell attached to the pin on disc tester is used to measure the evolution of the friction coefficient with sliding distance. Sliding wear of the disc can be measured after the pin on disc test using a simple piece of equipment called a Calo tester.

The pin on disc test has proved particularly useful in providing a simple wear and friction test for low friction coatings on machine components, such as the valve train, particularly in motor sports. These components are now coated with low friction coatings such as diamond-like carbon to reduce energy losses and the requirement for lubricant.

Fig.5.1 shows pin-on-disc tribometer, a flat pin is loaded onto the test sample with a precisely known weight. The pin is mounted on a stiff lever, designed as a frictionless force transducer. The deflection of the highly stiff elastic arm, without parasitic friction, insures a nearly fixed contact point and thus a stable position in the friction track. The friction coefficient is determined during the test by measuring the deflection of the elastic arm. Wear coefficients for the pin and disc material are calculated from the volume of material lost during the test. This simple method facilitates the study of friction and wears behaviour of almost every solid-state material combination with or without lubricant. Furthermore, the control of the test parameters such as speed, contact pressure and varying time allow a close reproduction to the real life conditions of practical wear situations.

It also facilitates study of friction and wear characteristics in sliding contacts under desired conditions. Sliding occurs between the stationary pin and a rotating disc. Normal load, rotational speed, sliding distance and It wear track diameter can be varied to suit the test conditions. Tangential frictional force and wear are monitored with electronic sensors and recorded on PC. These parameters are available as functions of load and speed.



MEASUREMENTS AND OBSERVATIONS

Friction:

Friction is applicable to the power requirements and efficiency of a machine. It is also an indication of the efficacy of a sliding system. Lubricity is the lubricant property that reduces friction. Friction force is measured, observed, and recorded during the run. Pin-on-disk tribometer may give a wavy friction force tracing due to non-uniform surface conditions around the wear track on the disk. In that case a range of values is recorded. A smooth and low friction force tracing is a prediction of effective lubrication. A jagged tracing is indicative of stick-slip, scuffing, distressed sliding, and lubricant failure.

The coefficient of friction, which is reported, is calculated from the observed friction force divided by the applied load.

Wear:

Wear is applicable to the life of a machine's lubricated component. High wear on the tribometer would predict short component life. After the run and disassembly, the undisturbed wear scar on the tip of the pin is examined. After cleaning, the condition of wear scar is observed microscopically. It may be smooth, polished, abraded, or scuffed. Finally, the average diameter is measured. The volume of metal removed from the pin is calculated from an equation given in the ASTM method.

The wear track on the disk is also examined for wear. The track may show very low wear, where only the micro peaks are worn off forming micro plateaus and most of the original grinding marks remaing.

EXPERIMENTAL DESIGN PROCEDURE

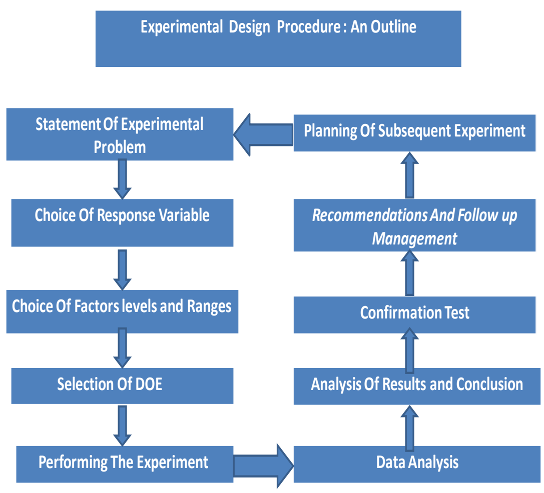


Fig.2 An Outline Of Experimental Design Procedure

The selection of design factors is the important stage for the design of experiments. There are many design factors such as filler content, load, speed, materials selected, sliding velocity etc., which will affect the test results of friction coefficient and wear rate. The key step in Taguchi method is to optimize the process parameter to achieve best quality performance. If the number of process parameter increases, there are lots of experiments have to be conducted to get the optimized parameter. To make the task easy, Taguchi method uses design of orthogonal arrays (OA) to study the process parameter with small number of experiments (Phadke., 1989; Bahadur and Tabor, 1985; Biswas and Satapathy, 2009; Rashmi et al., 2011; Siddharatha et al., 2011; Difallah et al., 2012).

In the present study filler content, normal load, sliding speed is considered as the design parameter. The design parameter with levels is shown in Table 2. In order to study the effect of parameter and the interactions, a pre-designed orthogonal array, L_9 is used in this study considering both the main factor effects and its interactions is chosen for this study.The complete table for L_9 OA is omitted here for brevity.

The additive assumption implies that the individual or main effects of the independent variables (factors) on response parameter are separate. Under this assumption, effect of each factor can be linear, quadratic, or of higher order, but the model assumes that there exists no cross product (interactions) among the individual factors. That means the effect of independent factor A on response parameter does not depend on different level settings of any other independent variable and vice versa.

III. INVESTIGATED COATING MATERIALS

A. TITANIUM NITRIDE COATING (TiN)

Titanium Nitride (TiN) is one of the best of the new ultra-hard coatings for gear cutting tools. Press tools and other engineering tools and parts. The performance of HSS cutting tools can be enhanced by TiN coating that give greater chip removal rates as well as increased tool life. TiN coating virtually eliminates the formation of built-up edge, and also protects the base material fromabrasive wear. TiN can applied to finished precision tools by physical vapour deposition (PVD) and chemical vapour deposition (CVD), which is widely, employed the world over.

Table.1 Properties of TiN

Appearance of coating	Gold-yellow
Micro-hardness (HV 0.05)	2300
COF against Steel (Dry)	0.4
Thermal conductivity	19.2W/ (m·°C)
Melting point	2930 °C
Odour	Odourless
Density	5.40 g/cm^3

Applications

TiN coating is widely used for metal cutting application. The following tools are currently being coated in this field of application resulting in substantial increases in the lifetime. Hob Cutter, Shaper Cutter, Broaches, Cutter, Shaving Cutter, Pinion type Cutter, and Milling Cutter are some of the applications. Another wide field of application is for metal forming tools. Coating of the metal forming tools not only leads to considerable increased lifetime, but frequently improves the quality of the machined work pieces, with a much better surface finish.

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B. TITANIUM ALUMINIUM NITRIDE (TiAlN)

The TiN coating has now been superseded in many machining applications by the TiAlN coating. The exact colour of the TiAlN coating is dependent on the Ti:Al ratio and can range from black to bronze.TiAlN offers superior performance than TiN for a range of metal machining and fabrication applications. This is due to the addition of aluminium, which reacts with the oxygen in the atmosphere to form aluminium oxide on the surface. This increases the operational temperature range of the coating to 800°C compared with 500°C for TiN. This operating temperature has recently been increased by the addition of chromium and yttrium or vanadium to the coating increasing the temperature range to beyond 900°C

Table2. Properties of TiAlN

Appearance	Blackish
Thickness	Typical applications are 2 to 5 microns
COF against Steel (dry)	Less than 0.30
Maximum Service Temperature	1000°C.
Deposition Temperature	Ranges from 200 to 800°C. Standard process is 450°C.

Applications

The high hot hardness and oxidation resistance (the aluminium oxide layer prevents further oxidation) properties of the TiAlN coating mean that it is used in high temperature cutting operations with minimum use of lubricant or dry machining. TiAlN is used quite successfully to machine titanium, aluminium and nickel alloys, stainless steels, alloy steels, Co-Cr-Mo and cast irons. TiAlN is also used to protect dies and moulds such as those in medium and hot forging and extrusion industries.

IV. COATING METHODS

It has always been a wish of mechanical engineers to extend the lifetime of tools, mechanical components or wearing parts, by increasing the "surface hardness" or by reducing the “wear and tear”. Over the last 50 years, many processes have been developed to increase the surface hardness by diffusion and/or coating deposition techniques; each of these techniques were designed to be applied on specific materials and for specific applications. The most popularly used and adopted methods for surface hardening and coating in industries can briefly be mentioned:

A. VARIOUS COATING METHODS USED

- Electrochemical And Chemical Method
    - Hard Chromium (Hard Chrome) Plating
    - Electro Less or Chemical Nickel Plating
- Spray Coatings
- Thermo Chemical Coatings
- CVD (Chemical Vapour Deposition)
- PVD (Physical Vapour Deposition)

1. PVD (PHYSICAL VAPOUR DEPOSITION)

PVD was also known many years before the breakthrough to produce hard, wear resistant coatings (consisting mainly of TiN) took place in the late seventies. Physical Vapour Deposition, or PVD, is a term used to describe a family of coating processes. The most common of these PVD coating processes are evaporation (typically using cathodic arc or electron beam sources), and sputtering (using magnetic enhanced sources or "magnetrons", cylindrical or hollow cathode sources). All of these processes occur in vacuum at working pressure (typically 10-2 to 10-4 mbar) and generally involve bombardment of the substrate to be coated with energetic positively charged ions during the coating process to promote high density. Additionally, reactive gases such as nitrogen, acetylene or oxygen may be introduced into the vacuum chamber during metal deposition to create various compound coating compositions. The result is a very strong bond between the coating and the tooling substrate and tailored physical, structural and tribological properties of the film.

Fig. 4 PVD Vacuum Coating Machine

V. CONCLUSION

In the present work the performance of coated tools in machining hardening steel under dry conditions is studied. The results show that the TiN, TiAlN and AlCrN coated tool perform better as compared to uncoated cutting tool. The effect of Coating is to reduce wear and friction 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. We are studied Design ofExperiment Procedure and see the different coating its applications and various coating process.

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