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Article

Comparative Analysis of Tribological Performance of AlTiN and CrN Coating

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A B S T R A C T

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 Aluminium Titanium Nitrate (AlTiN) and Chromium Nitrate (CrN) that allow contacting surfaces to rub against with reduced friction and wear. Low friction coatings are commonly used to solve tribological problems and in particular problems of fretting. Hence, the use of low friction coatings like AlTiN and CrN 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 the exhibits low friction and can be used for surface coating. Performance of low friction coating is analysed based on parameters such as coefficient of friction and wear rate.

Keywords: Aluminium Titanium Nitrate (AlTiN), Titanium (Ti) Materials, Coefficient

Introduction

Thin hard and soft coatings are used extensively by industry to combat friction and wear in a wide range of machine tools and moving mechanical assemblies' ranging in size from a few micrometers to several millimetres. Most coatings are now produced by vacuum-based deposition techniques. Soft coatings (such as Sn, Ag, MoS2, etc.) are mostly used to control friction in sliding bearing applications where use of liquid lubricants is neither desirable nor practical, while hard coatings are well-suited for controlling wear in a variety of metal-cutting and forming operations as well as rolling, rotating and sliding bearing applications. Among the many hard coatings available today, nitrides and carbides of certain transition metals (such as Ti, Cr, Zr, etc.) are the popular. In most metal-cutting and forming applications, it was found that the extent of improvement in performance and durability is dependent on the mechanical and tribological properties of hard coatings applied to the surface.[1]

The aluminium-rich hard AlTiN coatings have a number of beneficial characteristics. Firstly, they have a favourable combination of hardness and oxidation stability at elevated temperatures. Furthermore, these coatings have improved plasticity and fatigue fracture resistance. Thus during plastic deformation the coating has the ability to dissipate energy during friction. As a result, less energy is present to cause crack initiation and the probability of surface damage is reduced.[2] This is very beneficial for reduction of attrition wear intensity. These coatings also typically have low thermal conductivity, which protects the tool surface from heat transfer.

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 AlTiN, CrN etc. provide overall improved tool life and better machining performance.[3]

Literature Review

Fei Zhou, YuanWang, Feng Liu, Yuedong Meng, Zhendong Dai,The paper titled "Friction and Wear Properties of Duplex MAO/CrN Coatings Sliding Against Si3N4 Ceramic Balls in Air, Water and Oil", by the authors published in 'Journal of wear', states that the Micro-Arc Oxidation (MAO) ceramic coatings exhibit relatively high friction coefficients as sliding against many mating materials. The friction and wear behaviours of the duplex coatings sliding against Si3N4 balls in air, water and oil were investigated using a ball-on-disk tribometer. The wear rate of the duplex coating was determined by non-contact optical profilometer and the wear tracks on the duplex coatings were observed by SEM. The results showed the CrN coatings mainly consisted of Cr, CrN and Cr2N phases. The duplex coatings/Si3N4 tribopair exhibited the highest friction coefficient in air, while displayed the lowest friction coefficient in oil.[4] When the normal load and the sliding speed increased, the friction coefficient in air increased from 0.65 to 0.72, whereas decreased from 0.58 to 0.36 in water and 0.20 to 0.08 in oil. The specific wear rates for the duplex coatings in air were higher than those in oil. In comparison to the MAO coatings, the duplex MAO/CrN coatings displayed excellent tribological properties under the same conditions.

O¨ ztu¨ rka, K.V. Ezirmika, K. Kazmanlıa, M. U¨ rgena, O.L. Eryılmazb, A. Erdemirb, The paper titled "Comparative tribological behaviours of TiN–, CrN– and MoN–Cu nanocomposite coatings"published in'Tribology International' states that the purpose of this study is to investigate comparative tribological behaviours of Cu-doped TiN, CrN, and MoN coatings under a wide range of dry sliding conditions. Tin and CrN coatings have been developed and used by industry in numerous tribological applications including, machining, manufacturing and transportation. In contrast, MoN has attracted very little attention as a tribological coating in the past, despite being much harder than both TiN and CrN. In this paper, we will mainly concentrate on the Cu-doped versions of these coatings whose tribological properties have not yet been fully explored. The results of this study have confirmed that the addition of Cu into TiN, CrN and MoN coatings has indeed modified the grain size and morphology, but had a beneficial effect only on the friction and wear behaviour of MoN. The tribological behaviour of CrN did not change much with the addition of Cu but that of TiN became worse after Cu additions. Raman spectroscopy technique was used to elucidate the structural and chemical natures of the oxide films forming on sliding surfaces of Cu-doped TiN, CrN and MoN films. The differences in the friction and wear behaviour of Cu-doped TiN, CrN, and MoN is fully considered and a mechanistic explanation has been provided using the principles of a crystal chemical model that can relate the lubricity of complex oxides to their ionic potentials.

A. Biksa, K.Yamamoto, G.Dosbaeva, S.C.Veldhuis, G.S.Fox-Rabinovich, A.Elfizy, T.Wagga, L.S. Shuster, The paper titled "Wear behaviour of adaptive nano-multilayered AlTiN / Me_xN PVD coatings during machining of aerospace alloys" by the authors published in 'Tribology International' states that the Machining of aerospace materials is one of the major challenges of modern manufacturing. Application of nano-multilayered AlTiN / Me_xN PVD coatings (where Me_x is a transition metal of V–VI groups of periodic table) to cemented carbide tooling results in a significant tool life improvement under conditions of cutting hard to machine alloys such as Ni-based Inconel 718 super alloy and Ti-based $TiAl_6V_4$ alloy. Micro hardness and coefficient of friction of the coatings were measured during this experiment. Investigations of the coated tool life, wear behaviour, chip formation (chip type and under surface morphology) for cutting tools with nano-multilayered PVD coating were also performed. Morphology of worn tools has been studied using SEM and EDX. This study will show that metallurgical design of the nano-multilayered coating should be tailored to its application. To achieve better tool life when machining Inconel 781, adaptive nano-multilayered AlTiN / MoN coating is recommended, where as a AlTiN/ VN coating is better suited to machining $TiAl_6V_4$ alloy. A driving force behind selecting these coatings was a noticeably lower coefficient of friction at elevated temperatures.[5]

Investigated Coating Materials

Aluminium Titanium Nitrate Coating (AlTiN)

AlTiN is the newest PVD hard coating for carbide/ H.S.S.

tools with the substitution of aluminium for some of the titanium in the coating. AlTiN develops an amorphous Al_2O_3 layer on the surface of the coating at very high temperatures. This allows AlTiN to retain its hardness at higher temperatures than any coating. Thus AlTiN out performs those coatings in application such as high-speed continuous turning operations. Most tool coaters prefer Powder-Metal (PM) AlTiN source for AlTiN coating because they are easier and cheaper to machine for the coatings properties depend greatly on aluminium percentage in the coating. AlTiN has hardness of 300 – 3300 (HK 0.05 on hard metal) with higher roughness of Ra 0.67 to 0.75 in micro mm. It has higher oxidation stability (up to 800°C) than any other coatings. It also gives good ductility and adhesion to be said coating. AlTiN coating can be used for wear protection in applications like interrupted cut, difficult machining materials like Titanium and its alloys/ nickel alloys stainless steel and cast materials.[6]

Table 1.1 Properties of AlTiN

Hardness	300 – 3300 (HK 0.05 on hard metal)
Adhesion strength	excellent
Oxidation Temperature	800 / 900 °C
Friction Coefficient	0.7
Surface roughness	0.6 to 0.7 micro mm
Density	4.2 – 5.8 g/cm^3
Maximum working temperature	750 °C

Applications

- High temperature applications
- Holds sharp edges or corners
- Abrasion and erosion resistance
- Enhances corrosion resistance but does not perfectly encapsulate the part
- Little dimensional impact, perfect for close tolerance part

Chromium Nitrate Coating (CrN)

CrN coatings are characterised by their low stress structure, which permits coating thickness up to 50 microns. Another plus point is the high oxidation stability of CrN. However, adhesion can be slightly poorer than that of TiN depending on the substrate particularly at low coating temperature. On the other hand supported by the higher coating thickness

Table 1.2

Hardness	74 HrC
Coefficient of Friction	0.15 - 0.5
Appearance	Grey
Thickness	5 – 50 microns
Maximum working Temperature	750 °c
Deposition temperature	450 °c
Density	5.5 – 6.49 g/cm3

CrN coatings show much better corrosion resistance than TiN especially in aqueous solutions. The best proof of this is that CrN coatings show much better results in salt spray tests.

If CrN compared to conventional hard chrome plating it is apparent that-

- CrN is twice hard (74 HrC).
- CrN coatings are free from cracks.

Applications

- Higher temperature applications
- Sliding wear applications
- Wear resistance on precision components
- Eliminates galling, fretting, micro welding, seizing and adhesive wear
- Enhances corrosion resistance but does not perfectly encapsulate the part Low Friction.

Coating Materials

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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:

Hard Chromium (Hard Chrome) Plating

Chrome plating is a technique of electroplating a thin layer of chromium onto a metal or plastic object. The chromed layer can be decorative, provide corrosion resistance, ease cleaning procedures, or increase surface hardness, and sometimes for aesthetic purposes a less expensive imitator of chrome will be used.[1]

A component to be chrome plated will generally go through these different stages:

- Degreasing to remove heavy soiling
- Manual cleaning to remove all residual traces of dirt and surface impurities
- Various pretreatments depending on the substrate
- Placement into the chrome plating vat, where it is allowed to warm to solution temperature
- Application of plating current, under which the component is left for the required time to attain thickness

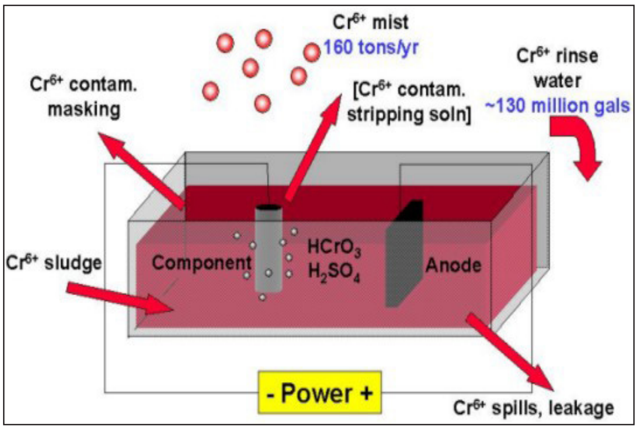

Figure 1.1 Crome Plating

Spray Coatings

Thermal spraying techniques are coating processes in which melted (or heated) materials are sprayed onto a surface. The "feedstock" (coating precursor) is heated by electrical (plasma or arc) or chemical means (combustion flame).Thermal spraying can provide thick coatings (approx. thickness range is 20 micrometers to several mm, depending on the process and feedstock), over a large area at high deposition rate as compared to other coating processes such as electroplating, physical and chemical vapor deposition. Coating materials available for thermal spraying include metals, alloys, ceramics, plastics and composites. They are fed in powder or wire form, heated to a molten or semi-molten state and accelerated towards substrates in the form of micrometer-size particles. Combustion or electrical arc discharge is usually used as the source of energy for thermal spraying. Resulting coatings are made by the accumulation of numerous sprayed particles. The surface may not heat up significantly, allowing the coating of flammable substances.[2]

Several variations of thermal spraying are distinguished:

- Plasma spraying
- Detonation spraying
- Wire arc spraying
- Flame spraying
- High velocity oxy-fuel coating spraying (HVOF)
- Warm spraying
- Cold spraying

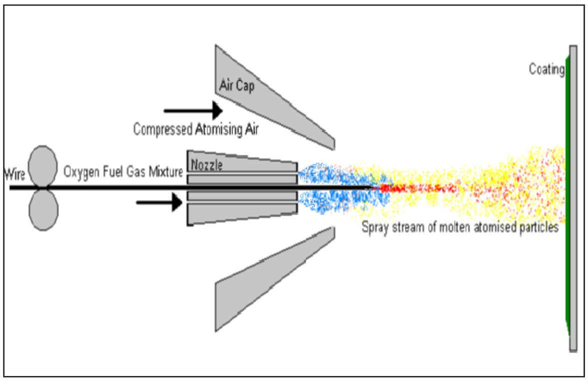

Figure 1.2 Spray Coating

Thermo Chemical Coatings

Totally different processes were developed to thermo chemically harden more particularly the surface of steels. These surface hardening techniques are based on diffusion methods which modify the chemical composition of the surface with hardening species such as carbon, nitrogen or boron. Diffusion methods allow effective hardening of the entire surface of a part, and are generally used when a large number of parts are to be surface hardened. The carburizing and nitriding processes are briefly described hereafter.[6]

Carburizing

- Gas carburizing
- Vacuum carburizing
- Plasma carburizing
- Salt Bath carburizing
- Pack carburizing

Nitriding

Combined Technique

Chemical Vapour Deposition (CVD) involves the dissociation and/or chemical Reactions of gaseous reactants in a activated (heat, light, plasma) environment, followed by the formation of a stable solid product. The deposition involves homogeneous gas phase reactions, which occur in the gas phase, and/or heterogeneous chemical reactions which occur on/near the vicinity of a heated surface leading to the formation of powders or films, respectively.

The first industrial application of this process to produce hard, wear resistant coatings, took place in the late sixties, when thousands of cemented carbide cutting inserts were coated with thin (typically 3 micron) layers of carbides (mainly in Ti), and oxides (mainly of Al). These techniques are achieved by a chemical gas-phase reaction occurring on a heated substrate, depending on controlled temperature, pressure and flow. Chemical and physical phenomena involved in CVD are complex and there are strong relations between chemical reactions and transport processes such as diffusion and convection.[3]

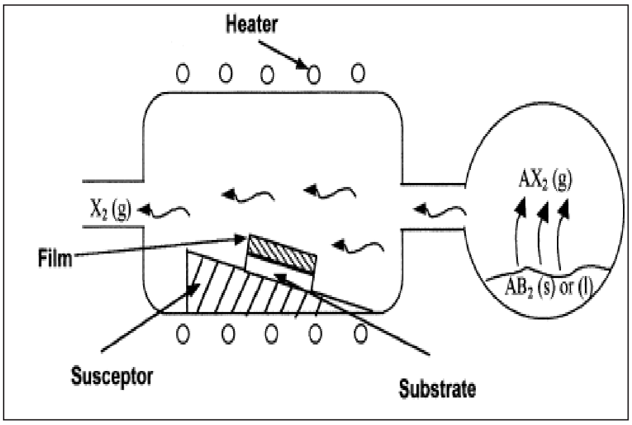

Figure 1.3 CVD Coating

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 (PVD) covers a broad class of vacuum coating processes in which material is physically removed from a source by evaporation or sputtering, transported through a vacuum or partial vacuum by the energy of the vapour particles, and condensed as a film on the surfaces of appropriately placed parts or substrates. Chemical compounds are deposited by either using a similar source material, or by introducing a reactive gas (nitrogen, oxygen, or simple hydrocarbons) containing the desired reactants, which react with metal(s) from the PVD source.[5]

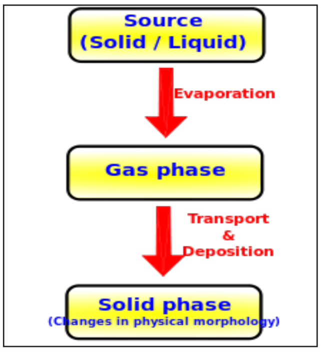

Figure 1.4 PVD Coating

Coating Characteristics

There are in reality many methods to characterize surfaces, coatings or interfaces. Each of these techniques is adapted to a set of conditions related to coating hardness, thickness, substrate nature, etc. Until approximately 10 years ago, there were practically no characterization methods for the evaluation of thin films with typical thickness of 1 to 10 microns. Even now most of these methods are relative. It is not the purpose of the authors to make an exhaustive review of the characterization methods; instead, attention will be given to adhesion, hardness, wear resistance and surface quality characterization of thin CVD and PVD types of coatings. Following are the important coating characteristics considered while selecting a coating for a specific coating.[7]

Coating Adhesion

Coating adhesion is mostly measured using the tape method, pull-off test, shock wave loading method and scratch test. Among these methods, scratch testing has proved to be very reliable. The basic principle is well known, but recent advance, mainly in the loading charge and sensitivity of the sensor, has given significant results in the measure of thin films coatings and even measurement of the adhesion of thin organic films can be achieved, in a reliable manner.

Hardness Measurement of Coatings

Hardness, and today micro hardness testing is a key point for characterization of the quality of coatings. With a background of experiments of nearly 10 years (11-12), micro-indentation testing techniques can provide important information about near surface mechanical and deformation properties of solids. Difficulties of the micro hardness testing methods are connected to the interpretation of curves which are obtained; discrimination between temperature effect (mostly eliminated in new equipment) plastic, elastic deformation, and crack enervations, is often very difficult. Coupling with AFh4 allows in some cases an easier curve in interpretation and combined instruments are showing good possibilities.

Coating Wear Resistance

There too, many techniques can be used. Among them, pin-on-disk systems are rather extensively used in the industry and comparative data is obtainable. In this instrument the pin or the ball is pressed onto the rotating disk by the weight of a fixed known load. The friction coefficient is determined during the test by measuring the deflection of the elastic arm, which is positioning the pin at an almost fixed point. Using a surface profilometer, the disk wear is measured at the end of the test. This test can be performed with lubricants or liquids and/or made under controlled atmosphere. Recent development allows measurement under vacuum or at temperatures up to 800° C for a short period of time.[5]

Coating Surface Quality

Recent advances in Scanning Force Microscopy (SFM or AFM) have shown excellent results in micro-roughness characterization as well as in nano tribological applications. The method consists in scanning a cantilever-stylus over a sample. By recording the deflection of the cantilever beam as a function of its position, three dimensional images of the sample surface with up to atomic scale resolution can be obtained.

Tribological Behaviour of Coatings

Analytical and Experimental Analysis

Analytical analysis is done by using Design Expert 7 Software and experimental analysis by using a Pin-on-disc, friction and wear machine. Pins of Alloy steel (SAE 4140) will be prepared in the sizes of diameter 6mm and length 30mm. Coatings of AlTiN and CrN applied on pins lateral surface. The testing will be done on above materials by varying load, speed and sliding distance. 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. Tangential frictional force and wear are monitored with electronic sensors and recorded on PC.

It appears that the pin-on-disc tests can give considerably useful and informative friction and wear results. Values of coefficient of friction and Wear obtained from test on Pin-on-disc tribometer are input to the Design Expert 7 software. It gives interaction effect of parameters such as load, speed and sliding distance on wear and coefficient of friction. It is methodology based on statistics and other discipline for arriving at an efficient and effective planning of experiments with a view to obtain valid conclusion from the analysis of experimental data. Design of experiments determines the pattern of observations to be made with a minimum of experimental efforts. To be specific Design of experiments (DOE) offers a systematic approach to study the effects of multiple variables / factors on products / process performance by providing a structural set of analysis in a design matrix.

A Tribometer

A tribometer is an instrument that measures friction on a surface. A tribotester is the general name given to a machine or device used to perform tests and simulations of wear, friction and lubrication which are the subject of the study of tribology. Often tribotesters are extremely specific in their function and are fabricated by manufacturers who desire to test and analyze the long-term performance of their products. An example is that of orthopedic implant manufactures who have spent considerable sums of money to develop tribotesters that accurately reproduce the motions and forces that occur in human hip joints so that they can perform accelerated wear tests of their products.

Pin-On-Disc Tribometer

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.

Specifications of Pin on Disc Tribometer

- Pin Size- ø 3 to 12 mm diagonal.
- Disc Size- 160 mm dia. X 8 mm thick.
- Wear Track Diameter (Mean) - ø 5 mm to 70 mm.
- Sliding Speed Range- 12 m/sec.
- Disc Rotation Speed- 80 – 3000 rpm.
- Normal Load-200 N max.
- Friction Force-0-200 N, digital readout, recorder output.
- Wear Measurement Range-4 mm, digital readout, and recorder output.
- Power- 230 V, 15A, 1 Phase, 50 Hz.

Investigated Bare and Coating Materials

Bare (SAE 4140)

Table 1.5Chemical Composition of Bare Materia

Content	Composition
Carbon	0.40%
Silicon	0.25%
Manganese	0.85%
Chromium	1.00%
Molybdenum	0.25%

Applications

- High temperature applications,
- Holds sharp edges or corners,
- Abrasion and erosion resistance,
- Enhances corrosion resistance but does not perfectly encapsulate the part,
- Little dimensional impact, perfect for close tolerance part.

Chromium Nitrate Coating (CrN)

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- CrN is twice hard (74 HrC).
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Table 1.6 Properties of CrN

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Coefficient of Friction	0.15 - 0.5
Appearance	Grey
Thickness	5 – 50 microns
Maximum working Temperature	750 °c
Deposition temperature	450 °c
Density	5.5 – 6.49 g/cm3

Experimental

Procedure for Design of Expert:

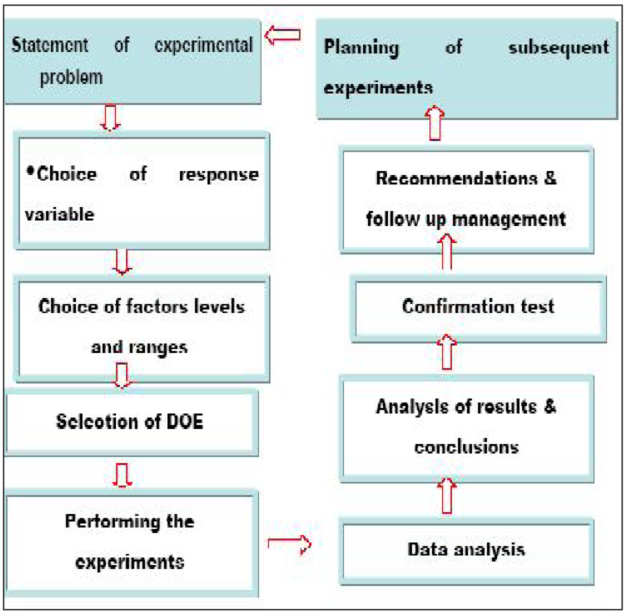
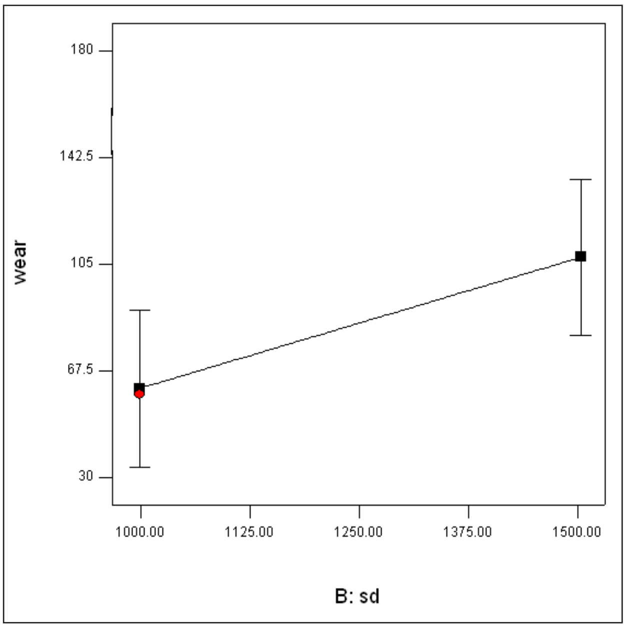


Figure 2.1 Effect of Parameter on Wear and COF Bare Material

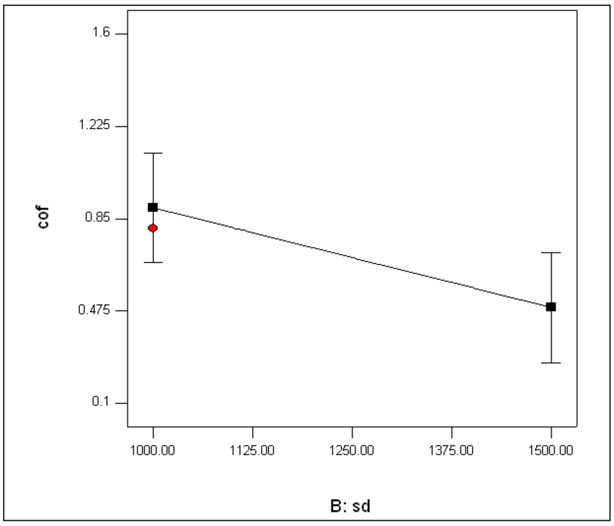
Bare Material



Wear v/s Sliding Distance for Bare Material

One can observe from the Fig. 7.1 that wear increases with the sliding distance. Since it is bare material the wear rate is higher than the coating materials.

Wear=-390.76935-238.32658*Load+0.24884*SD+1.56727*Speed+0.20221*Load*SD-0.064108*Load*Speed-9.89868E-0.04*SD*Speed.



COF v/s Sliding Distance for Bare Material

One can observe from the that COF decreases with the sliding distance.

COF=+4.87818+1.25628*Load-2.27026E-003*SD-7.30825E-003*Speed-1.00491E-003*Load*SD+1.21585E-004*Load*Speed+4.47540E-006*SD*Speed.

AlTiN Material

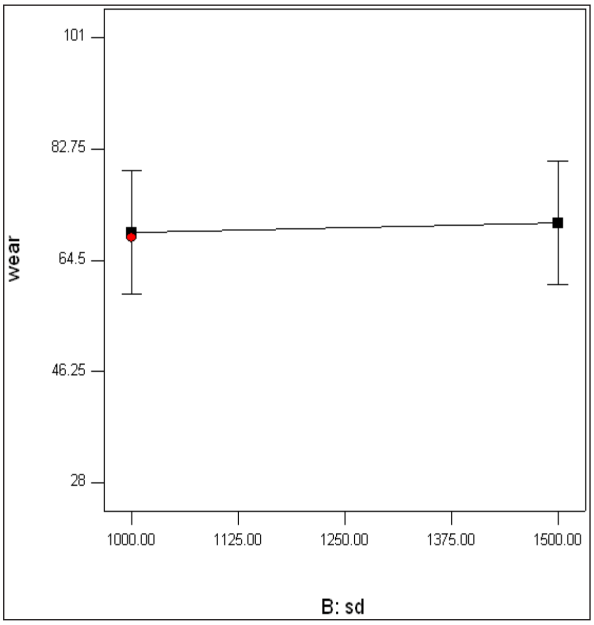
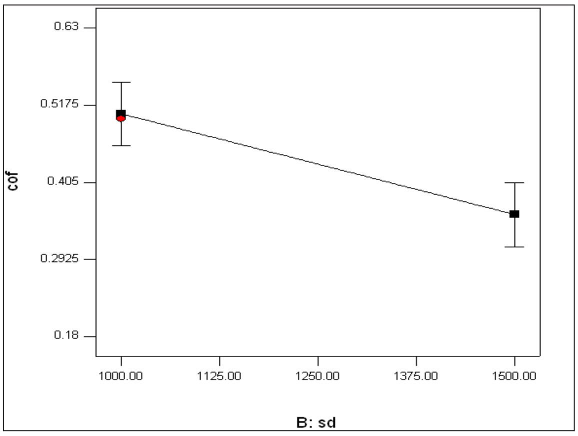


Figure 2.2 Wear v/s Sliding Distance for AlTiN Material

One can observe from the Fig. 7.3 that wear increases with the sliding distance. But the wear rate is very low compare with the bare material.

Wear=+18.09458-66.51301Lload+0.042890*SD+0.20831*Speed+0.043689*Load*SD +0.013014*Load*Speed -1.70807E-004*SD*Speed.



COF v/s Sliding Distance for AlTiN Materia

One can observe from the Figure 7.4, that COF decreases with the slidingdistance.COF=+2.65610+0.25304*Load-1.73566E-003*SD-2.78241E-003*Load*SD+5.51741E-005*Load*Speed+1.98833E-006*SD*Speed.

CrN Material

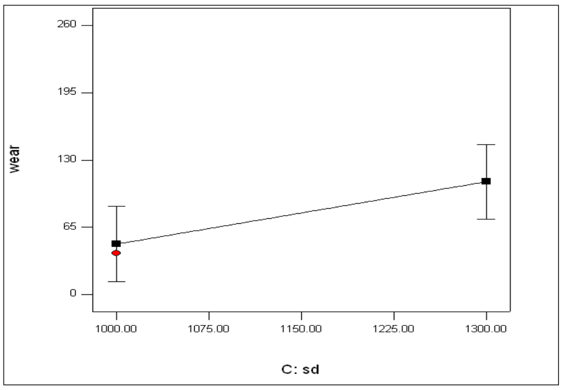


Figure 2.3 Wear v/s Sliding Distance for CrN Material

One can observe from the Fig. 7.5 that wear increases with the sliding distance. But the wear rate is low compare with the bare material.

Wear=+65.32141+358.36089* Load-1.38614*Speed+0.23526*SD+0.031191*Load*speed-0.28151*Load*SD+8.10210E-004*Speed*SD.

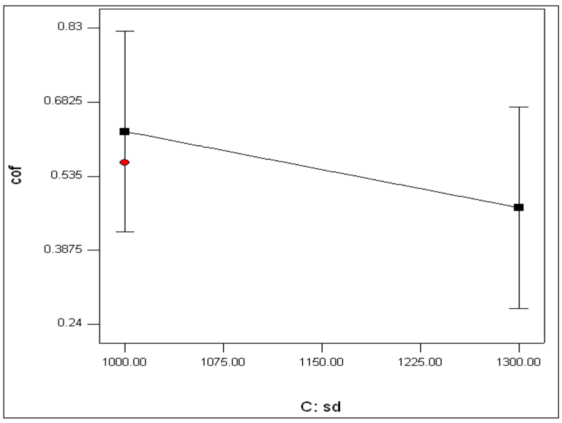


Figure 2.4 COF v/s Sliding Distance for CrN Material

One can observe from the Figure 7.6, that COF decreases with the sliding distance. COF= +0.22378-0.57077*Load+3.13583E-003*Speed-1.71445E-004*SD-1.72552E-004*Load*SD-194402E-006*Speed*SD

Interaction Effect of Parameters on Wear and COF

Bare Material

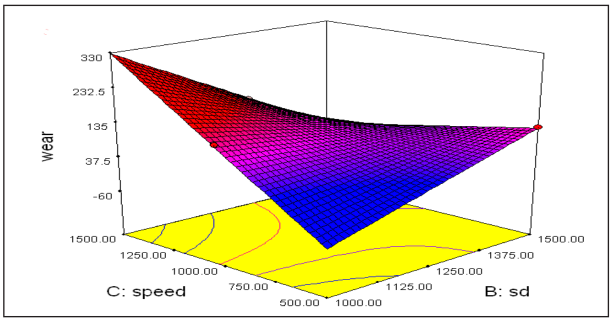


Figure 2.5 Speed and Sliding Distance with Wear for Bare Material

Figure shows the interaction effects of speed and sliding distance with wear rate. One can observe from that wear increases with the sliding distance and speed.

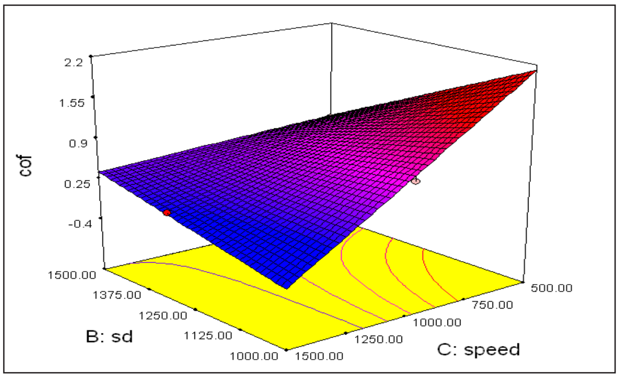


Figure 2.6(a) Speed and Sliding Distance with COF for Bare Material

Figure shows the interaction effects of speed and sliding distance with COF. One can observe from that COF decreases with the sliding distance and speed.

AlTiN Material

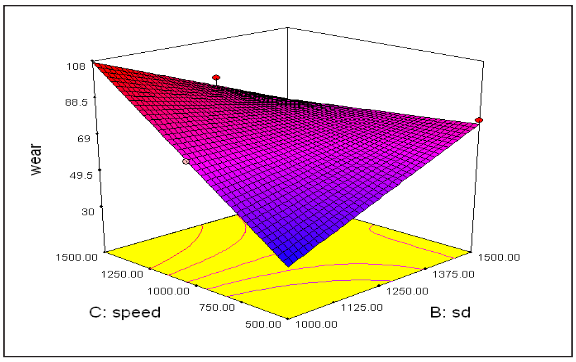


Figure 2.6(b)Speed and Sliding Distance with Wear for AlTiN Material

Figure shows the interaction effects of speed and sliding distance with wear rate. One can observe from that wear increases with the sliding distance and speed.

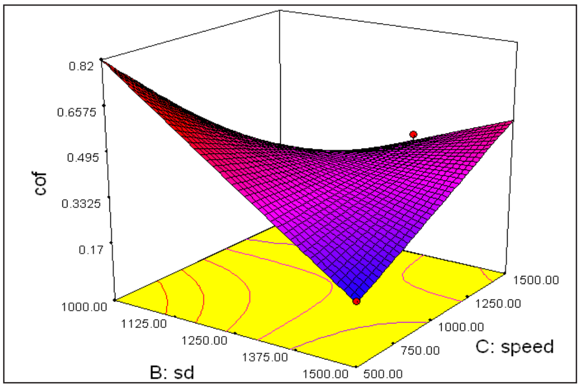


Figure 2.7 Speed and Sliding Distance with COF for AlTiN Material

Figure shows the interaction effects of speed and sliding distance with COF. One can observe from that COF decreases with the sliding distance and speed.

CrN Material

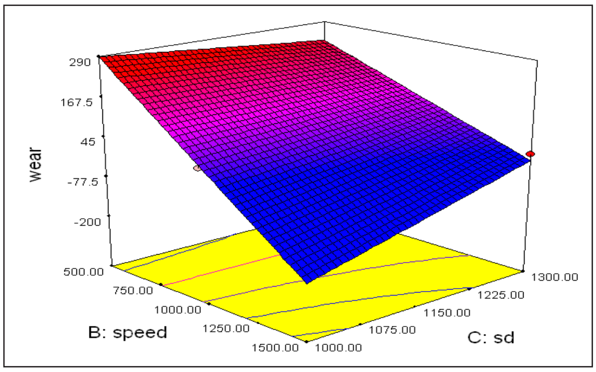


Figure 2.8 Speed and Sliding Distance with Wear for CrN Material

Fig. shows the interaction effects of speed and sliding distance with wear rate. One can observe from that wear increases with the sliding distance and speed.

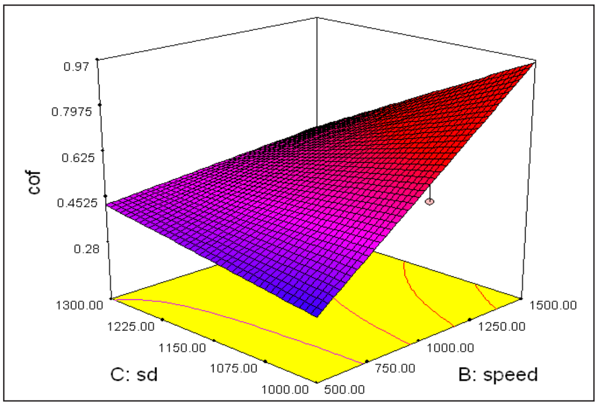


Figure 2.9 Speed and Sliding Distance with COF for CrN material

Figure shows the interaction effects of speed and sliding distance with COF. One can observe from that COF decreases with the sliding distance and speed.

Wear Rate

Bare Material

As sliding distance increases the wear rate increases. The average value of wear rate with increase in sliding distance is observed to be 83.93 microns.

AlTiN

As sliding distance increases the wear rate increases. The average value of wear rate with increase in sliding distance is observed to be 48.59 microns.

CrN

As sliding distance increases the wear rate increases. The average value of wear rate with increase in sliding distance is observed to be 63.41 microns.

Coefficient of Friction

Bare Material

Coefficient of friction decreases with respect to sliding distance. The average value of coefficient of friction with increase in sliding distance is observed to be 0.67.

AlTiN

Coefficient of friction decreases with respect to sliding distance. The average value of coefficient of friction with increase in sliding distance is observed to be 0.42.

CrN

Coefficient of friction decreases with respect to sliding distance. The average value of coefficient of friction with increase in sliding distance is observed to be 0.48.

Conclusion

A comparative study has been made between bare material and coating materials with respect to coefficient of friction and wear rate. The study demonstrated that in all above materials, the bare material gives highest wear rate while AlTiN and CrN give lowest wear rate. Coefficient of Friction of AlTiN and CrN decreases with increase in sliding distance. Coefficient of Friction is lowest for AlTiN and CrN than bare material. These coating are best suited for high temperature applications and also protect bare material from corrosion. Thus, use of surface coatings results in improvement in hardness and surface quality of bare material. Because of such good properties of coatings, it can be effectively use in places where mating parts suffering to high wear such as gears, bearings, cutting tools and dies. The future coating materials can be Multi-layered coating and self-lubricating coating as in spite of high cost they give low wear rate and lowest Coefficient of Friction.

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