Experimental Investigation of Wear Analysis on TiAlN and AlCrN PVD Coatings

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Abstract
Wear takes predominant role in reducing the life time of moving parts in machines having rotating and sliding motion and also the cutting life time of tool materials. Hard wear resistant coatings have been used to increase the wear resistance of these parts. This investigation focuses on the influence of FUTURA NANO(TiAlN) and ALCRONA PRO(AlCrN) coatings on mild steel (ms) material.TiAlN and AlCrN were coated on two different mild steel discs by using physical vapour deposition (PVD) technique. The stainless steel pins are selected as a work piece material. Methods for determining the wear on surfaces can be categorized according to the type of relative movement of the tested material and the applied bodies and the method of contact and its geometry. One of the method is more frequently used for wear on surfaces is the pin on disc method. The wear characteristics were analysed and compared between two different coatings(TiAlN and AlCrN) upon machining the stainless steel pins. The performance parameters were calculated by using coefficient of friction values which were obtained from the pin on disc test. Substantial resistance to wear has been achieved by the coatings.

IndexTerms - FUTURA NANO(TiAlN), ALCRONA PRO(AlCrN), Wear, pin on disc method

I. INTRODUCTION

1.1 INTRODUCTION TO COATING AND WEAR:

Coating of nitrides over the moving parts of machines and tool materials certainly enhances their life and productivity. Titanium Aluminium Nitride and Aluminium Chromium Nitride known for its hardness and high tenacity would be challenging to coat it on a material like Mild Steel(MS). Physical Vapor Deposition (PVD) techniques are widely practiced to coat the nitrides on machine parts and tool materials. Creation of material systems is an avenue thrown open for addressing many engineering problems; enhanced wear performance is one among them. Pin on disc tests are widely conducted in the laboratories to evaluate the wear of sliding contacts between metals. In this work Titanium Aluminium Nitride and Aluminum Chromium Nitride is coated on Mild Steel disc and analyzed the wear characteristics by dry sliding it with Stainless Steel pin.The Co-efficient of friction values were acquired from the experimental setup. These values were the basis to analyze the wear characteristics of the coatings.

1.1 PHYSICAL VAPOUR DEPOSITION (PVD):

It describes a variety of vacuum deposition methods which can be used to produce thin films and coatings. PVD is characterized by a process in which the material goes from a condensed phase to a vapor phase and then back to a thin filmcondensed phase. The most common PVD processes are sputtering and evaporation. PVD is used in the manufacture of items which require thin films for mechanical, optical, chemical or electronic functions. Examples include semiconductor devices such as thin film solar panels, aluminized PET film for food packaging and balloons, and titanium nitride coated cutting tools for metalworking. Besides PVD tools for fabrication, special smaller tools (mainly for scientific purposes) have been developed.

1.2 THIN FILM REQUIREMENTS:

Any deposition method must satisfy certain requirements:

- The deposition must be uniform throughout the wafer
- A very good control is necessary. If we want 1000 nm of the material deposited on the wafer, then the variation must be within one or two percentage. i.e. the thickness of the film after deposition must be at theminimum 980 nm and at the most 1020 nm.
- In the places where trenches or vias are made, the side wall coverage mustbe good. This is explained in the later section

- The material should adhere to the wafer well and should not peel off
- Dust particles should not fall onto the wafer during the deposition process
- The crystal structure of the film deposited must be of sufficient quality because it will affect the properties of the film. For example, when copper isdeposited, we need large grain size since it will result in less electrical resistance.
- If we are depositing alloys, then the composition must be uniformthroughout the process.

CHAPTER 3 WORKING PRINCIPLE

3.1 PHYSICAL VAPOUR DEPOSITION (PVD)

Physical Vapor Deposition (PVD) is a collective set of processes used to deposit thin layers of material, typically in the range of few nanometers to several
micrometers.PVD processes are environmentally friendly vacuum deposition techniques consisting of three fundamental steps.

1. Vaporization of the material from a solid source assisted by high temperature vacuum or gaseous plasma.
2. Transportation of the vapor in vacuum or partial vacuum to the substratesurface.
3. Condensation onto the substrate to generate thin films.

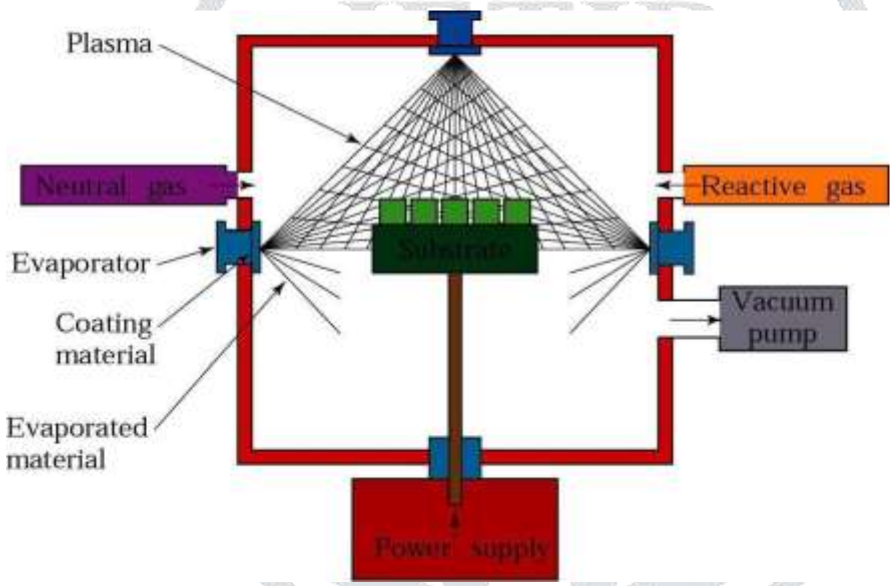

Figure 4.3.1.1 Schematic illustration of the physical deposition process

4.3.1 SPUTTERING:

The PVD equipment will be about 4 ft in height and 4 ft in diameter. The material to be deposited (e.g. titanium) will be at the top, as shown in schematic Fig 3.2

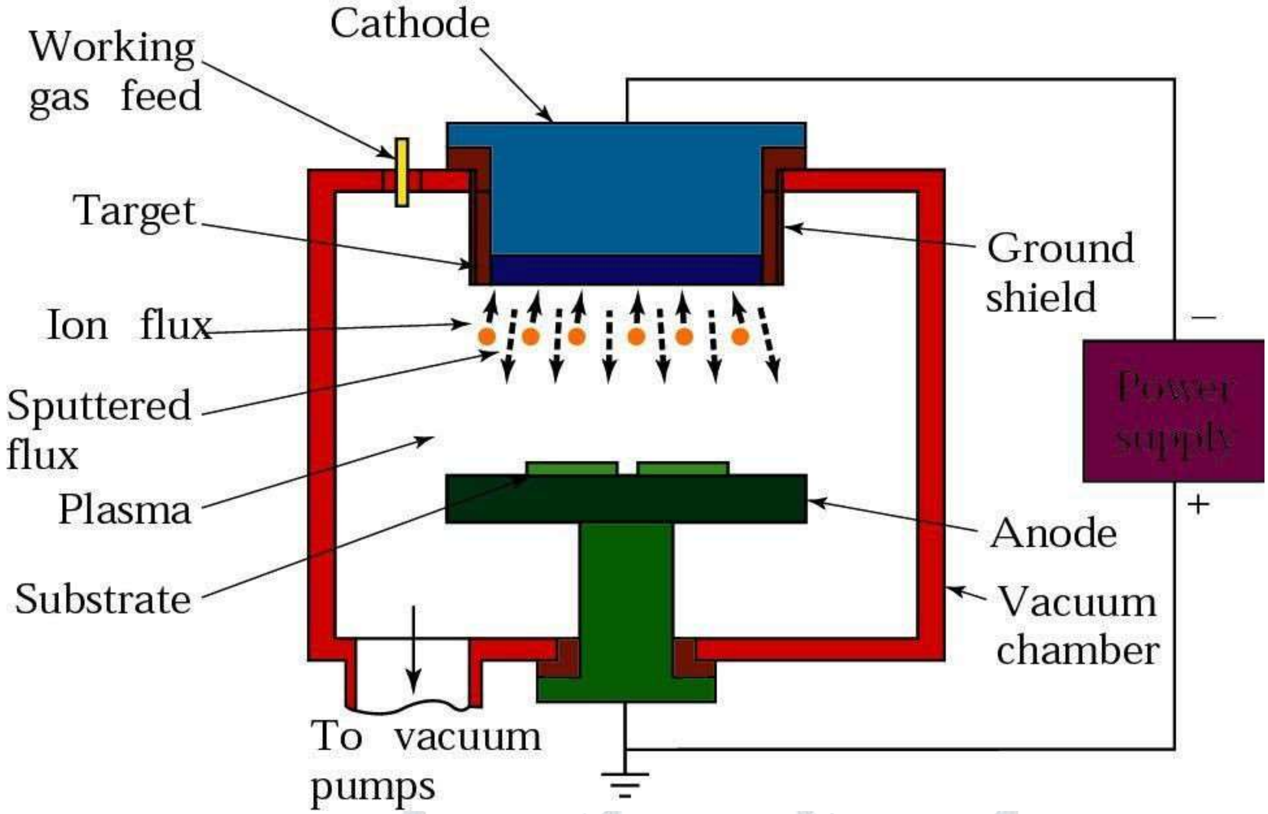

Figure 4.3.2.1 Sputtering process

The tungsten will be in the form of a disc of 1 inch thickness and 5 or 6 inches diameter. At the bottom, silicon wafer will be kept. Apart from these, there will be facilities to allow gases into the chamber and to evacuate the chamber with vacuum pump and electrical connections to apply very high voltage (of the order of 10000 V). The negative plate will be near the tungsten and the positive plate will be near the wafer. Tungsten (or any other material in its place) is called target. Why is it called target? How is it deposited onto the wafer?

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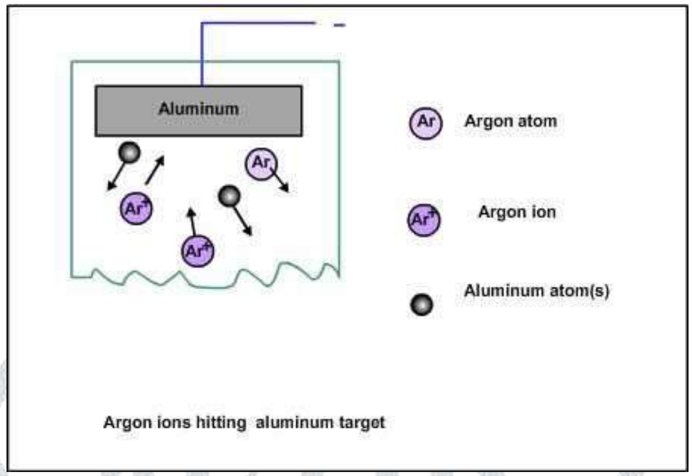
Figure 4.3.2.2 Argon ions hitting the target



Since the argon ions impinge on the target with large force, some of the target atoms will break and come out, as shown in Fig 3.3.3 How many tungsten atoms will come for each argon ion hitting the target? This number is called sputtering yield. It depends on the speed of the argon ions, the angle of the impact and also onthe bond strength of the target. Tungsten is one of the hard materials. If a relativelysoft material such as copper is used as target, then the yield will be higher.

The atoms from the target will come towards the wafer with some force. Not all of them will deposit on the wafer. Some will be deposited (Figure 3. 3.4), while some will bounce back (Figure 3.3.5). Some may even bounce back and remove some of the materials already deposited on the wafer (Figure 3.3.6)

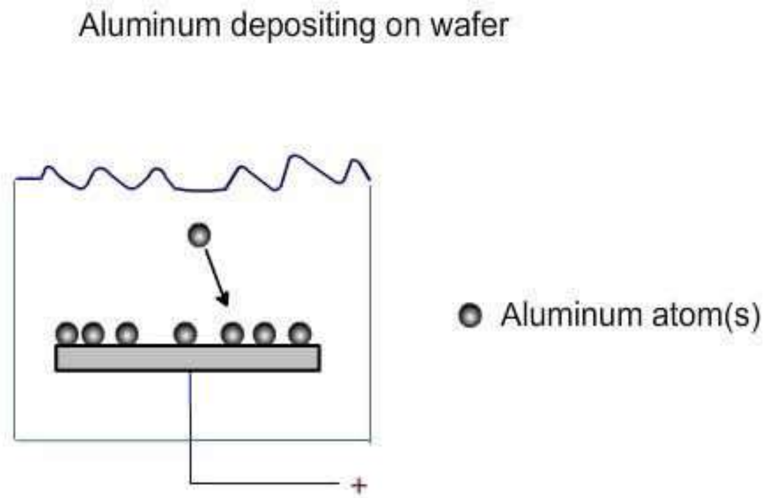


Figure 4.3.2.3 Processes near wafer in a PVD chamber deposition

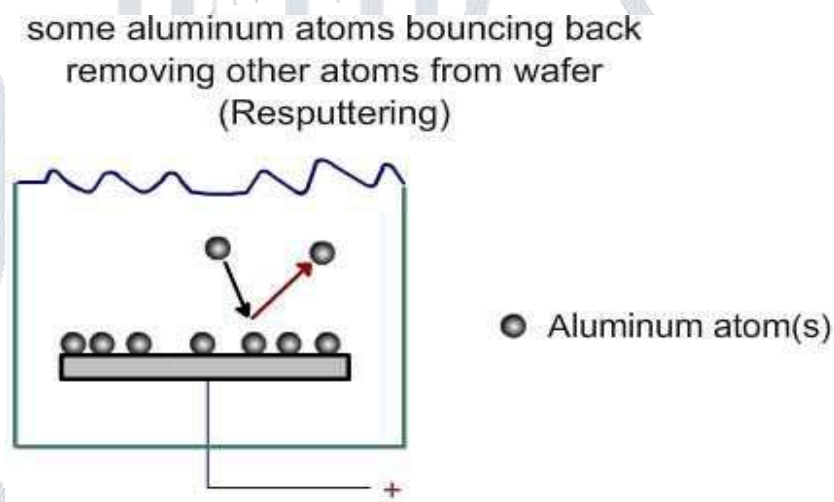


Figure 4.3.2.4 Processes near wafer in a PVD chamber. Bounce back

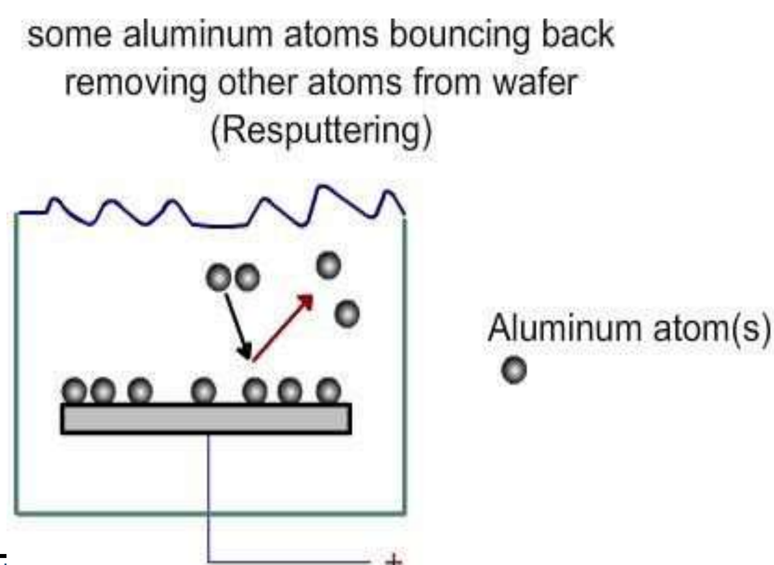


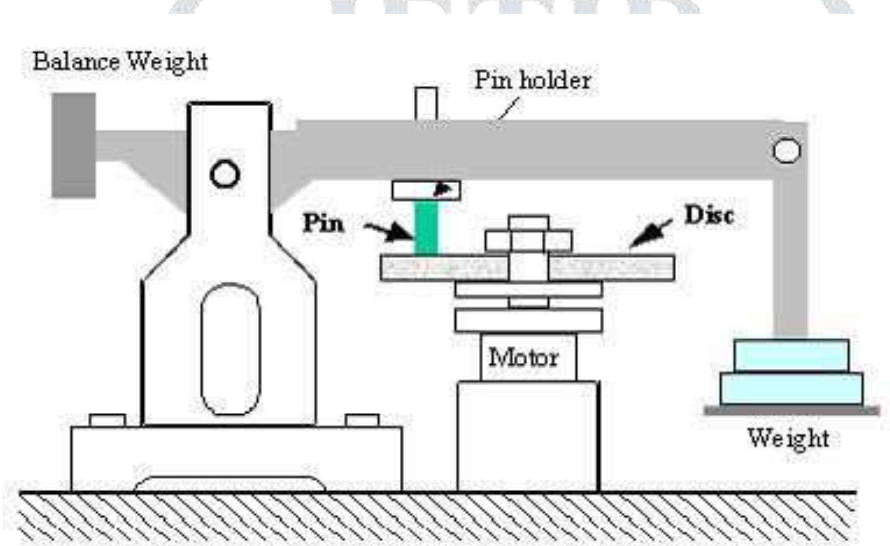
Figure 4.3.2.5 Processes near wafer in a PVD chamber. Resputtering

Among the tungsten atoms that fall on the wafer, the fraction that stick to the waferis called sticking coefficient. If all the atoms that fall on the wafer stick to it, then
the sticking coefficient is one. If none of them stick, then the sticking coefficient is zero. Typically, the sticking coefficient is about 0.7 to 0.8. Certain techniques are used to ensure that the deposition is uniform. The wafer can be rotated slowly. If the wafer is heated, then the deposited layer can soften and move and also stick well.

4.5 APPLICATIONS:

As mentioned previously, PVD coatings are generally used to improve hardness, wear resistance and oxidation resistance. Thus, such coatings are used in a wide range of applications such as: Aerospace, Automotive, Dies and moulds for all manner of material processing, Cutting tools, Firearms, Optics, Watches, Thin films (window tint, food packaging, etc.), Darts barrels, Metals (aluminium, copper, bronze, etc.)

EXPERIMENTAL SETUP AND PROCEDURE



5.1 EXPERIMENTAL SETUP:

A pin on disc tribometer consists of a stationary pin that is normally loaded againsta rotating disc. The pin can have any shape to simulate a specific contact, but cylindrical tips are often used to simplify the contact geometry. The coefficient of friction is determined by the ratio of the frictional force to the loading force on the pin.
The pin on disc test has proved useful in providing a simple wear and friction test for low friction coatings such as diamond-like carbon coatings on valve train components in internal combustion engines.

FIGURE 5.1.1 PIN ON DISC SETUP

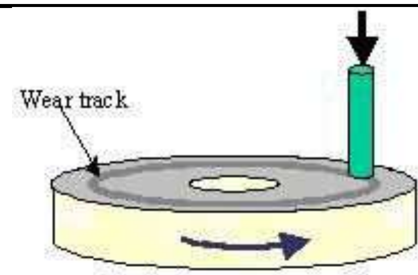
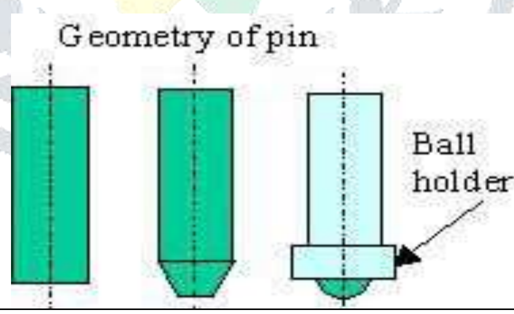


FIGURE 5.1.2 WEAR TESTING AND WEAR MEASUREMENT

FIGURE 5.1.3 GEOMETRY OF PIN

TABLE 5.1.1 PIN ON DISC SPECIFICATION

Diameter	100mm
Thickness	6mm min and 8mm max
Pin diameter	3,4,6,8,10,12,mm
Length	25mm
Wear track diameter	Average 32 mm
Disc speed	200-2000 rpm
Normal load	5mm minimum & 30 mm maximum(insteps of 5N)
Friction force	0- 200 N
Wear range	± 2
Preset diameter	1 min minimum & 9999 min maximum
Power	230 V, 1 Ph, 50Hz, 500VA



Timer	Max 99hrs, 59min , 59 sec
Least count	1 micron

II. EXPERIMENTAL PROCEDURE:

a) Clean the steel disk with acetone to free it from any debris from theearlier usage.
b) Remove the existing loads if any on the machine.
c) Fix the specimen in the pin holder using align key.
d) Note down the track radius.

e) Apply a load of 1Kg in the Pan.
f) Switch on the power of the control unit and set the timer to 5minutes.
g) Set the wear and frictional force to zero.
h) Start the wear testing machine and set RPM to 500.
i) Note down the readings of wear and frictional force at the interval of 20 secondsfor 5 minutes.
j) Tabulate the results and calculate the co-efficient of friction.

OBSERVATION AND TABLE

EXPERIMENTAL VALUES OF FUTURA NANO COATED AND UN COATED MS DISC.				EXPERIMENTAL VALUES OF ALCRNA PRO COATED AND UNCOATED MS DISC			
Time in sec	load in Kg	Coefficient of friction		Time in sec	Load in Kg	Coefficient of friction	
		Coated	Uncoated			Coated	Uncoated
20	1	0.39	0.82	20	1	0.74	0.82
40	1	0.66	0.66	40	1	0.69	0.66
60	1	0.73	0.94	60	1	0.79	0.94
80	1	1.45	0.65	80	1	2.14	0.65
100	1	0.45	0.48	100	1	1.56	0.48
120	1	0.85	0.96	120	1	2.02	0.96
140	1	0.83	1.42	140	1	2.13	1.42
160	1	0.89	1.08	160	1	1.08	1.08
180	1	0.94	1.42	180	1	1.09	1.42
200	1	0.83	0.09	200	1	0.79	0.09
220	1	1.09	0.24	220	1	0.65	0.24
240	1	0.3	0.5	240	1	0.99	0.5
260	1	1.09	1.24	260	1	0.63	1.24
280	1	0.69	0.94	280	1	1.65	0.94
300	1	0.79	0.56	300	1	0.35	0.56
320	1	0.49	0.66	320	1	0.34	0.66
340	1	0.48	0.43	340	1	0.32	0.43

III. RESULTS AND DISCUSSION

The PVD coating on the mild steel disc was carried out successfully and the machining of the stainless steel pin was also carried out. The performance parameters are described below.

1) Wear rate of the fatura nano(TiAlN) coated disc and uncoated disc are$6.567424\times 10^{-9}\, {mm}/{Nm}$ and $6.650231\times 10^{-9}\, {mm}/{Nm}$ respectively.

We could conclude that the wear rate is less for 44uture nano coated disc than uncoated mild steel disc.

Similarly wear rate of the Alcrona pro(AlCrN) coated disc and uncoated disc are $6.559586\times10^{-9}\, {mm}/{Nm}$ and $6.650231\times10^{-9}\, {mm}/{Nm}$

respectively.From
this we can conclude that the wear rate is less for Alcrona pro coated disc than uncoated mild steel disc.

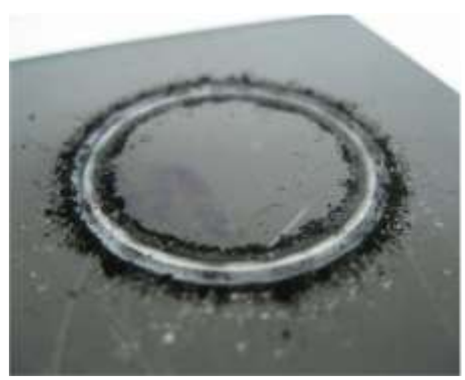
Comparing the wear rate of Futura nano and Alcrona pro coating,the wear rate of fatura nano is slightly higher than the wear rate of Alcrona pro coating.

2) In the case of compressive stress point of view the uncoated mild steel discis having around 606kPa and the fatura nano coated disc is having around 556kPa. So that less compressive stress is induced in the fatura nano coated disc.

Similarly the Alcrona pro coated disc is having its compressive stress around 588kPa.so that less compressive stress is induced in the Alcrona pro coated discthan uncoated mild steel disc.

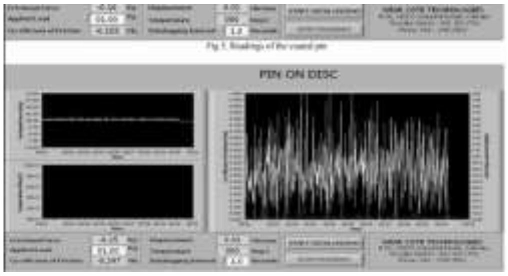
FATURA NANO COATED DISC

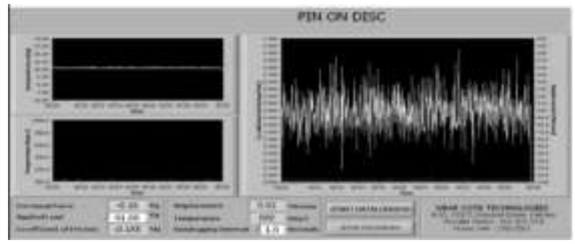
ALCRONA PRO COATED DISC



MILD STEEL

PIN ON DISC WEAR TESTED DISC





Comparing the compressive stress induced in fatura nano and Alcrona pro coating,the compressive stress induced in the Alcrona pro coating is higher than45uture nano coating.

3) And also the Temperature rise in the future nano coated disc (73K) whichis lesser than that of the uncoated mild steel disc (154K).

Similarly the temperature rise in the Alcrona pro coated disc (139K) which is lesser than that of the uncoated mild steel disc (154K).

Comparing the temperature rise of Futura nano and Alcrona pro coating,the temperature rise in Alcrona pro coating is higher than the Futura nano coating.

Thermal stress induced in the Futura nano coating (147Mpa) is lower than the uncoated disc (308Mpa).

Similarly thermal stress induced in the Alcrona pro coating(278Mpa) is lower than the uncoated disc (308Mpa).

Comparing the thermal stress induced in the Futura nano coating and Alcrona pro coating,the thermal stress induced in Alcrona pro coating is higher than the Futura nano coating.

IV. CONCLUSION

From the coating process we can conclude that the coating on the machine parts and tool enhances the properties of the machine parts and tool with increased productivity and increased tool life. It is possible to machine the work piece which is harder than the tool after the coating process.

Since titanium nitride coating supports bio medical field,the favourable properties of titanium nitride(TiN) enhances the surfaces of medical implants.Therefore TiAlN and AlCrN coatings has a wide applications and can be used in various fields to enhance the material surface.

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