Enhancing The Performance Of Sliding Materials By Tantalum Nanocoating

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Abstract

The aim of this work is to obtain Tantalum nano coating on the surface of EN31high chrome steel in the order of 200nm nano size using Sputtering process to improve the tribological properties (mainlywear resistance). Since the material structural properties are increased when combined with functional properties, the coated material will have considerably higher performance. The sample pins of EN3l were subjected to dry sliding wear tests against EN31 steel disc. The coated pins have been tested for its wear and frictional resistance properties using the Pin on disc tribometer.

Key words: Coefficient of Friction, Normal Load, Sliding Speed, Wear Rate.

1.Introduction

Conventional materials will be improved or replaced by nano-scaled, nano-structured components or compounds; materials exclusively build of nano-particles will have significantly higher performance with an overall lower manufacturing cost.

Nano material surface coatings will give rise to new classes of products with added functionality, enhanced energy efficiency as well as better reliability, availability and lifetime. Coatings with anti-stick, low-friction, high-friction, thermal barrier and diffusion barrier properties are some example of coatings being investigated in ongoing projects. The nano coating will enhance the properties of materials such as i) Scratch resistance ii) Abrasion resistance iii) Mechanical properties iv) UV-Protection v) Antimicrobial vi) Self-cleaning vii) Water repellence viii) Conductivity / Antistatic etc.(2)

2. Experimental setup

A pin on disc tribometer consists of a stationary "pin" under an applied load in contact with a rotating disc. Friction is determined by the ratio of the frictional force to the loading force on the pin.In a pin–on–disk, the specimen may have a spherical end or flat end. Normally the load is applied through a lever arm. The wear results are generally reported as volume loss or weight loss. Wear results are usually obtained by conducting a test for a selected sliding distance and for selected values of load and speed. The test specimen is cylindrical in shape and the diameter ranges from 6mm to 10mm.

Fig.1. Pin on disc tribometer apparatus

Initial and final mass of the pin gave the mass loss due to sliding wear. The volume loss due to wear was calculated by the use of corresponding density values of the pin. The wear rate of thecomposite pins was then calculated (ratio of volume loss to sliding distance). After the tests, the worn out surface (tribo-surface) of test specimens were observed by scanning electron microscope (SEM) to study the wear mechanisms. (1)

Preparation of specimens

Pins: In the fabrication of pins, round bars of EN31 alloy steel was utilized. The pins were machined by the conventional methods, i.e., turning and grinding to obtain the desired pin shape with a rounded tip with radius approximately 10mm and length of 20mm.

Discs: The Disc is made up of EN-31 alloy material

The pin on disc test has proved useful in providing a simple wear and friction test for low friction coatings (1).

RF Sputtering:

Fig.2.RF Sputtering Unit

Sputtering is a technology in which the material is released from the source at much lower temperature than evaporation. The substrate is placed in a vacuum chamber with the source material, named a target, and an inert gas (such as argon) is introduced at low pressure (0.76torr). A gas plasma is struck using an RF power source(Forward Power -40watts, Reflected Power -20watts) causing the gas to become ionized. The ions are accelerated towards the surface of the target, causing atoms of the source material to break off from the target in vapour form and condense on all surfaces including the substrate. As for evaporation, the basic principle of sputtering is the same for all sputtering technologies. The differences typically relate to the manner in which the ion bombardment of the target is realized. A schematic diagram of a typical RF sputtering system is shown in the figure above.

In its simplest representation, the phenomenon of sputtering consists of material erosion from a target (pure 99.999%Tantalum) on an atomic scale, and the formation of a thin layer of the extracted material on an EN31 substrate. The process is initiated in a glow discharge produced in a vacuum chamber under pressure-controlled gas flow. Target erosion occurs due to energetic particle bombardment by either reactive or non-reactive ions produced in the discharge.

The use of a radio frequency (RF) generator is essential to maintain the discharge and to avoid charge build-up when sputtering insulating materials such as PZT. The presence of a matching network between the RF generator and the target is necessary in order to optimize the power dissipation in the discharge. The thickness of layer deposition is 200nm approximately.

Scanning electron microscope

The scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. The signals that derive from electron-sample interactions reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample**.** This technique helps to get the scanned image surface at different resolutions**.**

Results & discussion:

The EN31 specimen of diameter 10mm was tested for its wear characteristics on pin on disc tribometer at a load of 20N for 20minutes duration at a sliding distance of 3581.4m. The results are tabulated and given below in table 1.

When the material was tested without coating at 20N, the wear rate is 0.000618mm^3/N-m at a sliding distance of 3581.4m.

When the EN31 material is tested after coating tantalum material on the surface at the nano level of 200nm using RF sputtering unit, the wear rate is 0.000554 mm^3/N-m.The deposition was carried out for more than 3 hours.

Table.1. Wear test results before coating

Load in N	weight before	weight after	Loss in gm	Wear rate (mm3/N-m)
20	12.7465	12.7155	0.031	0.000618

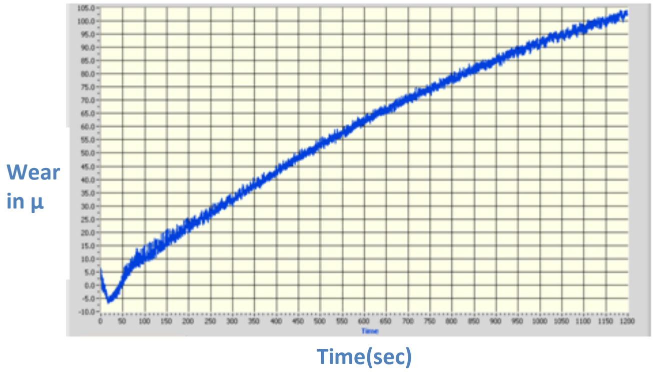

Fig.3.COF Vs Time before coating

In this thesis, the pin and disc are made of EN31 material. If the pin and the disc are made of the same material, the amount of wear will be dominated by the pin, whichever is rotating. The wear of the disc is negligible. (7)

Then the coated material was tested for its wear properties at 20N for the same time period. The results obtained were tabulated and given above in fig.3.

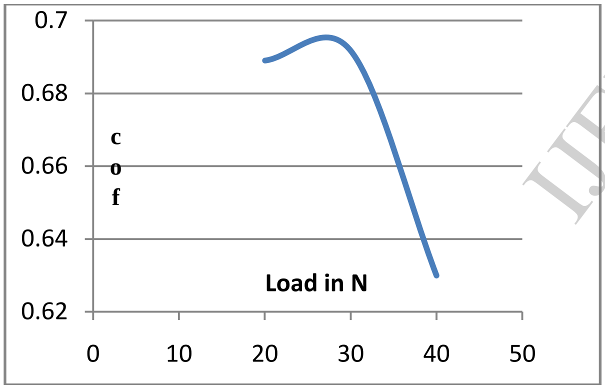

Fig.4. wear characteristics at various loads

The frictional coefficient is gradually increased till the load is 30N and this is decreased suddenly after 30N. At 40N, this is understood as shown in the above fig.4.

The wear rate is considerably decreased and it is 10.3% reduction at a load of 20N.The amount of wear loss is very much decreased after coating. This was found by comparing the EN-31 material before coating and after coating wear loss test.

Table.2. Wear test results after coating

Load in N	weight before	weight after	Loss in gm	Wear rate (mm3/N-m)
20	12.5118	12.484	0.0278	0.000554
30	13.0186	12.9478	0.0708	0.000941
40	12.6554	12.5426	0.1128	0.001125

SEM analysis:

The scanned image surface of the worn out specimen at the load of 20N is consisting of more groove linings which indicates adhesion strength of the material is very less when it subjected to higher loads. Thus, it might be reasonable to conclude that at higher sliding speeds, an increased plastic deformation of the matrix leads to a transition from cutting to ploughing or wedge formation during abrasive. Material is displaced on either side of the abrasion groove without being removed. While in wedge forming, tiny wedge shaped fragments are worn only during the initial contact with an abrasive particle

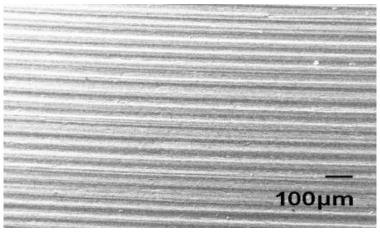

Fig.5. Before Coating

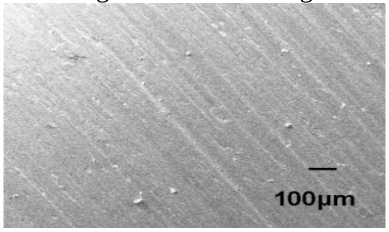

Fig.6.AfterCoating

The above scanned image obtained after tantalum nano coating of EN31 material shows the very less thickness grove linings present. The adhesion strength of material increases after coating the material at the rate of 200nm. (1)

Conclusion:

The adherence of the coating to the substrate is of major concern. The bonding mechanism operative between the coating and substrate can be classified into three categories: mechanical, physical and chemical. In the present investigation it is noted that, invariably in all cases the interface bond strength increases. And that is why the linings in the SEM image are very narrow after coating.

Tantalum coatings seem to be good choice to use as protective hard coatings against wear in sliding applications, especially if very low friction is required. It was found that nearly stoichiometric tantalum coatings performed better tribologically than the others comparatively.

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