Journal of Manufacturing Engineering, June, 2017, Vol. 12, Issue. 2, pp 99-102

TRIBOLOGICAL EVALUATION OF WEAR RESISTANT PVD COATINGS

***Sivarajan S[1] and Padmanabhan R[2]**

School of Mechanical & Building Sciences, VIT University, Chennai,India.

ABSTRACT

Physical Vapor Deposition (PVD) coatings have a thickness in the micro range and improve the tribological properties of the tool material enormously. For the enhancement of surfaces for wear resistant applications, two important PVD processes namely arc process and sputtering are widely used. In this work, AISI D2 tool steel is taken as substrate for evaluation. Three samples are coated with TiN,TiAlN and AlCrN by arc deposition process. Friction and wear tests were conducted on a Pin on Disc apparatus as per ASTM G99 standardThe pins were made with diameter 10 mm and length 32 mm. The pins were heat treated to 53HRC and ground to Ra value of 0.1μm.A tip with 5 mm radius was provided on one end of the pin.D3 steel was taken as counter material (disc). The normal load F was taken as 30 N and sliding speed v=0.3m/sec.The experiments were conducted at dry contact conditions. From the results, it is concluded that TiAlN coatings can be an excellent choice to modify friction behavior and improve wear resistance of tool material.

Key words: Friction, PVD coatings, Wear resistance.

1. Introduction

Engineering environments are usually complex, combining loading with chemical and physical degradation to the surface of the part. Surface wear damage is a phenomenon which effects how a part will last in service. Lubrication in tribological applications minimizes friction and wear, however conventional liquid lubricants fail under extreme conditions, namely low pressure, oxidative or corrosive environments, high speeds and high loads. Surface coatings can help deal with these circumstances. It is important to understand the physical and chemical make up of the applied surfaces, to design quality components which, yield high service lives.

Much tribological research, involves the minimization of friction and wear experienced by materials in service. Effective lubrication between moving surfaces considerably reduces friction and therefore wear. Another approach is to surface harden components. Nitriding steel with an ammonia and nitrogen-hydrogen flame mixture, causes an improvement in surface hardness. Diffusion methods such as carburizing, carbonitriding, nitrocarburizing, boriding and aluminizing, are also used to harden materials, however this process is time consuming.

Bulk materials, (ferrous and non-ferrous metals, alloys, ceramics and cermets), can be modified by alloying, mixing and coating to achieve adequate resistance to wear, corrosion and friction. Ceramics and cermets appear to be ideal wear-resistant materials, and suit many tribological applications provided that their strength and toughness are acceptable. Coating less wear resistive component materials with that of a high resistive material, offers an ideal method of surface protection.

Physical Vapor Deposition (PVD) coatings have a thickness in the micro range and improve the tool life and performance enormously. For the enhancement of surfaces in different application areas, two important PVD processes namely arc process and sputtering are widely used. The PVD process forms the coating through condensing mostly metallic materials in combination with gases, such as nitrogen. The base materials are converted from the solid state to the gaseous state and ionized by exposure to thermal energy, as in the arc process, or by kinetic energy, as in the sputtering process. The deposition of hard materials takes places in an evacuated vacuum chamber at a temperature range from between 200°C and 650°C. Coatings generated with a sputtering process are characterized by very smooth surfaces while coatings deposited with the arc process show excellent adhesion and higher surface hardness. Coating properties such as wear resistance, low friction, oxidation resistance,

**Corresponding Author - E- mail: sivarajan.s@vit.ac.in*

minimizing cold welding etc., cater to the main demands in forming industries.

M.A. AL-Bukhaiti et al developed a multilayer Ti/TiAlN/TiAlCN PVD Coatings by a industrial magnetron sputtering device. The coatings exhibited superior tribological and mechanical properties when compared with uncoated AISI H 11 hot work tool steel [1]. Liu Aihua et al deposited TiN,TiAlN,CrAlN and AlTiN on cemented carbide by cathode arc evaporation technique. Friction and wear properties were evaluated on ball on disc apparatus with SiC as counter material and concluded that TiAlN coatings possessed perfect tribological properties when compared with other coatings [2]. An innovative lubricant in the form of

Molybdenum Disulfide nanotubes can be used to reduce the coefficient of friction and improve wear behavior in hard PVD coatings [3].

TiN,CrN and DLC PVD coatings were applied to titanium Ti-6Al-4V substrate and their tribological properties were investigated .The results revealed that DLC coated Ti-4Al-4V and aluminum bronze exhibited higher wear resistance when compared with other coatings The selection of right combination of both counter materials(tribological pair) plays an important role in the estimation of friction coefficient in friction and wear test.

Eleonora Santecchia reviewed the performance of various titanium nitride based coatings developed in the last decade [4]. It has been reported that TiAlN coatings were more favorable than TiN coatings for applications involving higher sliding speeds. The wear characteristics of hard PVD coatings are strongly influenced by substrate, deposition technique, temperature, counter body properties, applied load and testing speed. In this work, the effect of PVD TiN, TiAlN and AlCrN coatings on D2 steel were investigated [5].

B. Podgornik et al examined the influence of the coating type (film composition) and work material on the friction coefficient [6]. Five different PVD coatings: TiN, TiB2, VN, TaC, DLC were compared in terms of galling properties when applied on forming tool steel and slide against stainless steel. The tribological properties were investigated in a load-scanning rig with a normal load gradually increased under dry conditions.

C. Donnet et all examined the dependence of friction and wear of PVD DLC coatings on environmental conditions and the nature of the coating as determined by the deposition process [7]. Most DLC films contain a significant amount of hydrogen, depending on the precursor material and deposition process. For varied deposition method, the hydrogen concentration ranges from less than 10% to about 50%. Doping elements such silicon, fluorine, nitrogen and various metals may be incorporated in the film structure.

PVD CrN coatings offer high thermal stability and oxidation resistance, high corrosion resistance, high wear resistance and a low adhesion to some engineering work materials. Furthermore, the relatively low intrinsic stress state and the relatively low deposition temperature make it possible to deposit relatively thick CrN coatings on most steels without any risk for thermal softening. It is demonstrated how CrN coating results in high friction when sliding against both Zn and 55%AlZn.

2. EXPERIMENTAL PROCEDURE

2.1Sample Preparation

The material(pin) investigated in this study was D2 steel with a composition of C 1.4 % Cr 12% Co 0.8 % Mo 0.7% S 0.03% Si 0.6% V 1.1 % Ni 0.25% and rest Fe. The pins were made with diameter 10 mm and length 32 mm. The pins were heat treated to 53HRC and ground to Ra value of 0.1µm.A tip with a radius of 5 mm was provided on one end of the pin. The pin specimens were prepared as per ASTM G99 standard.

2.2 PVD Coatings

One pin was coated with TiN(BALINIT A)The next pin was coated with TiAlN and the third one with AlCrN. All the PVD Coatings were carried out at Oerlikon Balzers Ltd, Chennai.

2.3 Friction and Wear Test

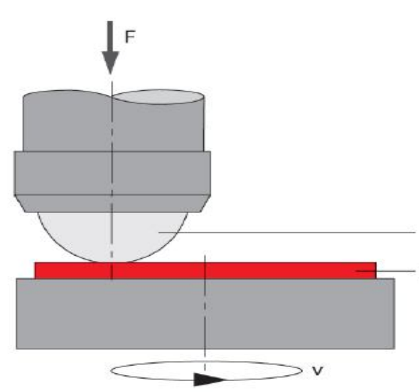

Fig. 1 Principle of Pin on disc testing

In order to investigate the influence of PVD coatings on the tribological conditions friction and wear tests were performed using pin on disc apparatus according to ASTM G99 standard .Before the friction and wear test the coated pins and the disc are ultrasonically cleaned in acetone and then dried in the air. Dry friction and sliding wear tests were conducted in ambient air at room temperature and relative humidity of 45%. In this test, the pin specimen is pressed against the revolving disc at a specified load by means of arm or lever and attached weights. During the test, the friction force was steadily measured, monitored continuously through a data acquisition system, which allowed the calculation of coefficient of friction through the tests.The normal load F was taken as 30 N and sliding speed v=0.3m/sec.The experiments were conducted at dry contact conditions. The output of the friction and wear test is the evolution of coefficient of friction and wear rate as a function of time. The Vickershardness of the specimen was measured by Vickers micro hardness testing machine manufactured by SHIMADZU (Model: HMV-G). The resolution was 0.01 µm and load used was 100 grams. The duration of the load applied was 10 seconds. Three sets of readings were taken to ensure consistency in results.

3. RESULTS AND DISCUSSION

The variation of friction coefficient as function of time for the TiN,TiAlN ,CrAlN coated D2 steel and uncoated D2 steel against D3 steel at room temperature and dry contact, normal load of 30 N and sliding speed of 0.3 m/sec are shown in Fig 2. The evaluation of friction coefficient with time of all the friction curves showed two different stages namely initial and steady stage.

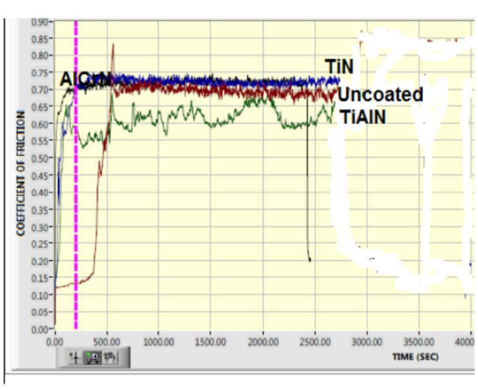

Fig. 2 Variation of friction coefficient with time

During the first 100 seconds the friction coefficient was found starting at a low level of 0.2 for uncoated D2 steel samples whereas the friction coefficient values were found at a range of 0.5 to 0.7 for the three coated D2 steel samples.. The high value of friction coefficient in the coated D2 samples is due to the coating defect breakdown during the initial rubbing cycles and the cracking of the roughness tips in both pin and disc materials.

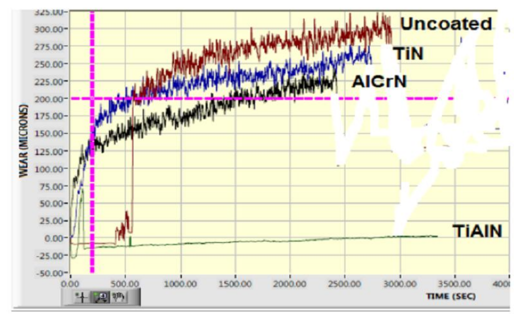

Fig. 3 Variation of Wear rate with Time

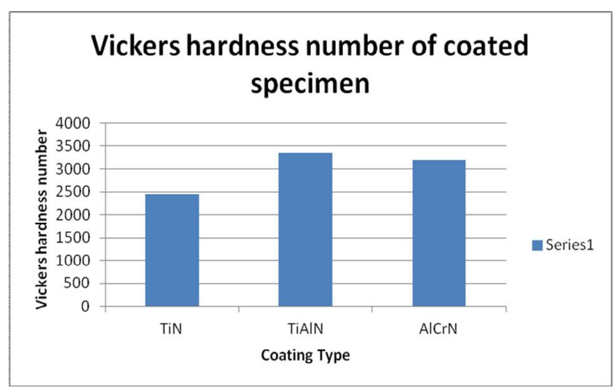

Fig 4.Vickers Hardness number of coated samples

After the initial stage period of 500 seconds the coefficient of friction reached a steady value of around 0.7 for uncoated D2 steel sample. After a period of 500 seconds the friction value reached a steady value of 0.7 for TiN coated D2 steel sample. The test has to be stopped after 2600 second due to cold welding of pin and disc (adhesive wear or seizure).AlCrN coated D2 steel also exhibited the same behavior as TiN sample and the experiment has to be stopped due to seizure after 2600 seconds. Normally D2 steel is tempered at 220° C to improve the mechanical properties. For coatings to be successful the final heat treatment temperature of substrate should be higher than the coating temperature. The coating temperature for TiN and AlCrN is 450 °C.Since the coating temperature is higher than that of heat treatment temperature, the

TiN and AlCrN coated D2 steel samples seized during the friction and wear test. Since the coating temperature of TiAlN is 200 ° C and D2 steel is tempered at more than 200° C the TiAlN coated sample was able give relatively low friction coefficient values. Moreover it was possible to continue the experiments even after 2600 seconds. During the steady state sliding period, it was obviously observed that in case of TiAlN coated D2 steel sample, the friction curve is not smooth and coefficient of friction fluctuates significantly. This indicates that debris of both worn TiAlN coated D2 steel and D3 counterparts are produced due to the detachment of particles from the counterfaces as a result of sliding wear.

The fig 3 shows the variation of wear rate with time for coated and uncoated D2 steel sample against D3 steel sample. From these curves it is clear that under normal load conditions the wear rate increases with time for uncoated D2 steel, TiN coated and AlCrN coated D2 steel. The wear rate is negligible in case of TiAlN coated D2 steel.

Fig.4 shows the Vickers hardness number of PVD coating. The micro hardness values of PVD coated specimen indicate that PVD coated specimen has the potential to offer good wear resistance to D2 steel by increasing its hardness. The improvement in the hardness of TiAlN coated specimen was due to the presence of TiN with Al content and it can be considered as a sign of wear resistance improvement. Apart from good wear resistance, the PVD coatings will reduce mechanical material fatigue of AISI D2 steel.

4. CONCLUSION

TiAlN coatings exhibit good wear resistance, high hardness and low friction when compared with TiN and AlCrN coatings. TiAlN coatings can be an excellent choice to modify friction behavior and improve wear resistance of D2 steel used in sheet metal forming dies and punches.

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