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Tribological Behaviour of AISI 304 Steel on Electrodeposited Hard Chrome Coated Steel

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Abstract: In day to day life, wear and friction plays vital role in the energy consumption including various mechanical operations. Various measures have been adopted to prevent the wear and friction including such as coatings etc. The Electrode deposited hard chrome coating is widely used in the field of aircraft, automotive, manufacturing and mechanical industries and it is well known fact that the hard chrome electroplating provides protection against wear and friction. This paper investigates the tribological characteristics of hard chrome deposited on AISI 204 steel Disc having corrosion resistance and wear resistance properties during sliding against AISI 304 steel pin under dry condition and at room temperature. The test was carried out on pin on disc tribometer under three different loads ranging from 5N to 15N with sliding speed of 1.25m/sec,1.57m/sec, 1.88m/sec and sliding distance of 500m, 750m and 1000m respectively. The result revealed that variation of load and sliding distance is the most prominent factor affecting the weight loss & coefficient of friction.

Keywords: Chrome; Wear; Coating; Abrasion; Steel; Tribology

1. Introduction

Tribology is a multifaceted approach which gives information related to mechanical engineering, chemical engineering, material sciences, and several more. Wear is defined as removal of layers of material from solid surface. Wear is unfavorable because it leads to friction and leads to breakdown of bodies. Abrasive, adhesive, corrosive, erosive, fatigue and fretting wear are the different types of wear. The frictional force is directly proportional to surface roughness and the load. As load and unevenness in layer of materials increases, friction also increases. Surface engineering is a flexible solution to resolve the tribological complexities which comprises deposition and surface treatment. Coating is frequently used procedure to lessen the wear. It decreased the effect of friction coefficient, enhances the surface strengthens, change the surface chemistry and induce the compressive stresses. Different type of coating is done to minimize the friction and wear of specimens. Electrode facing is another term used for electrochemical deposition.

Hard chromium coating is applied in different sector of engineering such as manufacturing companies, aero engineering and automobile factories. In the mixed and boundary lubrication environment the crack initiation enhances the surface ability and surface having grooves, pits and asperities manipulates the tribological characteristics. Many authors have performed worked on the study of tribological properties of various coatings like, Syed et.al [1)]experimented under wet lubrication system of EP-PAO10 increases the load bearing capacity up to 12 times at load of 240N as comparison of dry sliding system. The addition of EP additive in base oil also achieves the COF of 0.15 with a reduction of 74.1% and also reduces the wear up to 51.8% as comparison to the dry sliding condition. Kalyan et.al [2)] showed that tribological behavior of CFUMS system deposited CrXN having more abrasive wear to the balls of AISI 52100 steel as compared to the pin on disc test and HFRR test. The friction and ball wear coefficients was different in both Pin on disc test and HFRR test than the IBAD coating test. Sosiati et al.[3)] conducted a study on how the fiber volume content affects the mechanical properties of a composite material. Dubey et al. [4] experimented on aluminum composite and studied the wear of the workpiece material. The deviation of 8.65% is reported from predicted value. Fedrizzi et.al [5] found that the nanoparticles addition in the conventional powder may improve the wear behavior because the nanoparticle decreases the contact porosity, decreases the surface roughness and provided equally division of CrC in the metal composite. The result also showed that the HC facing degradation in steel primarily relied on adhesive wear mechanisms due to the presence of a substantial ceramic module in the composite facing, which mitigated oxidation degradation

Biberger et.al [6] showed that the originated compressive stress diminished the wear rate by reducing the metal atoms activity and the wear and friction properties induced in hard chrome plating having different stress profile and easy to recognize. Ismaiel et al. [7] performed fatigue analysis of composite used in wind turbine and found that the blade is not influenced by resonance. Bozyazi et.al [8] revealed that the CrN performed better wear and friction properties than Hard Chrome under wet condition and due to lower feed rates the wear depth of hard chrome and PVD CrN could not be determined at room condition and to enhance the wear resistant properties and decrease the friction the brushed CrN played an awfully important function. Sharma et al. [9] studied the tribological impact on hybrid nanofluids in comparison to alumina nanofluids. The hybrid nanofluids resulted in enhanced properties in terms of surface finish. Srisattayakul et.al [10] showed that the MoC-HC and MoCN-HC and MoN-HC, MoC-HC implies statistically non-significant variances in the wear rates of chromium plated steel which were not greater than other facing combinations. Amoush et.al [11] revealed that the weight loss from the uncoated part was higher than the faced one which was measured by weight measurements technique after sliding wear test. The Cr faced layer during the lubrication exhibit more wear resistances as compared to the uncoated steel. The coating thickness also enhances the material loss resistances and decreases the COF. Singh et.al [12] observed that by increasing the value of load the wear of pin was increased and COF was also increased. The wear of disc showed the self- lubricant characteristics. The result also showed that the on increasing the reciprocating speed the wear and COF was increased and the wear resistance of HC coating was increased. Rahman et al. [13] emphasized on germanium structure and studied the honeycomb structure at different annealing temperature. Darbeida et.al [14] worked on dry sliding condition and suggested that the best wear resistance observed in a customary weight of 10N and the pre occurrence cracks or friction fatigue doesn't have any negative impact on the wear life which is improved in the case of lubricated condition environment. Han et.al [15] result showed that the wear characteristics of CrNr steel and CrNrCr steel was better than the Cr coated steel and the internal change in length of the CrNr coated steel shows maximum at the interface of disc and ball but the internal change in length was minimum for the contact surface of disc and ball. Dubey et al. [16] compared the lubrication and cooling effect in minimum quantity lubrication, cryogenic cooling, air cooling etc. Minimum quantity lubrication was found to be effective than other techniques. Maurya et al. [17] experimented on composite and tested the properties on altering the percentage of silicon carbide. At 8% of SiC maximum tensile strength was reported. Podgornik et.al [18] observed that the pre coated specimen under same condition exhibit the more wear and higher value of COF as compared to the post coated specimen. The post polishing improved the tribological characteristics of HC coating by eliminating the on-process coefficient of friction & wear.

The coefficient of friction was highly improved upto 0.05 and the wear rate was found below 2×10^{-8} mm^3/Nm. Psyllaki et.al [19] result revealed that when the steel slides against an alumina ball, the frictional coefficient of the two coatings stabilizes to a constant value meet upto 0.60. In addition, the wear rate obtained of the Flame Spraying coatings was nearly twice of air plasma spray method. In the case of sliding experiment of AISI 304 steel against a cBN - coated conical pin, the coefficient of friction for both the oxide coating also meets up to the same constant value of 0.55 and the wear rates reached to identical value ($2.01\times10{-}5$mm3/Nm) to ($2.40\times10{-}5$mm3/Nm. Sahraoui et.al [20] studied that the friction coefficient was decreased by applying load due to the effect of solid lubricant which acts as third body. Pandey et al. [21] reviewed the effect of tribological properties of different nanofluid in machining. Wulan et al. [22] explored the effect of coating nickel on stainless steel. The coating resulted in improved quality and quantity of CNT produced. Hamadi et al. [23] worked on CK50 steel to enhance its wear resistance using hard chromium plating process. The effect of temperature had a significant role on the chromium coating. Sanz [24] stated that the chromium plating played a very important role for reducing wear, gives low wetted capability, high stiffness and having cheapest in nature. The wear behavior of the tungsten carbide (Co with CS) particulate coating in casted steel shows tremendous effect because no wear tracks were noticeable which was calibrated by optical microscopic method.

This paper investigates the tribological characteristics of hard chrome deposited on AISI 204 steel disc having corrosion resistance and wear resistance properties during sliding against AISI 304 steel pin under dry condition and at room temperature. The experiment was conducted using a pin- on -disc tribometer under three different loads ranging from 5N to 15N with sliding speed of 1.25m/sec,1.57m/sec, 1.88m/sec and sliding distance of 500m, 750m and 1000m respectively.

2. Materials and Methodology

In present study, the AISI 204 steel is used as a disc of diameter 165mm and 8mm thickness coated with hard chrome coating of 120 microns. The hard chrome coating thickness of 120 µm is done by electrode deposition technique. The experimental pin is made up of AISI 304 steel with diameter of 10mm.

Table 1. Experimental conditions for tribological testing

Materials	**Conditions**
Substrate Material	AISI 204 austenite grade steel
Substrate Dimensions	Diameter 165mm
Coating Material	Hard Chrome
Coating Thickness	120µm
Coating Technique	Electrode deposition technique
Pin Material	AISI 304 austenite steel
Pin Dimension	Diameter 10 mm and length 32 mm
Machine Used	Ducom pin on disc tribometer
Loads-(N)	5, 10 & 15
Sliding velocity (m/sec)	1.25, 1.57, 1.88
Sliding Distance- (m)	500, 750 & 1000
Wear track Diameter	60 mm

The different experimental conditions for the tribological investigation are mentioned in Table 1. The arrangement of pin on disc tribometer is depicted in Fig.1 upon which the tribological tests are performed.

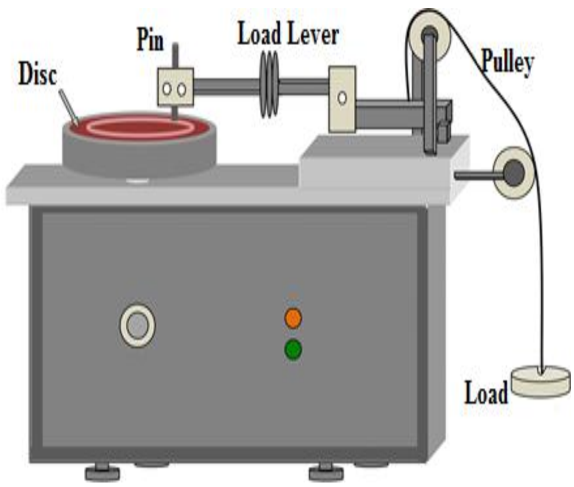

Fig. 1: The schematic of Pin on disk tribometer.

The tribology experiment was carried out by maintaining the wear track diameter equal to 60 mm and the temperature was maintained at room temperature for all the runs in order to study the impact of variation of load, sliding speed and sliding distance on wear and friction. The different set of experimental condition at different setting of process parameters are given in the below Tables 2, 3 and 4.

Table 2. Tribology test with constant sliding speed and sliding distance with varying load.

S.NO	**Load (N)**	**Sliding speed (m/sec)**	**Sliding distance (m)**
1	5	1.25	500
2	10	1.25	500
3	15	1.25	500

Table 3. Variable Sliding Distance tribology test with Constant Sliding Speed and Constant Load Condition.

S.NO	**Sliding distance (m)**	**Sliding speed (m/sec)**	**Load (N)**
1	500	1.25	10
2	750	1.25	10
3	1000	1.25	10

Table 4. Variable Sliding Speed tribology test with Constant Sliding Distance and Constant Load Condition

S.NO.	**Sliding speed (m/sec)**	**Sliding distance (m)**	**Load (N)**
1	1.25	500	10
2	1.57	500	10
3	1.88	500	10

Sliding speed is calculated as per the Eq.1

$$V = \pi DN/60 \quad (1)$$

Where
V= Sliding Speed in m/sec
D= Wear track Diameter in m
N= Sliding Speed in RPM
The number of revolution is calculated as per Eq.2

$$N = (\text{Sliding Distance})/(\text{Circumference}) \quad (2)$$

The wear is analysed by taking the difference of weight of pin before the experiment and pin weight after the experiment. The coefficient of friction is analysed by recording the frictional force value given by the tribometer and the coefficient of friction is computed by using standard Eq.3.

$$F = \mu_f N' \quad (3)$$

Where F= frictional force, N'= applied load, μ_f = coefficient of friction.

3. Results and Discussions

3.1 Influence of Load on Wear & Coefficient of friction

The wear and friction characteristics of hard chrome on AISI 204 stainless steel disc is evaluated by the pin on disc tribometer.

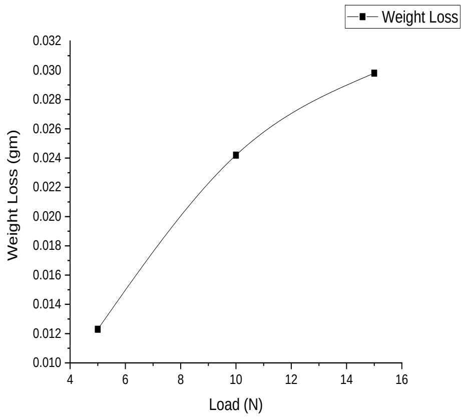

Fig.2: Influence of Load on wear

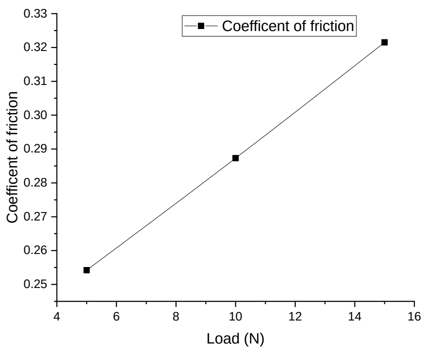

Fig. 3: Influence of Load on COF

Figure 2 and 3 show the influence of load on wear and the frictional coefficient. The material loss of the pin is increasing by increasing the value of load due to abrasive wear mechanism generation and the wear is in the form of chips are deposited in the surface of disc and the coefficient of friction is also increases by increasing load due to the wreckage of HC coated disc specimen and uncoated pin specimen are formed and deviated from the contact area [25].

3.2 Influence of the sliding distance on wear & frictional coefficient.

Figure 4 and 5 illustrate the impact of the sliding distance on the wear & the coefficient of friction by which the hardness value of coated specimen is high as compared to the uncoated pin sample. The hard chromium is act as self- lubricant and provides less wear as compared to the non-faced sample and the hardness value of HC is increasing by increasing the sliding distance 11) and increases the wear and coefficient of friction.

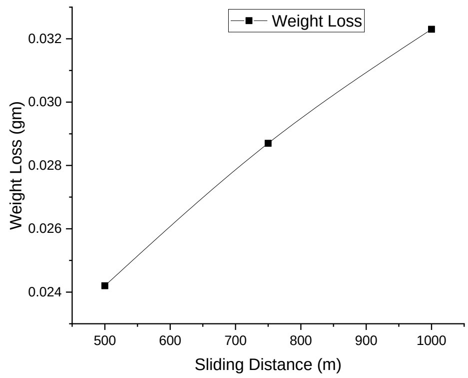

Fig. 4: Influence of sliding distance on wear

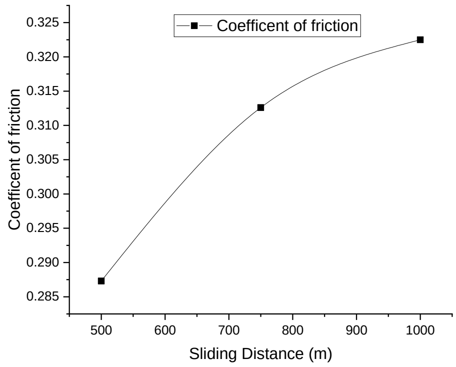

Fig.5: Influence of sliding distance on coefficient of friction

3.3 Influence of sliding velocity on the wear & the coefficient of friction.

Figure 6 and 7 illustrates the impact of sliding speed due to which the temperature increases at the mating area. By increasing the sliding speed, the area of contact of the uncoated pin and coated disc become heated and their temperature increases which scrap the material of pin and the weight loss and COF is increases[12].

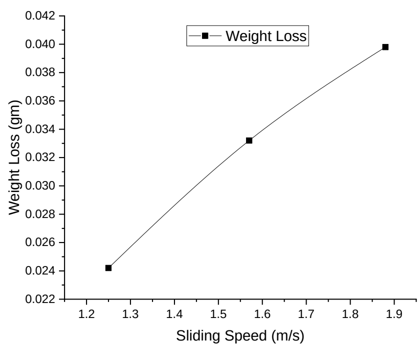

Fig. 6: Influence of sliding velocity on wear

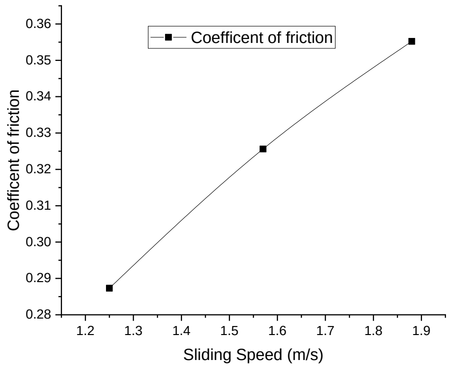

Fig.7: Influence of sliding speed on coefficient of friction

4. Conclusions

As per the aforementioned research experiment, the noteworthy conclusion which show the impact of different loads, sliding distances & sliding speed on material loss and frictional coefficients are as followed:

- The material loss and frictional coefficient arises because of the abrasive wear & the presence of particles which is left down on the surface which increases the weight loss of pin and frictional force by increasing load.
- By increasing sliding distance, the wear as well as the frictional coefficient are increased due to the third particle involvement and introduction of axial and tangential force which need the lubricant and deteriorates the surface.
- The wear & coefficient of friction are increased by increasing sliding speed because temperature of the contact area is increased which results the debris formation on the coated disc.
- The increasing factor of load and increasing sliding distance has more impact on hard chrome coated steel as compare to the increasing moving speed.

The investigation on nanoparticle addition in base oil to check variation of parameters on wear and coefficient of friction can further be investigated. Moreover, the coating thickness can also be optimized for different working environmental conditions.

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