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TRIBOLOGICAL BEHAVIOUR OF NANOCOATED PISTON RING

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ABSTRACT

The nanopartical material coating can help to improve performance and life of Internal combution automobile engines by reducing the frictional wear and friction between IC engine components. In this research study tribological properties of titanium ***dioxide (TiO_2) nanocoatings for piston ring application are investigated. Nanocoating Samples were*** *prepared by sol-gel process of varying dipping and drying process cycles (40, 50, 60 and 70).In this reaserch studyof frictional wear have carried out on Pin on Disc Tribometer and the tests were taken in varying load and speed. The obtained results shows that TiO_2Nanocoating exhibits good friction reduction and anti-wear properties andalso decreased the coefficient of friction by 4% and 8% at 60 and 70 dipping-drying process cycles respectively, as compared with conventional chromium platting.In addition, the topography of worn surfaces was analyzed by using Scanning Electron Microscopy (SEM).*

KEYWORDS- *TiO2 nanocoating, tribological properties, friction coefficient*

I. INTRODUCTION

The subject tribology generally deals with the technology provision of lubrication, friction control and wears prevention of surfaces having relative motion under load.Tribology indicates that the subject is truly multi-disciplinary in nature. Therefore, it is really difficult for an individual to master the subject. A lubrication Engineer may not know much about the areas, like the bearing design and friction and Wear of metals. Similarly, people who are given much attention on the principle of Lubrication or lubrication bearings. The efforts of all the workers which include chemists, the physicists, the mathematicians, the material scientists and mechanical engineers are directed towards the methods to control friction and minimize wear of machinery by Adopting new lubrication technology, developing new lubricants and finding new wear resistant materials. The development of the subject is possible if there is a close Interrelation ship between tribological design principles and practices.

II. LITERATURE REVIEW

Peter J. Blaub et al. [1] have been studied review on various tribological aspects of automobile power train system including the engine, transmission, driveline, and other automobile components. They have been studied integration of lubrication and surface engineering concepts into a unified automotive power train system. They had used lightweight materials such as a non-ferrous material (Al, Mg) for engine and drive train material to replace the current heavy-weight cast iron blocks.

F. Gonzalez et al. [2] have been studied on Nano crystalline materials and test result shown that the decrease of grain size and their significant volume fraction of grain boundaries and triple junctions. They also studied many unusual mechanical, physical, chemical and electrochemical properties compared with conventional polycrystalline amorphous materials. The yield strength, and toughness of polycrystalline materials are commonly improved with reduction grain size, which is additionally suitable for nanostructure coatings.

Narendra B. Dahotre et al. [3] studied a review on engineering coating of engine applications. In this examination dimensional stability, tribological properties on the coating material to improve wear resistance, lubrication, coefficient of friction and hot hardness, amenability for coated honing cylinder wall, surface roughness and topography, residual stress, adherence, Coatings for engine and other automotive power systems, Laser induced reaction nano composite coating suitable for automotive engine applications damage tolerance and resistance, pores density and conditions and cost performance are talked.

P. Hariharan et al. [4] have examined tribological behaviour and surface interface characterization of Fe based alloy coating. The result shows Powder particles were in the size range of 40 to 80μm which were deposited by HVOF thermal spray under

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the controlled condition and produce coating layer 400µm and Microstructure and the micro abrasive wear performance of the coating were characterized by Optical microscopic, Video Measuring system and Non-contact surface roughness testing analysis methods were used. Evaluation of coating was done by Micro hardness test, Micro abrasion wear test, Surface Roughness test etc. Experimental results show that coating provides high surface hardness with excellent wear resistance.

M. Josephson et al. [5]have been studied developing production process of WC-Co Wolfram – Carbide cobalt alloy coating to decrease the grain size in the material structure to nano domain and minimizing non-WC-Co phases in the material can increase the hardness. Result shows Comparison between the microstructure of nano-structured WC-Co coating and the conventional microstructure of WC-Co coating that the mechanical properties such as hardness value is double then the conventional micro-grained WC-Co and also improved wear resistance and cutting performance observed.

Jeremy (Zheng) Li [6] examined anti-corrosive material performances based on computational simulation, to study the fundamental anti-corrosive behaviour in several different coating materials. The applied model in this computational simulation can be potentially used in future research to analyze different coated material properties and performances. The experiments have been performed to check the coating performances and compare the experiments with computational simulation

S.Prabhu et al.[9] have been studied the coating of CrN deposition on the piston ring and Piston head, as result reduction in friction and increase its wear properties using PVD machine. The uses of deposition technology increased advantages of the hard coatings. In this investigation and study experimental test conducted on Spark Ignition engine and measured its performance analysis. The power output of the S.I engine is increased by 0.76% and torque produced by the S.I engine is increased by 0.67%.The surface roughness is reduced by more than 63%

SimonC.Tung et al.[7] studied comprehensive review of various tribological aspects on automobile power train system. These systems consist of engine, transmission, driveline, and other driving components. They have shown that the integration of lubrication and surface Engineering concepts into a unified automotive power train system. The application of Tribological principles is required for their performance and efficiency of the motor vehicle and in the area of power train technology has led to enormous advances in the field of tribology.

Rajiv Asthana et al.[8]have investigated nonmaterial's are an emerging family of novel Materials that have designed for specific properties. These materials will probably Bring about significant shifts in the manner of design,develop,and use materials. For example, nonmaterial's those are1000 times stronger than steel,and10 times lighter than paper, are cited as a possibility. The following properties can be presumably be tailored resistance to deformation and fracture,ductility,stiffness,strength,wear, friction,corrosion resistance,thermal and chemical stability,and electrical properties.

Andrzej Adamkiewicz et al.[12] studied the working evaluation of piston ring Wearing in large marine internal combustion CI engines based on inspection through cylinder liner scavenge ports.In this study a description of verification methods of piston rings based on visual inspections,clearance measurement of piston rings in piston grooves and piston rings gap measurement.The results shows that piston ring gap measurements can lead to an evaluation of piston ring wear and by calculating into running hours can be treated as a reference parameter at next inspections and a parameter determining wear trends.

Kenneth Holmberg et al.[11] have been studied simulated and modeled friction and wear of coated surfaces. They shown the basic of friction and wear mechanisms, scale effects and parameters influencing the friction and wear of surfaces coated with diamond like carbon thin films.This forms the basis for surface optimization by modeling,stress simulation and surface fracture calculations.The scale effects in a tribological contact have illustrated by explaining typical surface roughness related tribological mechanisms for diamond and DLC coated surfaces

M.Shunmuga Priyan et al.[10]have been studied tribology and surface interface Characterization of Fe based alloy coating Powder particles were in the size range of 40 to 80µm which were deposited by HVOF thermal spray.Experimental Evaluation of coating done by Micro hardness test,Micro abrasion wear test,Surface Roughness test etc.Results indicated that coating provides high surface hardness with excellent wear resistance.

According to the Literature Survey, the nanocoating can results in better tribological properties. The following outcomes can be drawn from the literature review of the nanocoating

1. Successful implementation of Nanocoating is done in various areas such as hydrophobic nanocoating as a water replant coating for mobile phones, hydrophilic etc.
2. Besides DLC and TBC,not much work has been reported in the field of nanocoating in engine applications.

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3. Nanocoating exhibits good friction reduction and anti-wear behavior therefore successfully implementation of nanocoating in engine application is possible.
4. Simulation of wear prediction Is possible by Archard's wear theory which is based on Contact pressure distribution

III.EXPERIMENTAL

A. *Fabrication of TiO_2Nanocoating by Sol-gel Technique*

In materials science, the sol-gel process is a method for producing solid materials from small molecules. The method is used for the fabrication of metal oxides mostly.Fig.2.shows procedure for sol get technique for TiO2 deposition. The process involves conversion of monomers into a colloidal solution (*sol*) that acts as the precursor. A coating sol was prepared by keeping the molar ratio of $C_{16}H_{36}O_4Ti$: EOH: H2O constant at 1: 5.63: 1.58 and stirred for 30 min at room temperature then (0.5 M) HNO_3 as a catalyst was added in solution. The cleaned metal substrates were dipped for 1min in the sol and taken out for drying. Dipping and drying process repeated for various cycle (40, 50, 60, 70). These cycles ensures uniform deposition of TiO_2. Further, these substrates were annealed at 450 °C for 45 min to remove residual solvent and cooled for 24 hours.

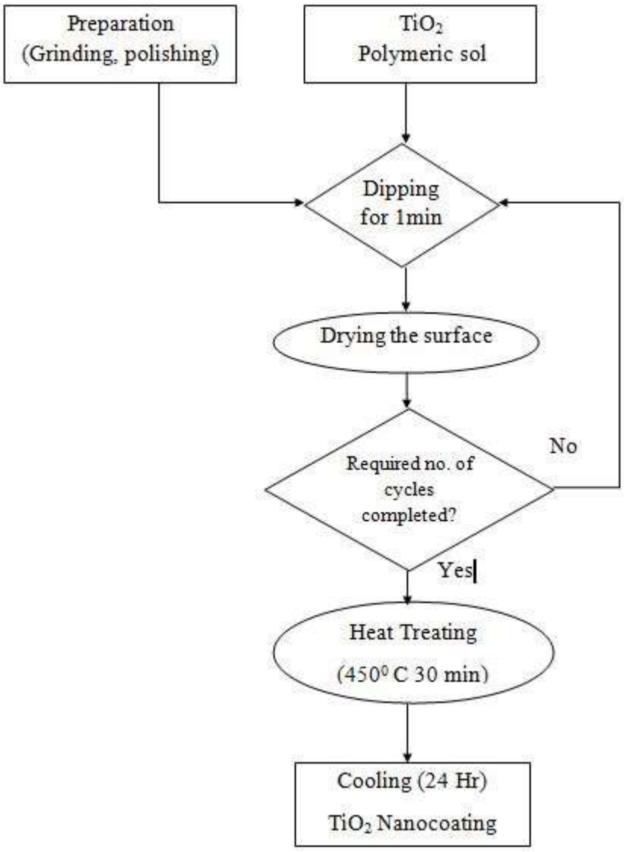

Fig.2 Sol gel technique for TiO_2 Deposition

B. *Materials*

The materials for tribological testing are selected according to real material configuration. Steel SAE 8620 (Piston ring material) is selected for Pin with various coating and for disk, Gray Cast Iron that of cylinder bore material is selected.Table 1 shows that material of Pin and Disk specimen which were used in pin on disk Tribometer for wear and friction testing.

Table 1: Specimens

Specimens	Material	
Disks	Grey Cast Iron, hardness=130-180BHN, d=165 mm, t=8mm, E=66-157GPa, ν=0.26	
Pins	A	Steel SAE 8620 without any coating
	B	Steel SAE 8620 with conventional chromium platting
	C	Steel SAE 8620 with TiO2 nanocoating (with 40 deposition Cycle)
	D	Steel SAE 8620 with TiO2 nanocoating (with50 deposition Cycle)
	E	Steel SAE 8620 with TiO2 nanocoating (with60 depositionCycle)
	F	Steel SAE 8620 with TiO2 nanocoating (with70 deposition Cycle)

C. TribometerTest Procedure

The Pin on Disc Friction & Wear Testing Machine designed and developed by Ducom Instruments, which is used to conduct trials. The friction and wear testing machine was set for pure sliding contact, with a pin-on-disk configuration. The manufactured test pins were run against a counter face of the manufactured disk. All tests were carried out at loading condition 9kg, 15kg and 20kg. The disk was rotated at speed of 1000, 1500 and 2000 rpm at room temperature for 10 minute time with continuous supply of 15W40 lubricating oil. The coefficient of friction and wear rate was recorded using strain gauge in tribotester. Wear surfaces on pin were characterized using Scanning Electron Microscopy (SEM).

IV. RESULTS AND DISCUSSION

A. Anti-friction Properties

In order to confirm the repeatability of experimental data, the coefficient of friction was measured using the pin on disk tribotester under 9kg, 15kg and 20kg load conditions for 10 minute at 1000, 1500 and 2000 rpm speed condition with continuous supply of 15W40 lubricating oil. The coefficient of friction at various speeds at 9 kg load is as shown in Fig. 3.The x-coordinate shows speed of disk in rpm whereas y-coordinate shows coefficient of friction. Coefficient of friction for uncoated pin A is always higher than coated pin. The pin F, TiO_2 (70 cycles) nanocoating exhibits better results than conventional chromium platted pin B. The pin C, D, E exhibits poor frictional resistance than the pin B and pin F. TiO_2 (70cycle) sample possess near about 8% improvement in frictional resistance at 9 kg load.

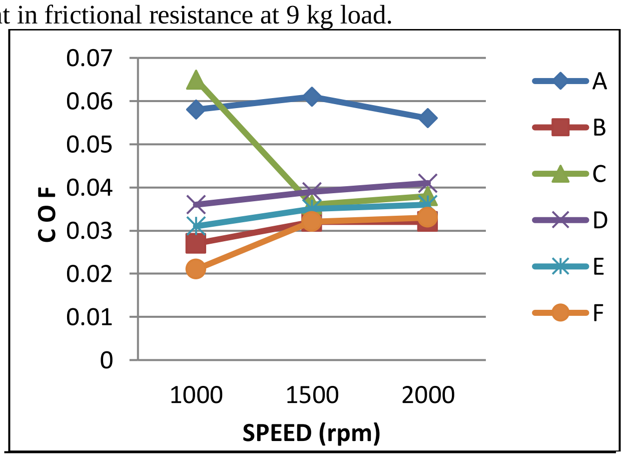

Fig. 3 Coefficient of friction at 9Kg load

The coefficient of friction at various speeds at 15 kg load is as shown in Fig.4.The pin E and F exhibits better results than chromium platted pin B. Overall from 3 test set we see that TiO_2 (60 and 70) posses better frictional resistance properties than Cr platted pin. Pin E exhibits average 4% better results than the pin B and pin F exhibits 8% better frictional performance than pin B.

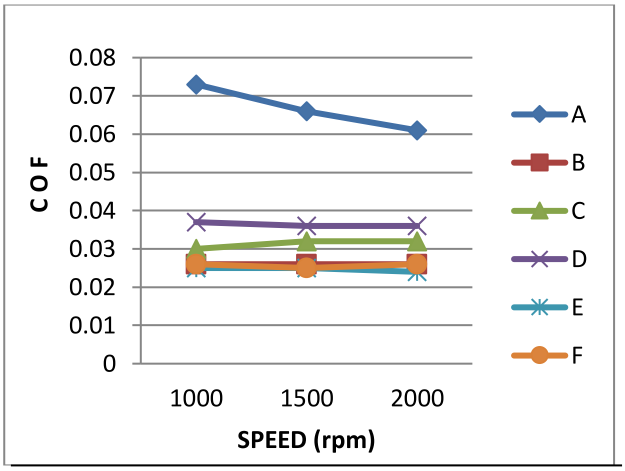

Fig. 4 Coefficient of friction at 15Kg load

The coefficient of friction at various speed sat 20kg load is as shown in Fig.5. The pin A (uncoated) exhibits poor results. The pin E and F exhibits better results than Chromium platted pin B. Over all from test results we see that TiO2 (60and70)posses Better frictional resistance properties than Cr platted pin.

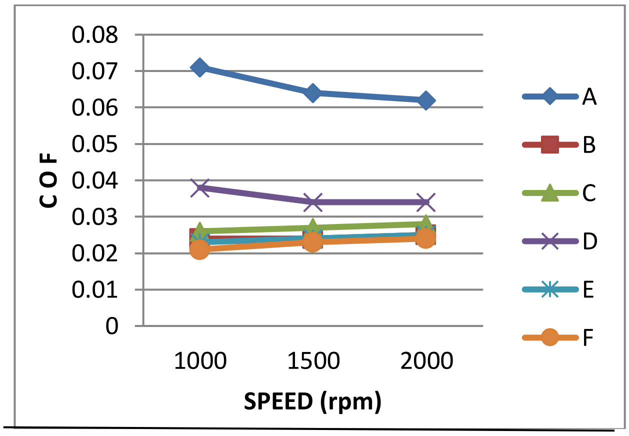

Fig. 5 Coefficient of friction at 20Kg load

B. Anti-wear Properties

Anti-wear properties were examined in Tribometer by two ways. Collecting information regarding wear depth of pin from load cell sensor we can compute wear rate of particular pin. Other method is very simple in which weights of pins were noted down before and after test with the help of weighting machine. The weights of pins before and after Tribometer test are as shown in Table 2. There is no such wear difference between chromium coated pins and TiO_2 nanocoated pins. The tests were conducted at room temperature but in actual I C engine the inlet temperature is in range of 500^0 C to 700^0 C. Temperature plays important role in wear properties. In modern tribometer there is provision for separate individual temperature set up both for disk and pin.

Table 2 Weights of pins

Sample	Weight before test	Weight after test
A	25.834 gm	25.821 gm
B	26.248 gm	25.845 gm
C	25.625 gm	25. 621 gm
D	25.694 gm	25.692 gm
E	25.638 gm	25.636 gm
F	25.614 gm	25.612 gm

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C. Analysis of Specimen surfaces

The SEM morphology was employed to investigate the worn surface of the specimens with and without any coating. By observing Fig.6 and Fig. 7 the surfaces appears to have many thick and deep furrows and pits or spalls because of contact fatigue and adhesive fatigue. Also gradual removal process of metals fibers is observed, normally occurring in the sequence of fiber thinning, fiber fracture and final removal of broken fiber pieces.

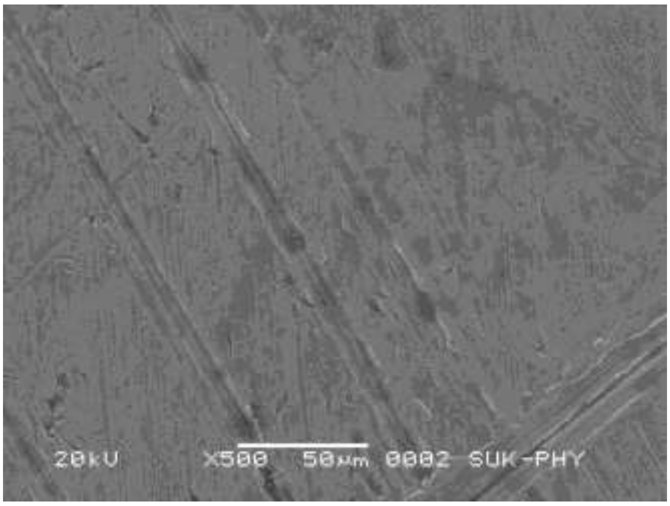

Fig. 6 SEM image of worn surface of uncoated pin

Fig. 7 SEM image of worn surface of chromium coated pin

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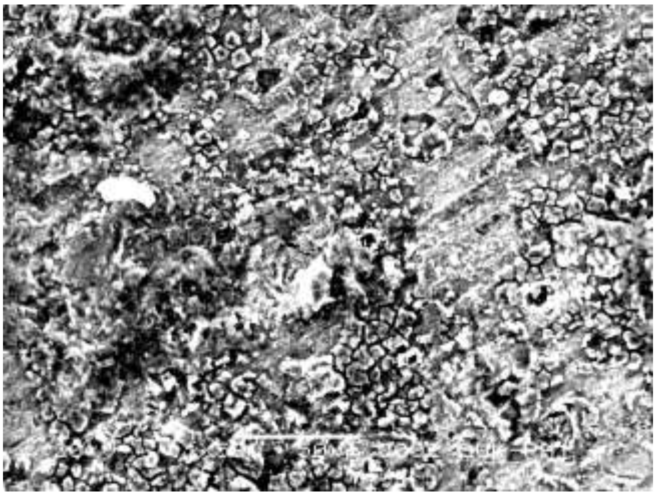

Fig. 8 SEM image of worn surface of TiO_2 Cycle 60 (Pin E) nanocoated pin

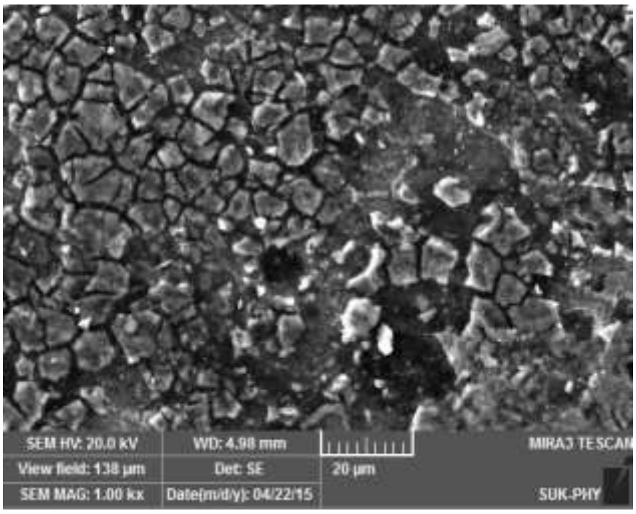

Fig. 9 SEM image of worn surface of TiO_2 Cycle 70 (Pin F) nanocoated pin

TiO2 nanocoatings were shown by small wear depth comparing with chromium plating. As shown in Fig 8 and Fig. 9 worn surfaces appear much smoother without severe scuffing. The fiber removal was gradually and fully contributed to the wear resistance of the composites. As the result, the specific wear of the material was much more stable, and load carrying capacity of the material was significantly improved. In this study an interesting result was obtained from the wear surface analysis that with increase in the number of cycles of deposition, friction resistance properties of engine oil improved. As speed of disk increases the thickness of lubrication film increases which enhance wear resistance but cause more frictional forces. As load on pin increases thickness of film lubrication decrease. Adequate film thickness provides minimum frictional losses. This means that systematic investigation of all the relevant characteristics and properties of nanoparticles is still a matter of further research.

CONCLUSIONS

The following conclusions have been drawn from the conducted research work:

Titanium dioxide nanocoating has successful deposited by sol-gel technique for Piston ring application with minimum 60cycles of deposition process. Experimental as Well as numerical analysis indicates that both anti-wear and anti friction properties of Titanium dioxide are slightly better than conventional chromium coating. Thus chromium coating can be replaced by titanium dioxide nanocoating with adequate coating thickness.

- ***A.*** The coefficient of friction exhibits by TiO_2 nanocoating with 70 deposition cycles is 8% less than conventional chromium platting. ThusTiO2 results in lower Frictional losses.
- ***B.*** The deposition of nanocoating on the worn surface can decrease the shearing stress, and hence reduce friction and wear.

C. Antiwear properties of TiO2 nanocoatings were found as good as chromium platting. The dimensional wear coefficient of TiO2 found equal to 9.5555 10-8

D. As load on pin increases thickness of film lubrication decrease.

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