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An Experimental Analysis of Various Coatings Used in Piston Top Rings

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Abstract:Piston rings play a crucial role in the IC engines. They act as a media between the piston and the cylinder liner. The piston rings play a major role when the piston is in reciprocating motion. The rings should withstand the high temperature and pressure during the combustion cycle. In this research project we are concentrating in three fields: the chemical, metallurgical and mechanical. We are considering 3 top rings with different coatings. Chrome, Molychrome and Molychrome ceramic (MCC) [1]. These rings are subjected to wear test and the results obtained are compared to find out the ring with least wear rate. The ring with MCC coating is then fixed in an engine test ring and the various engine parameters are recorded.

Keywords: Chrome, Molychrome, MCC, pin on disk equipment, engine test bed, rate of wear.

I. INTRODUCTION

The working of an IC engine involves the reciprocating motion of the piston in the cylinder. Piston rings are located on the piston head and act as a cushioning mechanism between the piston head and the cylinder liner. During the reciprocating motion a lot of friction is generated between the piston head and the cylinder liner. Earlier reports suggested that the frictional loss was responsible for about 25% of the overall fuel consumption in engines [2-4]. Almost 75% of the frictional loss occurs on the sliding surface between the piston ring and cylinder block in the engine [5-7]. There are many factors which determine the rate of wear and friction such as, mechanical properties, surface properties, sliding environment, chemical properties, etc [8]. Several experiments have been conducted in order to improve the life period of the piston rings. One of them is the application of different materials over the surface of the piston rings. This method is known as surface coating of piston rings.

Piston rings generally serve for three main purposes. They are:

- Sealing the combustion/expansion chamber.
- Supporting heat transfer from the piston to the cylinder wall.
- Regulating engine oil consumption.

In this research work we are conducting several metallurgical tests as well as mechanical tests and comparing the properties and durability of the various surface materials of the piston rings.

II. MATERIALS AND METHODS

In this research work we are conducting metallurgical as well as mechanical tests with three different piston rings with different surface coatings. The base material and the dimensions are the same for all the piston rings. The different surface coatings used are:

- Chrome
- Molychrome
- Molychrome ceramic[1]

These materials are coated over the surface of the rings by electroplating process.

III. RING SPECIFICATIONS

Ring number	Outer diameter
R 3872	88.90 mm
R 3766	88.90 mm
R 3894	88.90 mm

Table 1.1: Specification of Piston Rings

Fig 1.1: Piston Rings Before Electroplating

Fig 1.2: Piston rings after electroplating

IV. EXPERIMENTAL

The following tests are conducted in order to obtain the properties and characteristics of the piston top rings:

- Vickers hardness test
- Chrome depth evaluation
- Microscopic analysis of the rings
- Pin on disk wear test

Vickers hardness test is used to determine the hardness of the material which is coated above the ring surface. It consists of indenting the test material with a diamond indenter. The load is applied for about 10-15 seconds [9]. The area of the sloping surface of the indentation is calculated [10]. The Vickers hardness quotient is obtained by dividing the kgf load by the square of the mm area of indentation [11].

V. MICROSCOPIC ANALYSIS

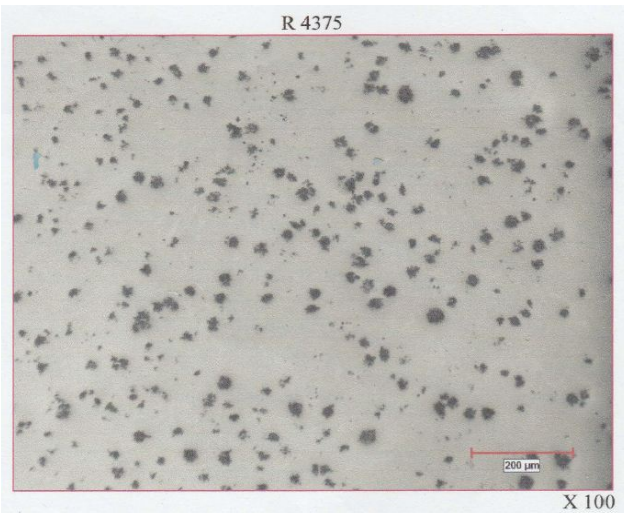

Fig 1.4: Uncoated ring

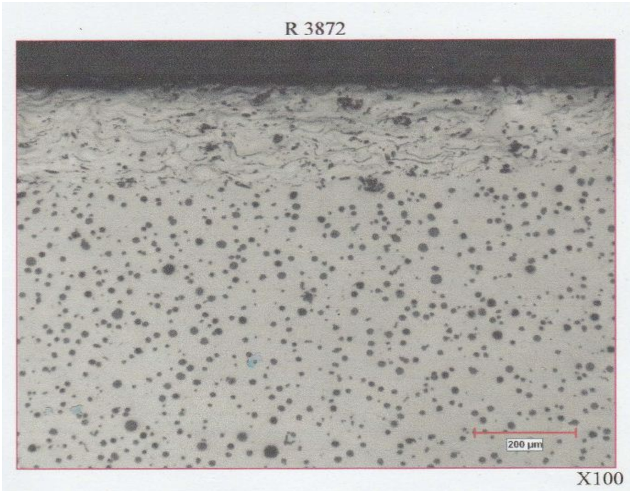

Fig 1.5: Microscopic View of Molychrome Ceramic Ring

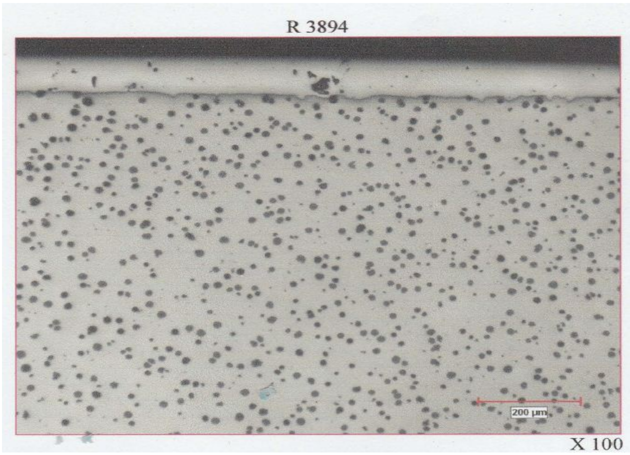

Fig 1.6: Microscopic View of Molychrome Ring

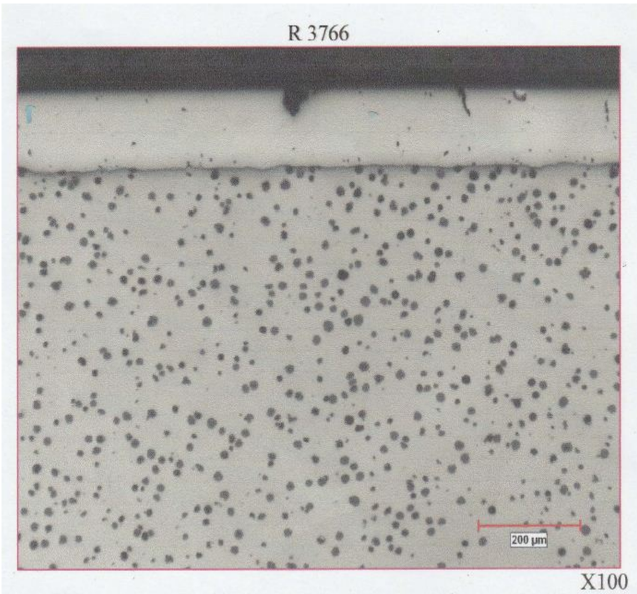

Fig 1.7: Microscopic View of Chrome Ring

VI. PIN ON DISK WEAR TEST

This test is done to evaluate the rate of wear under particular conditions such as temperature, load, etc. In this research work we are using DUCOM Wear and Friction test rig for this test. The wear test was done for 6 hours under similar temperature and load conditions.
Specifications

Normal	20 kg max
Pin diameter	3-12 mm diagonal
Wear disc size	Ø160 mm x 80 mm
Disk rotation speed	100-2000 rpm
Frictional force measurement range	0-20 kgf
Wear measurement range	±2 mm

Table 1.2: Specifications Of DUCOM Wear Test Ring.

VII. RESULTS AND DISCUSSION

No.	Ring Reference number	Chrome hardness(VPN)
1	R- 3872	366
2	R-3766	905
3	R-3894	889

Table 1.3: Chrome hardness

No.	Ring Reference number	Plating depth (mm)
1	R-3872	0.20
2	R-3766	0.16
3	R-3894	0.15

Table 1.4: Chrome Depth

The Results For Different Rings Are Given Bel

A. Wear Test Results

- *Chrome Ring*

Test: 1

Specimen Material : Chrome

Initial weight: 1.273 gm

Wear track diameter: 116mm

Applied Load: 10 kg

Duration of Test: 6 hrs

After test (6 hrs.) weight: 1.2720 gm

Set Temp: 200 deg

Disk Material : Cast Iron; Used side: A

Surface finish Avg : 0.9µ

Lubricating Oil : Castrol 15W40CH4

Disk rotation speed : 600 rpm

Wear: 0.0010 gm

Time	RPM	Displacement indicator reading in 'micron'	Frictional force reading in 'N'	Coefficient of friction in 'µ'	Specimen holder temperature in °C
09.59 am	0	0	-	-	200
10.00 am	605	65	14.4	0.22	197
10.10 am	602	64	14.3	0.22	199
10.20 am	601	62	14.0	0.23	211
10.30 am	598	61	14.1	0.23	204
10.40 am	599	60	14.3	0.24	200
10.50 am	602	59	14.0	0.24	197
11.00 am	603	57	14.2	0.24	197
11.10 am	603	59	14.5	0.24	200
11.20 am	604	55	14.3	0.24	200
11.30 am	606	53	14.1	0.28	200
11.40 am	606	52	14.2	0.27	202
11.50 am	607	50	14.3	0.28	202
12.00 pm	608	49	14.0	0.27	202
12.10 pm	610	48	14.4	0.30	200
12.20 pm	611	46	14.1	0.29	200
12.30 pm	612	43	14.0	0.31	201
12.40 pm	612	41	14.0	0.33	205
12.50 pm	613	43	14.2	0.34	200
01.00 pm	614	45	14.4	0.36	200
01.10 pm	615	42	14.3	0.37	200
01.20 pm	616	40	14.2	0.39	203
01.30 pm	618	38	14.1	0.42	204
01.40 pm	619	36	14.2	0.43	203
01.50 pm	620	34	14.3	0.45	204
02.00 pm	621	31	14.1	0.41	203

02.10 pm	622	32	14.0	0.43	201
02.20 pm	624	30	14.2	0.42	200
02.30 pm	624	30	14.3	0.44	200
02.40 pm	625	29	14.1	0.46	200
02.50 pm	625	29	14.1	0.45	203
03.00 pm	627	28	14.3	0.43	205
03.10 pm	626	26	14.2	0.42	208
03.20 pm	627	27	14.2	0.42	207
03.30 pm	630	27	14.0	0.47	206
03.40 pm	631	28	14.0	0.50	206
03.50 pm	632	30	14.3	0.48	206
	618.5	**55.3**	**14.35**	**0.38**	**203**

Table 1.5: Chrome Ring Wear Test Results

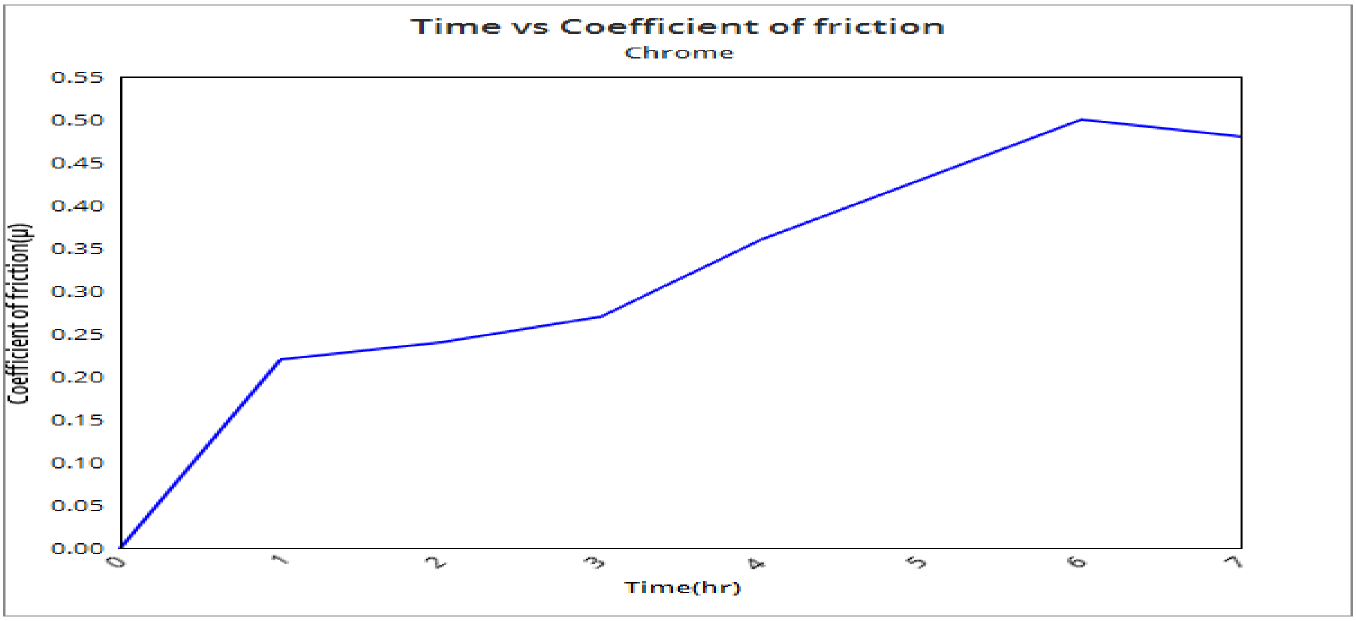

Fig 1.9: Time Vs Coefficient of Friction

B. Molychrome Ring

Test: 2
Specimen Material : Molychrome
Initial weight: 1.351 gm
Wear track diameter: 116mm
Applied Load: 10 kg
Duration of Test: 6 hrs
Wear: 0.0012 gm

Set Temp: 200 deg
Disk Material : Cast Iron; Used side: A
Surface finish Avg : 0.9μ
Lubricating Oil : Castrol 15W40CH4
Disk rotation speed : 600 rpm
After test (6 hrs.) weight: 1.3498 gm

Time	RPM	Displacement indicator reading in 'micron'	Frictional force reading in 'N'	Coefficient of friction in 'μ'	Specimen holder temperature in °C
08.59 am	0	0	-	-	200
09.00 am	610	65	16.3	0.25	199
09.10 am	607	61	16.2	0.27	210
09.20 am	595	61	16.1	0.26	205
09.30 am	598	62	16.0	0.26	204
09.40 am	599	63	16.0	0.25	195
09.50 am	601	64	16.2	0.25	197
10.00 am	603	60	16.2	0.27	196
10.10 am	602	60	16.4	0.27	198
10.20 am	605	57	16.4	0.29	202
10.30 am	607	58	16.3	0.28	202
10.40 am	610	56	16.3	0.29	201
10.50 am	611	56	16.1	0.29	201
11.00 am	612	53	16.0	0.30	200
11.10 am	613	55	16.0	0.30	200
11.20 am	611	54	16.3	0.31	200
11.30 am	615	50	16.2	0.32	198
11.40 am	616	52	16.2	0.32	298
11.50 am	616	51	16.0	0.31	195
12.00 pm	618	50	16.0	0.36	202
12.20 pm	620	50	16.4	0.33	202
12.30 pm	621	47	16.3	0.39	201
12.40 pm	621	45	16.2	0.36	200
12.50 pm	622	48	16.2	0.35	200
01.00 pm	623	48	16.1	0.45	203
01.10 pm	623	44	16.0	0.44	203
01.20 pm	622	44	16.0	0.44	203
01.30 pm	624	42	16.1	0.41	201
01.40 pm	624	38	16.1	0.42	201
01.50 pm	624	36	16.1	0.45	201
02.00 pm	625	36	16.2	0.48	200
02.10 pm	625	35	16.2	0.46	200
02.20 pm	626	37	16.3	0.44	202
02.30 pm	627	37	16.4	0.44	206
02.40 pm	627	33	16.0	0.48	205
02.50 pm	622	34	16.3	0.48	205
03.00 pm	622	32	16.3	0.51	205
	618.20	**47.26**	**16.2**	**0.40**	**202.50**

Table 1.6: Molychrome Ring Wear Test Results

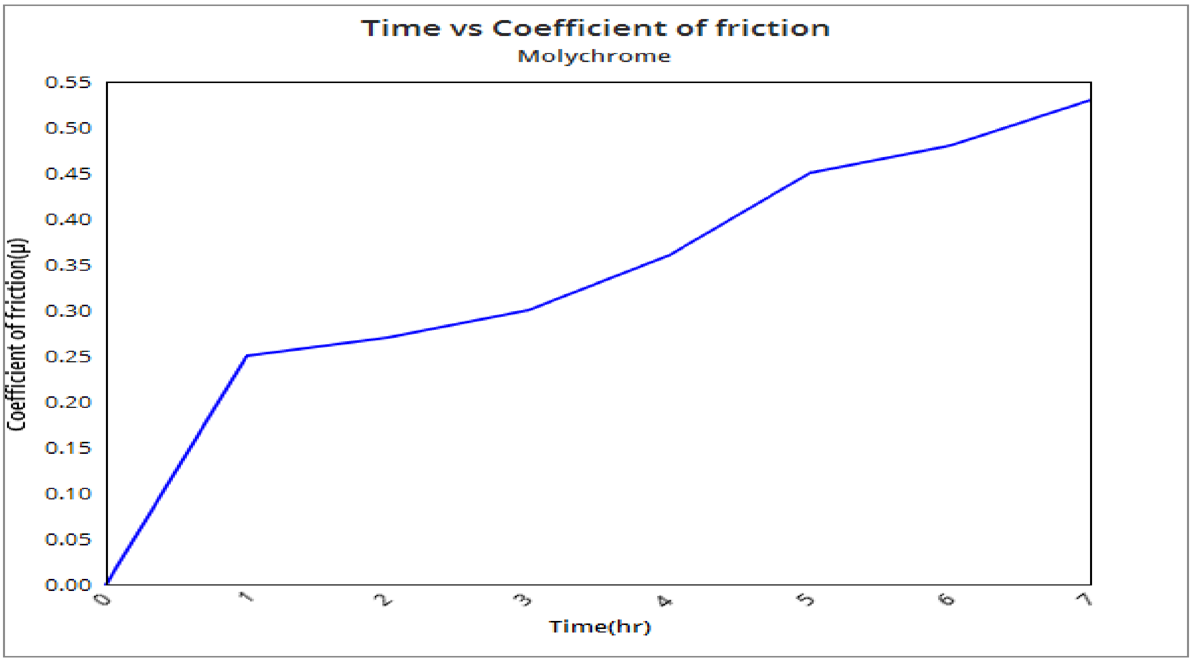

Fig 2.0: Time Vs Coefficient Oof Friction

C. *Molychrome Ceramic Ring*

Test: 3
Specimen Material : Molychrome ceramic
Initial weight: 1.157 gm
Wear track diameter: 116mm
Applied Load: 10 kg
Duration of Test: 6 hrs
After test (6 hrs.) weight: 1.1562 gm

Set Temp: 200 deg
Disk Material : Cast Iron Used side: B
Surface finish Avg : 0.9μ
Lubricating Oil : Castrol 15W40CH4
Disk rotation speed : 600 rpm
Wear: 0.0008 gm

Time	RPM	Displacement indicator reading in 'micron'	Frictional force reading in 'N'	Coefficient of friction in 'μ'	Specimen holder temperature in °C
08.59 am	0	0	-	-	200
09.00 am	607	53	10.0	0.19	199
09.10 am	599	52	10.4	0.20	211
09.20 am	599	51	10.5	0.21	209
09.30 am	602	49	10.2	0.21	207
09.40 am	599	46	10.9	0.23	209
09.50 am	605	51	10.2	0.20	204
10.00 am	608	43	10.2	0.24	196
10.10 am	609	41	10.2	0.25	196
10.20 am	611	37	10.2	0.28	200
10.30 am	612	35	10.2	0.29	200
10.40 am	612	34	10.2	0.30	200
10.50 am	613	33	10.2	0.31	201
11.00 am	614	33	10.2	0.31	200
11.10 am	615	31	10.1	0.33	200
11.20 am	617	31	10.1	0.33	200
11.30 am	618	31	10.2	0.33	201
11.40 am	619	30	10.2	0.34	200
11.50 am	619	28	10.2	0.36	200
12.00 pm	620	27	10.1	0.37	200
12.20 pm	621	26	10.1	0.39	199

12.30 pm	621	26	10.1	0.39	199
12.40 pm	622	25	10.1	0.40	201
12.50 pm	623	25	10.0	0.40	201
01.00 pm	623	24	10.0	0.42	204
01.10 pm	623	23	10.0	0.42	204
01.20 pm	623	23	10.2	0.44	205
01.30 pm	624	23	10.2	0.44	207
01.40 pm	625	23	10.1	0.44	208
01.50 pm	625	23	10.1	0.44	208
02.00 pm	625	23	10.2	0.44	208
02.10 pm	626	23	10.2	0.44	207
02.20 pm	626	23	10.1	0.44	206
02.30 pm	626	23	10.1	0.44	206
02.40 pm	627	24	10.0	0.42	206
02.50 pm	626	24	10.1	0.42	205
03.00 pm	627	24	10.1	0.42	205
	600.82	**30.79**	**10.17**	**0.35**	**202.97**

Table 1.7: MCC Ring Wear Test Results

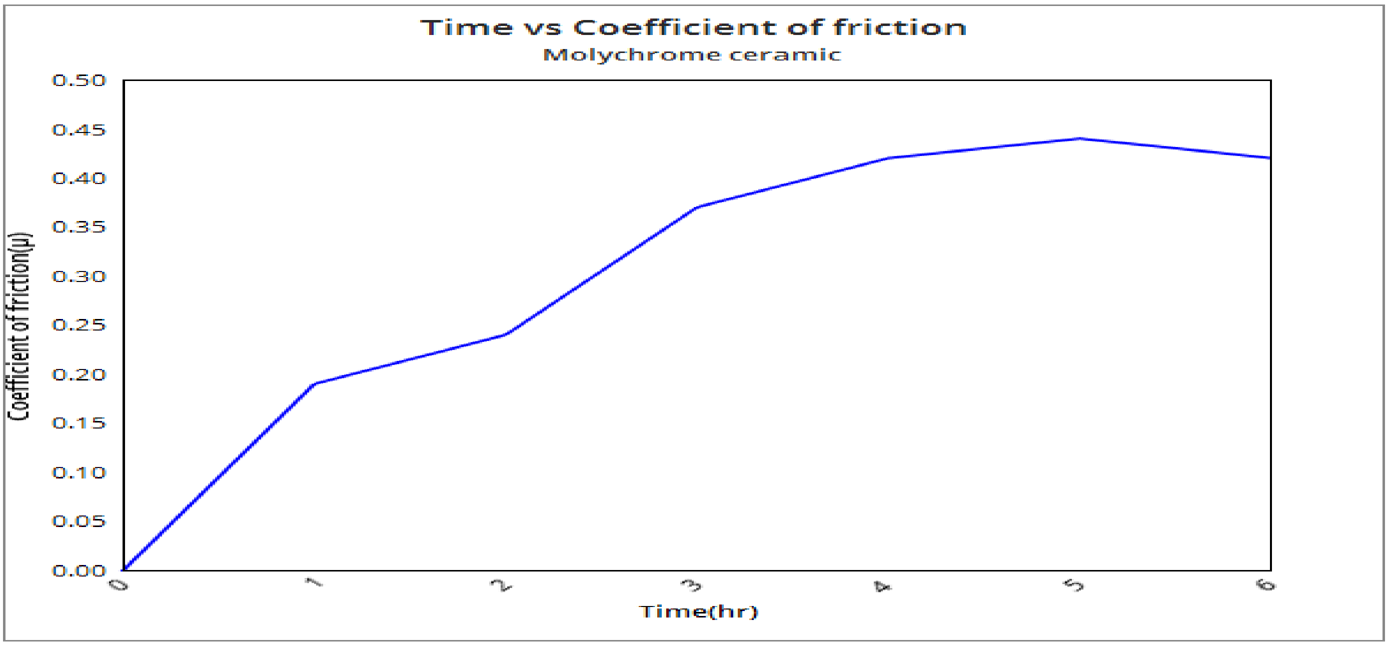

Fig 2.1: Time Vs Coefficient Of Friction.

VIII. CONCLUSION AND FUTURE WORKS

Wear testing of Chrome, Molychrome and Molychrome ceramic rings shows that rate of wear is the highest for Molychrome ring and thus the best characteristics are exhibited by the MCC rings. The average coefficient of friction of MCC is 0.35 which is lower than other rings. Then the Molychrome ceramic ring was installed in a TATA 4S PTC engine and the engine was run for about 7 hours. During the test, several parameters such as Brake load, Observed power and specific oil consumption were noted. In addition to the above mentioned parameters the quantity of fuel injected as well as blow by values were noted. The important parameter is the blow by value which yielded a value of 0.00314 litres per minute on an average for 7 hours. Hence, with the above results it can be concluded that the durability and life period of Molychrome Ceramic rings are higher when compared with Chrome and Molychrome rings. Thus the Molychrome ceramic ring can be economical for the customers. With the Molychrome ceramic rings currently in use in the market, there is an improved surface coating currently in research stage. This coating uses nana crystals of diamond. It is known as Nana Diamond Coating abbreviated as NDC. If the NDC research is successfully implemented, then the life period of the piston rings can increase drastically simultaneously the emission and fuel wastage can also be reduced due to the subsequent increase in the engine efficiency.

REFERENCES

[1]. Advances in Surface Engineering by Dr. R. Mahadevan, Mobility Engineering, First edition, Dec 2013.

ISSN No: - 2456 – 2165

[2]. Alex Weiss (22008), Bearings. Special Interest Model Books.

[3]. VDi-richtline 2840 Kohlenstoffschichten, Grundlagen, Schttypen, Eigenschafte.

[4]. “Piston Ring Coating Reduces Gasoline Engine Friction” Federal-Mogul.

[5]. Dimitrios Dardalis, PhD (February 2004). “Rotating linear engine: A new approach to reduce engine friction and increase fuel economy in heavy duty engines” Austin, TX: RLE Technologies, Inc.

[6]. “Profile of Piston rings” prepared by Micro, Small & Medium Enterprises Development institute, Raipur, Chattisgarh.

[7]. Alex Weiss (2008). Bearings. Special Interest Model Books.

[8]. VDi-richtlinie 2840 Kohlenstoffschichten, Grundlagen, Schichttypen, Eigenschafte.

[9]. Gal-Or, L.; Silberman, I.; Chaim, R. (1991). "Electrolytic ZrO_2Coatings:I. Electrochemical Aspects". J. Electrochem. Soc. **138** (7): 1939. doi:10.1149/1.2085904.

[10]. Ju, Hyungkuk; Lee, Jae Kwang; Lee, Jongmin; Lee, Jaeyoung (2012). "Fast and selective Cu2O nanorod growth into anodic alumina templates via electro deposition". Current applied Physics.

[11]. 60. doi:10.1016/j.cap.2011.04.042.“Vickers HardnessTest”gordonengland.co.