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Experimental Exploration on Influence of Gas Nitriding and chromium coated Piston rings in reduction of Wear and Lubricant Consumption in Petrol Engines

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The tribological parameters like friction, lubrication and wear influence strongly the engine component's life. The appropriate lubricant can eliminate the tribological effects. The economy in lubricant consumption needs design modification. This research focuses on industrial problem of reducing piston ring wear within warranty periods and control of excess lubricant consumption on petrol engines. the proposed Gas Nitriding on Piston rings gave appreciable performance than the conventional chromium plated piston rings. The constructive problem solving approach, that is Field Claim Data Analysis (Early Mileage, Durability Claims), Pareto Preparation, Voice of Customer, Brain Storming , Cause & Effect Analysis, Problem Analysis & Process Improvement, Bench Marking Trial Study, Final Countermeasure Implementation, Improvement Monitoring and Standardization were employed to solution the identified real world issues. The necessary inspection and testing methods like oil consumption testing, wear analysis, metallurgical inspection like hardness and chemical composition characterization were included for evaluating the comparative of effects proposed Gas Nitriding of piston rings than conventional chromium plated.

***Keywords*:** Tribology; piston rings; petrol Engines; TQM approach;

1. Introduction

In IC engines the piston rings are exposed to high operating temperature 160°C and that connect piston and cylinder in the high velocity to froth motion. The rings made sliding fit for piston in the cylinder as well as providing air tight seal for piston head side of the combustion chamber. The replacement of worn-out rings is nearly equal to re condition of the engine. That is that task demands more time, labor cost and consumables. The piston ring also helps in heat transfer, lubricating the sliding surfaces and one of responsible part for lubrication oil consumption. The piston rings and their functions are self explanatorily furnished in the figure 1. Hence the piston rings are to be prepared with extensive care. This work is motivated by an industrial case of customer complaints excess oil consumption over time and piston rings worn-out within the warranty period etc. So the objectives of this research are to minimize the piston ring wear and lubrication oil consumption and maximize the engine life and its performance. The methodology is demonstrated in the following topics.

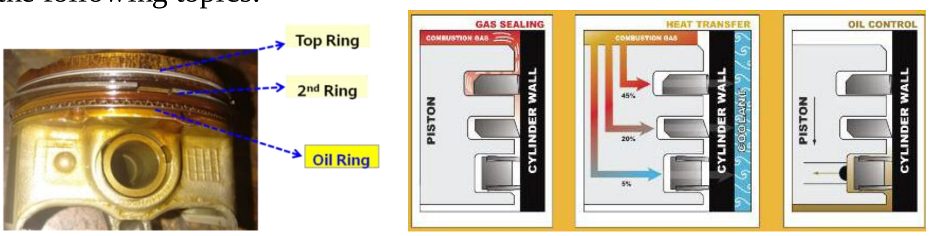


Fig.1. Piston Rings and their functions

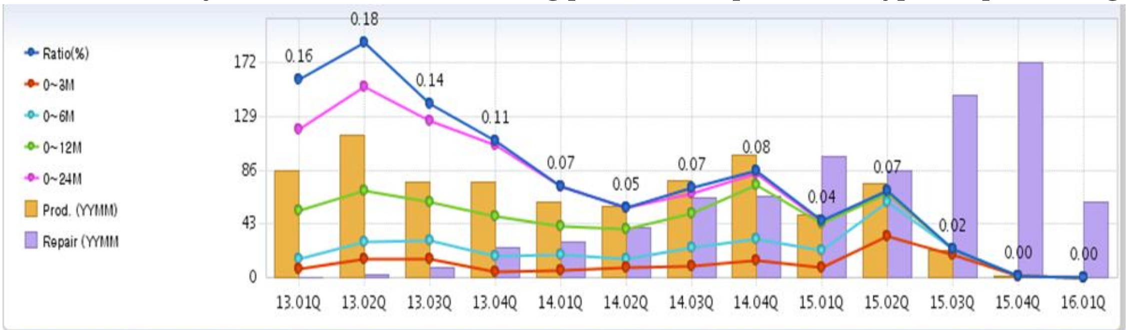
[1] investigated the performance of various lubrication oil individually and along with diesel fuel and methyl ester combined with tobacco seed oil gave best performance that low wear that is less 50% than diesel and engine oil lubrication. [2] addressed the issue of lubrication oil film thickness influenced by engine oil employed for it. The despoiled lubrication oil demeans oil film thickness on piston rings there by influencing in friction. [3] investigated the tribological properties of the composite coating (Cr2AlC and Ni-Mo-Al alloy) on the piston rings and suggested. [4] suggested to composite coat on the piston rings, that is conformist ceramic coatings and rigid fluid graphite for achieving better-quality reduction of oil consumption and improving the wear resistance. The piston rings damaged due to the reasons of residual stresses induced by thermal impact, compressive forces etc. These are depends on the tangential load on piston rings, operating temperature, sliding velocity of piston rings [5]. [6] suggested Ni-P-MoS2-GO coating for piston rings which are lubricating by bio oil. [7] developed friction prediction model for the heavy duty diesel engine with a range by piston rings. The piston rings are responsible for fuel and oil consumption [8]. In this paper detailed the issues of higher oil consumption and poor durability of piston rings in petrol engines. The coating performance also evaluated experimentally and verified with the proposed coating on the piston rings.

2. Materials and Methods

TQM Approach

Field Claim Data Analysis

It is concerned with early mileage and durability claims. For this analysis customer complaints on 13 different classes of piston rings were considered. The claims are classified as product and repair. Apart from total repair, ratio to total claims for four different periods like first three months, first six months, one year and two years. The Field claim analysis is depicted in the Figure 2. It was confirmed that some manufacturing defect is there in the piston rings and more are less common fault may exist in the manufacturing process irrespective of types of piston ring.



Month		Sum	13.01Q	13.02Q	13.03Q	13.04Q	14.01Q	14.02Q	14.03Q	14.04Q	15.01Q	15.02Q	15.03Q	15.04Q	16.01Q
Vehicles		1,068,342	55,078	61,782	55,699	70,942	84,958	104,533	109,627	116,064	112,023	110,494	98,644	79,596	8,902
Product	Claim	793	86	114	76	76	61	57	77	98	50	75	22	1	0
	Ratio(%)	0.07	0.16	0.18	0.14	0.11	0.07	0.05	0.07	0.08	0.04	0.07	0.02	0.00	0.00
	Cost($)	582,230	85,997	101,114	38,253	47,128	57,432	48,069	72,463	74,571	31,295	21,419	4,465	24	0
By Repair	Claim	793	0	2	8	24	29	40	64	65	97	86	146	172	60
0~3M	Ratio(%)	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.03	0.02	0.00	0.00
0~6M	Ratio(%)	0.02	0.01	0.03	0.03	0.02	0.02	0.01	0.02	0.03	0.02	0.06	0.02	0.00	0.00
0~12M	Ratio(%)	0.05	0.05	0.07	0.06	0.05	0.04	0.04	0.05	0.07	0.04	0.07	0.02	0.00	0.00
0~24M	Ratio(%)	0.07	0.12	0.15	0.12	0.10	0.07	0.05	0.07	0.08	0.04	0.07	0.02	0.00	0.00

Fig. 2 Field Data Analysis

The customer complaints were consolidated and classified only top five as per quantity of claim and furnished in the Table 1. The voice of customers also reveals that excess oil consumption due to piston rings shows highest claim. The Pareto Analysis has shown in figure 2 and reveals that the primary defect is on Piston Rings than others.

Cause and effect Analysis

This diagram was completed by means of brain storming. The contribution various input factors for excess oil consumption were derived through brain storming and constructed the Ishikawa diagram (refer Figure 5).

Route cause analysis

The route cause analysis also called as 'why? why?' analysis. the examination of identifying actual fact behind the cause by think and found the answer for the why in each stage. the self explanatory route cause analysis depicted for this case in the figure 6.

Table 1: Voice of Customer (Customer claim)

Top 5	Part Name	Symptom	Claim Qty	
1	Piston Rings	Oil Consumption	477	60%
2	Engine Cylinder Block	Oil Consumption	195	25%
3	Oil Seal	Oil Leak	70	9%
4	Valve Stem Seal	Oil Consumption	39	5%
5	PCV (Positive Crank Case Ventilation)	Oil Consumption	12	1%

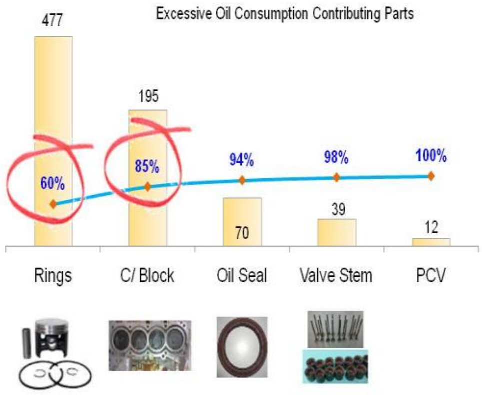


Fig. 3 Pareto analysis on Voice of Customers

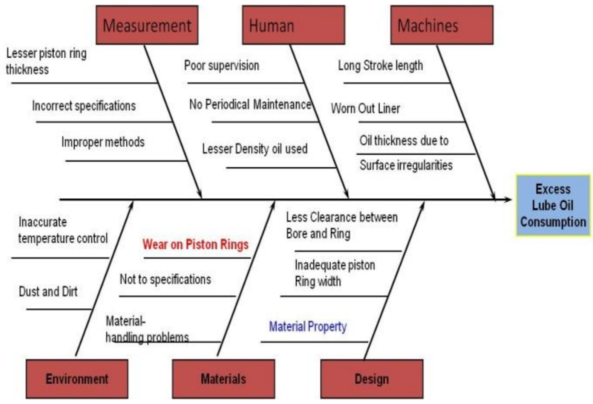


Fig.5. Ishikawa Diagram

Fig. 7. Route Cause Analysis

Fig. 6. PDCA analysis:

PDCA Cycle

PDCA is used to address the chronic loss in the engine from Field for Performance and Dimensional parameters. By use of PDCA defective part analysis parameters are arrived through the meeting and major points are summarized in the Figure 7. During the 'Plan' stage, selection of defective engine was finalized based on mileage covered and also the geographical region where the problem has occurred. in the 'Do' stage it was fixed the parameters that need to examine in field failure engine such as oil Consumption, visual observation, wear and tear of parts and dimensional deviations. In the 'Check' stage, all the parameters were checked and the dimensional variation and performance test study were conducted. some of notable observations on the piston rings are: wear noticed on the peripheral of side rails and carbon deposition found on the rails. In the 'Act 'stage the findings were disclosed for sustaining improvements.

Finally it is found that piston wear resistance to be improved. According literature it was noticed that Gas Nitriding is often proved good wear resistance. Nitriding offers anti-galling properties, boosted up the fatigue life and cost effective method. In this case gas Nitriding was proposed instead of chromium plating on the piston rings for petrol engines. The Nitriding was done on the sample piston rings and tested.

3. Results and Discussions

Oil Consumption Test

The uniform petrol Engines tested with 'C' mode that is 2500 rpm with 50% throttle. The first engine equipped with chrome plated piston rings and the second one was piston rings with gas nitriding. The oil consumption was measured after 30 hours of running the engine. It was 676 grams. That is 22.5 grams per hour or 25.15 cc per hour for the chrome plated case. The proposed case at the same condition after thirty hours of engine run the lubrication oil consumption was 221 grams. That is 7.4 gram per hour in other words 8.22 cc per hour.

Table 2 Oil Consumption Test

Description	Before	After
Weight of oil filled at 0 time	3.156	3.106
Weight of oil drained after 30 Hours run	2.48	2.885
oil consumption CC/Hr	25.15	8.220

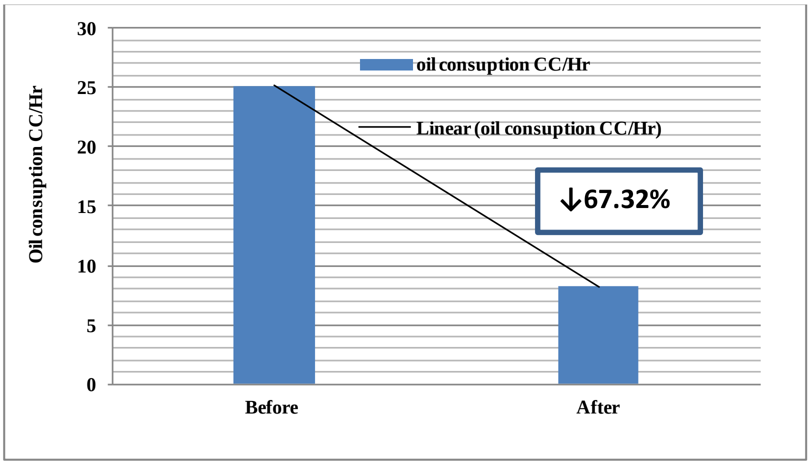


Fig.7. Reduction of Lubricant consumption

Dimensional Stability Investigation

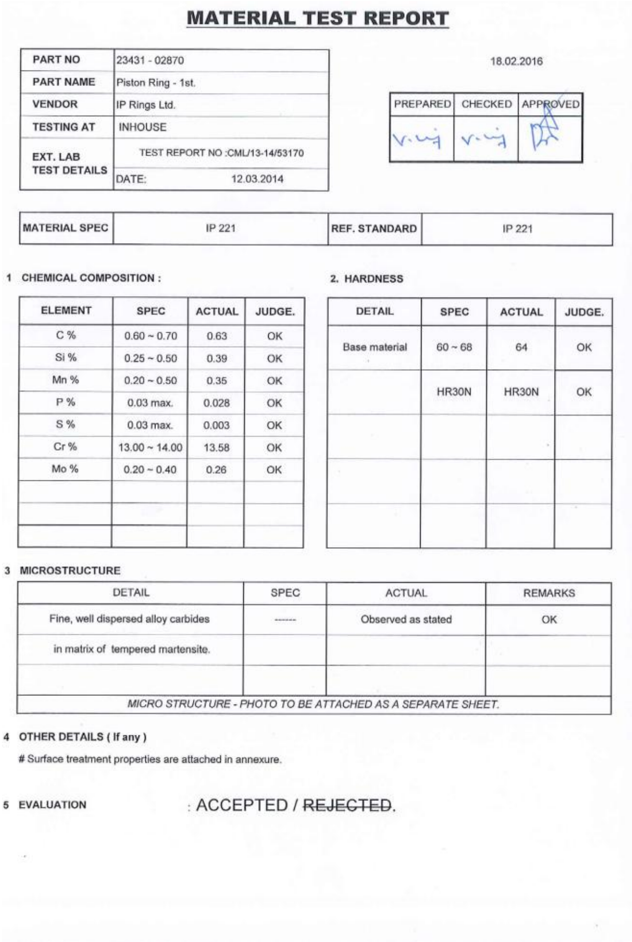
The finishing process causes the slight dimensional variations. The critical dimensions and tangential load were measured and the deviations were presented in the table 3. The dimensional stability was achieved through gas Nitriding. The CP denotes chromium plated piston rings and GN denotes piston with gas nitriding in the Table 3.

Table 3 Dimensional variation by finishing Processes

Parameter Description	**Specification**	**Actual Values of piston rings finished by**							
		Sample 1		**Sample 2**		**Sample 3**		**Sample 4**	
		CP	**GN**	**CP**	**GN**	**CP**	**GN**	**CP**	**GN**
Side Rail Width (mm)	0.4	0.390	0.400	0.395	0.394	0.392	0.395	0.385	0.395
Side Rail Thickness (mm)	2.2±0.1	2.105	2.265	2.117	2.255	2.116	2.257	2.16	2.255
Tangential Load (N)	10.1±3.0	7.500	10.500	7.400	11.700	7.400	11.400	7.250	10.250

Metallurgical Investigation and Characterization

The piston rings like top ring and oil ring with Gas nitriding was examined and characterized metallurgical methods. The tested reports were shown in the Figure 8 and Figure 9. Respectively and found satisfactory results.



MATERIAL TEST REPORT

18.02.2016

PART NO	23431 - 02870
PART NAME	Piston Ring - 1st.
VENDOR	IP Rings Ltd.
TESTING AT	INHOUSE
EXT. LAB TEST DETAILS	TEST REPORT NO :CML/13-14/53170
	DATE: 12.03.2014

PREPARED	CHECKED	APPROVED

MATERIAL SPEC	IP 221	REF. STANDARD	IP 221

1 CHEMICAL COMPOSITION :

ELEMENT	SPEC	ACTUAL	JUDGE.
C %	0.60 ~ 0.70	0.63	OK
Si %	0.25 ~ 0.50	0.39	OK
Mn %	0.20 ~ 0.50	0.35	OK
P %	0.03 max.	0.028	OK
S %	0.03 max.	0.003	OK
Cr %	13.00 ~ 14.00	13.58	OK
Mo %	0.20 ~ 0.40	0.26	OK

2. HARDNESS

DETAIL	SPEC	ACTUAL	JUDGE.
Base material	60 ~ 68	64	OK
	HR30N	HR30N	OK

3 MICROSTRUCTURE

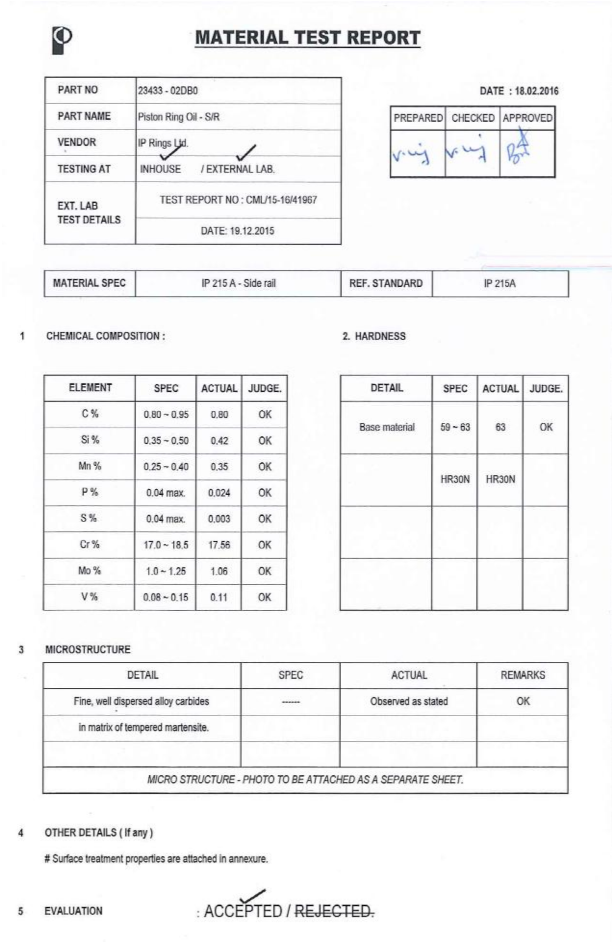
DETAIL	SPEC	ACTUAL	REMARKS
Fine, well dispersed alloy carbides	------	Observed as stated	OK
in matrix of tempered martensite.			
MICRO STRUCTURE - PHOTO TO BE ATTACHED AS A SEPARATE SHEET.			

4 OTHER DETAILS (If any)

Surface treatment properties are attached in annexure.

5 EVALUATION : ACCEPTED / ~~REJECTED~~.

Fig. 8. Characterization of top ring



MATERIAL TEST REPORT

DATE : 18.02.2016

PART NO	23433 - 02DB0
PART NAME	Piston Ring Oil - S/R
VENDOR	IP Rings Ltd.
TESTING AT	INHOUSE / EXTERNAL LAB.
EXT. LAB TEST DETAILS	TEST REPORT NO : CML/15-16/41967
	DATE: 19.12.2015

PREPARED	CHECKED	APPROVED

MATERIAL SPEC	IP 215 A - Side rail	REF. STANDARD	IP 215A

1 CHEMICAL COMPOSITION :

ELEMENT	SPEC	ACTUAL	JUDGE.
C %	0.80 ~ 0.95	0.80	OK
Si %	0.35 ~ 0.50	0.42	OK
Mn %	0.25 ~ 0.40	0.35	OK
P %	0.04 max.	0.024	OK
S %	0.04 max.	0.003	OK
Cr %	17.0 ~ 18.5	17.56	OK
Mo %	1.0 ~ 1.25	1.06	OK
V %	0.08 ~ 0.15	0.11	OK

2. HARDNESS

DETAIL	SPEC	ACTUAL	JUDGE.
Base material	59 ~ 63	63	OK
	HR30N	HR30N	

3 MICROSTRUCTURE

DETAIL	SPEC	ACTUAL	REMARKS
Fine, well dispersed alloy carbides	------	Observed as stated	OK
in matrix of tempered martensite.			
MICRO STRUCTURE - PHOTO TO BE ATTACHED AS A SEPARATE SHEET.			

4 OTHER DETAILS (If any)

Surface treatment properties are attached in annexure.

5 EVALUATION : ACCEPTED / ~~REJECTED~~.

Fig. 9. Characterization of oil ring

4. Conclusion

The customer complaints of excess oil consumption and warranty claim of piston rings replacement within the warranty period is addressed in detail in this paper. The systematic approach explained well. The lubrication oil consumption reduced drastically by 67.32% than before. The reliable finishing processes identified and examined. The proposed gas Nitriding finishing process gave appreciable dimensional stability. Hence the worn-out claim closed.

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