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Investigation of Alternative Material for Piston Rings for ImprovedPerformance

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ABSTRACT

With the ever-increasing of reduction of thelifetime of the piston rings, we have to focus our attention on alternative material such as EN-31. Generally the piston rings are made up of Cast Iron and Steel. The steel ring is four times better than Cast Iron ring.The reason for less lifetime for piston rings due to more wear rate in working condition. So,we have tried to reduce the wear rate of the piston rings. The main advantage of EN-31 Steel is more Harder and Tensile than SAE 9254.This material proves to improve engine performance.

Keywords: piston rings, EN-31 steel, SAE-9254, engine performance.

I. INTRODUCTION

Manufacturers of internal combustion engines continuously face the challenging task of finding means to reduce fuel consumption and emissions in an attempt to improve the engine efficiency. Research shows that frictional loss in an internal combustion engine is the most important factor in determining the fuel economy and performance of a vehicle.

Piston ring is one of the most important part of the Diesel/Petrol engines to be focused for improving the performance. The piston rings is used to prevent combustion gases from passing into the crankcase and oil from passing into the combustion chamber. The three main functions of piston rings in reciprocating engines are: 1.Sealing the combustion/expansion chamber .2. Supporting heat transfer from the piston to the cylinder wall. 3. Regulating engine oil consumption. Piston ring and cylinder liner friction pairs are most important parts in the internal combustion (IC) engines because 30-40% of the energy consumption is caused by the piston ring-cylinder liner system. When this happens it is time for a new set of rings**.** Piston rings is used to seal the combustion chamber of the engine, minimize the friction against the cylinder liner but also transfer heat from the piston to the cooled cylinder liner. The piston ring also evenly distributes oil along the cylinder liner in order to avoid engine seizure. One cylinder in a modern marine two-stroke diesel engine usually contains four to five piston rings referred to as the ring pack and for each of the piston rings there is a corresponding piston ring groove at the piston in which the piston ring is mounted. The top ring of the ring pack normally has a base material of higher grade cast iron and sometimes the ring is thicker and higher than the other piston rings in the ring pack.

Thus the final scuffing between the heavy-loaded components working in contact will determine the reliability and durability of the whole machine. Therefore, more information on the endurance limit of ring materials in the piston assembly is required to know their effective action against scuffing under extreme-pressure working conditions, and simultaneously the wear characteristics of the mating surfaces in the scuffing tests need to be well understood. These design modifications are added because the top ring is working under higher thermal and mechanical load compared to the lower rings. When the engine is turned off, the single piston ring is only affected by the contact surfaces against the cylinder liner and the piston ring groove. But when the engine is running the piston ring pack is also affected by gas pressures and temperature resulting from compression and combustion. The cylinder pressure acts on the upper part of the top piston ring and a fraction of the cylinder pressure acts below the top piston ring. Automobile reciprocating engines normally use three rings, two compression rings and one oil ring. Piston ring moves freely within its groove. Such movements depend on the forces and the moments acting on the piston ring system such as: the static ring tension from installation of piston ring in the cylinder liner, the gas pressure forces caused by cylinder pressure and blow-by gas, the hydrodynamic forces caused by lubricant film, the inertia forces related to component mass and engine speed, and asperity contact forces caused by a direct contact to the cylinder walls. The movements are even found to affect sealing efficiency, engine liner wear mechanism, and lubricant consumption mechanism. Working conditions of piston rings are very demanding and it is desirable to understand the design of such component subjected to various loads.

II. LITERATURE SURVEY

Kim Dallwoo et al.,(2013), Friction Characteristics of Steel Pistons for Diesel Engines. This paper concluded the use of iron pistons is increasing due to the higher power requirements of diesel truck engines.The purpose of this study is to clarify the lubrication conditions of cast iron and steel pistons.The cast iron piston showed boundary lubrication at compression top dead center (TDC). Steel pistons showed hydrodynamic lubrication conditions at TDC and BDC through each cycle, due to a good oil supply. Markus Soderfjallet al.,(2016), Component test for simulation of piston ring – Cylinder liner friction at realistic speeds.This paper describes the design of a

novel component test rig which is developed to be run at high speeds with unmodified production piston rings and cylinder liners from heavy duty diesel engines.The functionality and repeatability of the test are investigated and an unexpected
behaviour of the twin land oil control ring is found.

Nautiyal.C et al.,(1983), Friction and wear processes in piston rings. In this paper it has been recognised that a large part of the top piston ring wear of an ICE takes place in boundary lubrication around top dead centre (TDC) position.The factors responsible for wear under these conditions have been identified as surface temperature, peak combustion pressure, total energy on the wearing surfaces and other physical properties of the material under sliding.

Kontou.A et al.,(2017), Effect of steel hardness on soot wear. Due to incomplete combustion, high levels of soot can accumulate in engine lubricants between drain intervals. wear tests have been conducted in a High Frequency Reciprocating Rig (HFRR) with HFRR steel discs of various hardness against a hard steel ball. Carbon black (soot surrogate) dispersions in model lubricants based on solutions of ZDDP and dispersant in GTL base oils have been studied. The results support the prevalence of a corrosive-abrasive wear mechanism when carbon black and ZDDP are both present in a lubricant and suggests that selection of very hard surfaces may not be a useful way to control soot.

Jayanth.P et al., (2015) Investigation and Analysis of Wear Reduction in Piston Rings through Coating.In this study, the surface of a Piston Ring in the engine is coated with multilayered coating powder using plasma-spray technique, and its surface behavior is analyzed.The results show less deformation and fewer scratches due to wear on the multilayer coated Piston Ring as compared to the uncoated one.

Pradip M. Patel et al.,(2013) Recent Trends To Increase The Service Life Of The Engine With The Help Of Improvement Of Wear Resistance Of Piston Ring – A Review Study. This review paper describes the various materials for piston ring coating as well as various methods recently using to increase the wear resistance and also increase life of the piston rings.

Ashok Atulkar et al.,(2021),Role of textured piston rings/liners in improving the performance behaviours of IC engines: a review with vital findings. This paper brings forth the efforts made by investigators in the field of IC engines aimed to improve its fuel efficiency and reduce its emissions.

Arthur Rozario et al.,(2019),The Influence of a Piston Ring Coating on the Wear and Friction Generated during Linear Oscillation.In this paper,it is concluded that a coating that is based from CrN and TiN allows the piston ring to perform better in engine settings.

Chaanthini, M.K et al.,(2019), Improving Surface Hardness of EN31 Steel by Surface Hardening and Cryogenic Treatment. In this paper, Micro-hardness and microstructures of the specimen were studied. Microstructure study shows that considerable amount of retained austenite has been transformed to plate martensite with precipitates of carbide particles, increasing the hardness of the surface.

Guoxing Li et al., (2017),A dynamic deformation based lubrication model between the piston rings and cylinder liner. This study shows that the friction force obtained from the improved model manifests obvious fluctuations, and shows a significant reduction compared to original model.

Akbarzadeh et al., (2018), Effect of Untampered Plasma Coating and Surface Texturing on Friction and Running-in Behavior of Piston Rings.The running-in behavior and the associated transient friction characteristics of a piston ring with different surface treatments are experimentally evaluated using a custom-made engine testing apparatus.A combination of the texturing and coating showed 12.5% improvement in the frictional behavior and up to 50% improvement in break-in time compared to cases when only one surface treatment was applied.

Chenheng Yuan et al.,(2015) "Tribological Characteristics of Piston Ring in a Free-piston Engine for Linear Generator".This research aims to obtain the piston ring tribological characteristics of a free-piston engine.Results show that seal working time of free-piston ring is longer than conventional engine's during a cycle time, but the leakage loss is lower.

Delprete C et al.,(2018), Gas escape to crankcase: impact of system parameters on sealing behavior of a piston cylinder ring pack. Here study of some parameters which could affect the sealing efficiency of a ring pack.These results confirm that ring gaps and ring unstable motion have an important role in the phenomenon of gas blow-by. In addition, the second ring emerged to have a more important role on the blow-by reduction with respect to the top ring.

III. MATERIAL SELECTION

The piston ring is basically made up of EN 31 alloy steel. It is readily available, economical, available in standard & required sizes, has good mechanical properties, and more reliable than cast iron.

Cast iron rings were used for ring material in early automotive days. The ability of iron to break-in easily, to conform to cylinder irregularities and resistance to high heat made it an ideal material. Cast iron however is brittle. A ring that is made out of grey cast iron when bent too far will snap. The material has little flexibility because of its sharp rectangular granular microstructure. Oil control rings are still commonly made from this material so it is important to use a ring expander when installing these rings on a piston. Today, cast iron compression rings may only ever be used rarely during rebuilding of gasoline engines.

A much better material for compression rings than cast iron and ductile iron is steel. This material is twice as strong as ductile iron. Since steel is the best material for withstanding the pressure and temperature loads found inside high compression turbocharged diesels, this material has been used for thirty years or more in many heavy-duty diesel applications.Steel compression rings have the following advantages: Better breakage resistance,improved heat resistance, better mechanical stress resistance, reduced ring side wear, reduced groove side wear, longer service life, less expensive and complex to manufacture (made fromcoiled wire).

IV MATERIAL PREPARATION, COMPOSITION AND PROPERTIES

Specimen was prepared by various manufacturing process like metal cutting where unwanted material was removed, machining process, grinding for smooth finish and was hardened by gas nitriding to improve wear and corrosion resistance as well as fatigue endurance of steel parts.

Table 4.1 Chemical Composition of EN-31 Steel and SAE-9254 steel

Compositions	**% Composition in EN-31**	**% Composition in SAE-9254**
Carbon (C)	0.90 – 1.20	0.51 – 0.59
Chromium (Cr)	1.0 – 1.60	0.60 – 0.80
Manganese (Mn)	0.30 – 0.75	0.60 – 0.90
Silicon (Si)	0.10 – 0.35	1.20 – 1.60
Phosphorus (P)	0.050 Max	0.035 Max
Sulphur (S)	0.050 Max	0.040 Max

Table 4.2 Properties of EN-31 Steel and SAE-9254 steel

Properties	**EN-31 steel**	**SAE-9254 steel**
Tensile Strength	750 (mPa)	650 (mPa)
Yield Strength	450 (mPa)	350 (mPa)
Hardness	53–64 (HRC)	44–53 (HRC)
Density	7810 (kg/m^3)	7700 (kg/m^3)
Melting Temperature	1540 (°C)	1450 (°C)
Thermal Conductivity	46.6 (W/mK)	25 (W/mK)

V. EXPERIMENTAL ANALYSIS

A. Hardness test- Rockwell hardness test

Hardness is determined by the Rockwell Hardness test. The Rockwell method measures the permanent depth of indentation produced by a force/load on an indenter. Type of indenter used was diamond cone.

Table 5.1 Hardness value of SAE-9254, EN-31 and EN- 31 surface hardened

Material	**Hardness (HRC)**	**Load (kg)**
SAE-9254(Existing material)	48	150
EN-31	59	150
EN-31(Surface hardened)	70	150

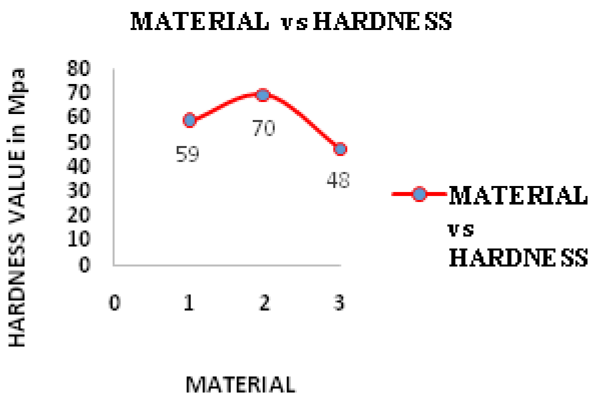


Figure 5.1 Hardness Vs Material

1 - EN-31
2 - EN-31 (Surface Hardened)
3 - SAE-9254 (Existing Material)

Figure 5.2 Specimen before hardness test

Figure 5.3 Specimen after hardness test

B. Tensile Test

Tensile strength of the specimen is determined using Universal testing machine.

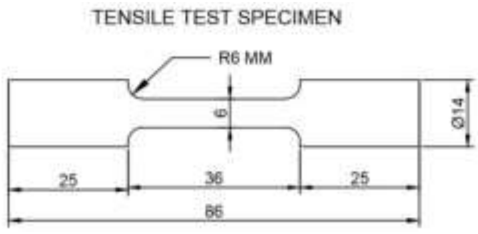


Figure 5.4 Tensile test specimen

Table 5.2 Tensile value of SAE-9254,EN-31 and EN-31surface hardened

Material	Tensile Strength (mPa)
SAE-9254(Existing material)	670
EN-31	812
EN-31(Surface hardened)	993

1 - EN-31
2 - EN-31 (Surface Hardened)
3 - SAE-9254 (Existing Material)

Figure 5.5 Tensile Value Vs Material

Figure 5.6 Specimen before Tensile test

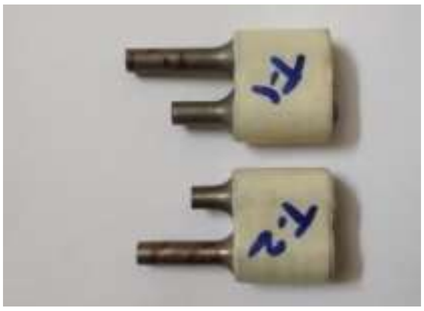


Figure 5.7 Specimen after Tensile test

C. Wear test

Wear test is carried out in pin-on-disc wear tester to predict the wear performance and to investigate the wear mechanism.Wear measurement is carried out to determine the amount of materials removed after a wear test.

Table 5.3 Coefficient of friction value with respect to time for EN-31 & SAE-9254

Time	SAE-9254	EN-31	EN-31(S.H)
0	0	0	0
0.30	0.53	0.43	0.15
1.0	0.58	0.48	0.31
1.30	0.49	0.56	0.44
2.0	0.55	0.56	0.52
2.30	0.48	0.47	0.47
3.0	0.86	0.58	0.53
3.30	0.88	0.41	0.43
4.0	0.76	0.47	0.42
4.30	0.67	0.52	0.47
5.0	0.65	0.49	0.4
5.30	0.63	0.52	0.5
6.0	0.64	0.5	0.49
6.30	0.59	0.42	0.48
7.0	0.56	0.57	0.55
7.30	0.59	0.57	0.53
8.0	0.56	0.45	0.42

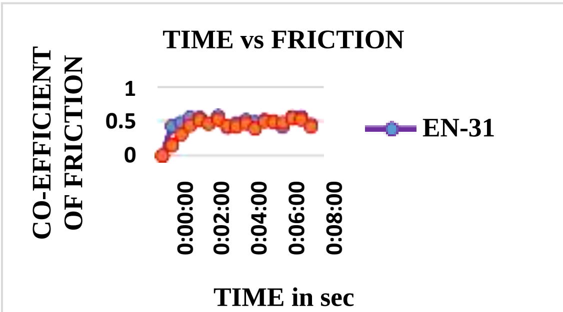


Figure 5.8 Coefficient of friction Vs Time for EN-31 steel

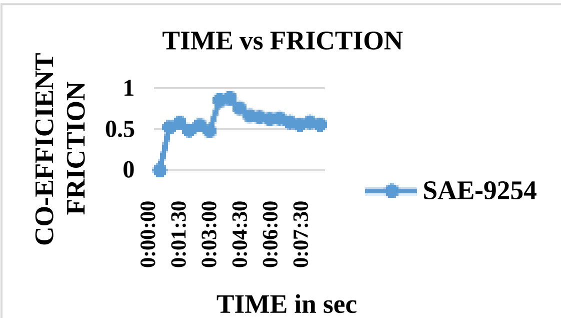
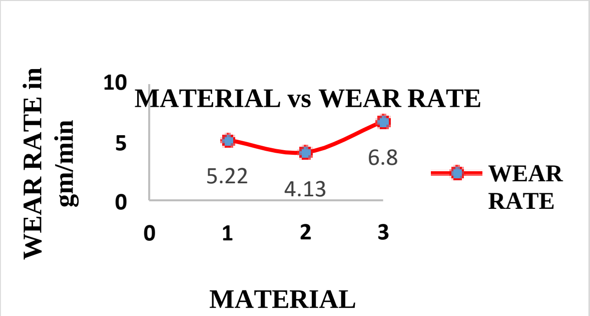


Figure 5.9 Coefficient of friction Vs Time for SAE-9254 steel

Table 5.4 Wear Rate value for EN-31 & SAE-9254

Material	Mass before wear (kg)	Mass after wear (kg)	Time (min)	Wear rate (gm/ min)
SAE-9254	13.6119	13.6063	8.23	6.80 E^{-4}
EN-31	14.2935	14.2892	8.23	5.22 E^{-4}
EN-31 (Surface hardened)	14.0005	13.9971	8.23	4.13 E^{-4}



1 - EN-31
2 - EN-31 (Surface Hardened)
3 - SAE-9254 (Existing Material)

Figure 5.10 Wear Rate Vs Material

Figure 5.11 Specimen before Wear test

Figure 5.12 Specimen after Wear test

IV RESULT AND DISCUSSION

Hardness, Tensile and wear test was determined for EN-31 and SAE-9254 steel and the result is higher for EN-31 than the existing SAE-9254 material. In Rockwell hardness test, hardness of EN-31 was 46% higher than existing material SAE-9254. The tensile strength of EN-31 is 48% more than the SAE-9254. and wear rate is 39% lesser than SAE-9254.

VI. CONCLUSION

The selected material EN-31 was subjected to various tests like hardness, tensile and wear& were compared with the existing material SAE-9254. The tensile, hardness results for EN-31 are comparatively higher than SAE-9254. The wear rate of EN-31 is lower and shows better wear resistance, higher life and better performance than the SAE-9254. From the properties it is observed that melting temperature of EN-31 is more. EN-31 material has better hardenability, more corrosion resistance, less distortion and cracking with better machinability at high hardness. Thus the EN-31 material for piston rings would give higher life and better performance than the SAE-9254 material.

REFERENCES

[1] Akemi Ito, Dallwoo Kim , Yasuhiro Ishikawa, Katsuyuki Osawa, Yoshiyuki Iwasaki, “Friction Characteristics of Steel Pistons for Diesel Engines” (June 2012), pg.no. 96-102.

[2] Anderson, Peter, Tamminen, Jaana & Sandstorm, “Piston Ring Tribology”, Carl-Erik, (DEC2012).

[3] A.P. Semeno & Mashgiz, “Scuffing of Metal”, Moscow, 2013.

[4] “Design and Piston Ring Friction Coefficients Measuring Method”, SAE Paper 930685, 2013.

[5] Huang, J.Y.; Zhu, Y.T.; Liao, X.Z.; Beyerlein, I.J.; Bourke, M.A.; “Microstructure of M2 tool steel”, Materials Science and Engineering, 2003, pg.no. 241-244.

[6] Kevin L Hoag, “Piston and Rings,” in Vehicular Engine Design, Springer-Wien New York 2006, pg.no. 170-186.

[7] Jayanth, P., and E. Sangeeth Kumar. “Investigation and Analysis of Wear Reduction in Piston Rings through Coating.” Applied Mechanics and Materials, vol. 813–814, Trans Tech Publications, Ltd., Nov. 2015, pp. 874–879.

[8] Pradip M. Patel, Narendra R. Makwana, Nimesh A. Patel, Prof. Paresh D. Patel, 2013, Recent Trends To Increase The Service Life Of The Engine With The Help Of Improvement Of Wear Resistance Of Piston Ring – A Review Study, IJERT Volume 02, Issue 04 (April 2013)

[9] Ashok Atulkar,R.K.Pandey,P.M.V.Subba Rao,”Role of textured piston rings/liners in improving the performance behaviours of IC engines: a review with vital findings”, Surface Topography: Metrology and Properties, Volume 9, Number 2,2021.

[4] Arthur Rozario, Christoph Bauman, Raj Shah,”The Influence of a Piston Ring Coating on the Wear and Friction Generated during Linear Oscillation”,Lubricants 2019, pg.no. 7-8..

Chaanthini, M.K., Sanjivi, A. Improving Surface Hardness of EN31 Steel by Surface Hardening and Cryogenic

Treatment. J. Inst. Eng. India Ser. D 100, 37–42 (2019).
G. Li, F. Gu, T. Wang, X. Lu, R. Zhang and A. Ball, "A dynamic deformation based lubrication model between the piston rings and cylinder liner," 2017 23rd International Conference on Automation and Computing (ICAC), 2017, pp. 1-6,
[13] Akbarzadeh, Amirabbas; Khonsari, M M..,"Effect of Untampered Plasma Coating and Surface Texturing on Friction and Running-in Behavior of Piston Rings"Coatings;Basel Vol. 8, Iss. 3, (2018)
[14] Chenheng Yuan, Huihua Feng, Zhengxing Zuo, and Yanxiao Li. "Tribological Characteristics of Piston Ring in a Free-piston Engine for Linear Generator" Energy Procedia, vol. 61, 2015.
[15] Delprete, C., Selmani, E. & Bisha, A. Gas escape to crankcase: impact of system parameters on sealing behavior of a piston cylinder ring pack. Int J Energy Environ Eng 10, 207–220 (2019).