

A Review Paper on Redesigned Piston Rings to Improve Engine Performance

Tejas Raval^{[a][b][c][d]}, Deepak Wadhvani^[b], Anand Bhatt^[c] Nipun Raval^[d]
^[a] Corresponding Author, ^{[a][b][c][d]}Institute of Technology, Nirma University, Ahmedabad
^[a] tejas.raval@nirmauni.ac.in

Abstract-The usage of internal combustion engines is increasing day by day to satisfy human thirst, which has led to consumption of fossil fuel at a drastic level contributing more than 80% human CO₂ emission. As we know that the government norms are becoming stringent day by day due to increase in percentage of CO₂ in the atmosphere. Reducing the global emissions of the internal combustion engines is a prime focus of this paper by decreasing fuel consumption. Friction in Internal combustion engines is mainly due to constantly abrading parts like Piston, Piston Rings, Cylinder Liner and other engine auxiliaries. Fuel consumption can be scaled down by reducing friction between piston ring assembly and cylinder liner, which nearly accounts for approximately 20% of Engine losses. The friction in the ring assembly is mainly due to top ring (compression) friction which is maximum at T.D.C and B.D.C. positions. Friction can be reduced by analysing and experimenting various materials, shapes, sizes, coatings of the piston Rings for Internal Combustion engine. Model prediction indicated that by employing Skewed Barrel Profile with a positive twist, Taper napier Profile with negative twist and tapered ring with negative twist in the first, second and third piston rings grooves respectively reduces a considerable amount of friction of piston rings assembly, ultimately reducing the consumption of fuel and thereby reducing the emissions from internal combustion engines.

Index terms-IC Engine-Internal Combustion Engine, Engine Performance, Piston Rings, Piston Ring profile

1 INTRODUCTION

1.1 Present Scenario

Internal Combustion engines are by far the most common power source for land and water vehicles, including automobiles, motorcycles, ships, etc. The utilization of internal combustion engines is increasing day by day to satisfy human thirst, which has led to consumption of fossil fuel at a drastic level contributing more than 80% human CO₂ emission. Internal combustion engines such as reciprocating internal combustion engines produce air pollution emissions, due to incomplete combustion of carbonaceous fuel. The main derivatives of the process are carbon dioxide CO₂, water and some soot — also called particulate matter (PM). Fig. 1 shows the CO₂ emissions in metric tons per capita of World and India.

As we also know that the rules and regulation of government to control emissions are becoming strict due to increase in percentage of CO₂ and other harmful gases in the atmosphere. So to do that different norms such as India 2000, Bharat Stage II, Bharat Stage III, Bharat Stage IV, etc.

In an internal combustion engine piston, piston ring and cylinder are the most important assembly for transmitting the forces produced by the combustion

process. The friction between piston ring pack and cylinder accounts for major portion of friction in an internal combustion engine and it also significantly affects the mechanical efficiency of the engine.

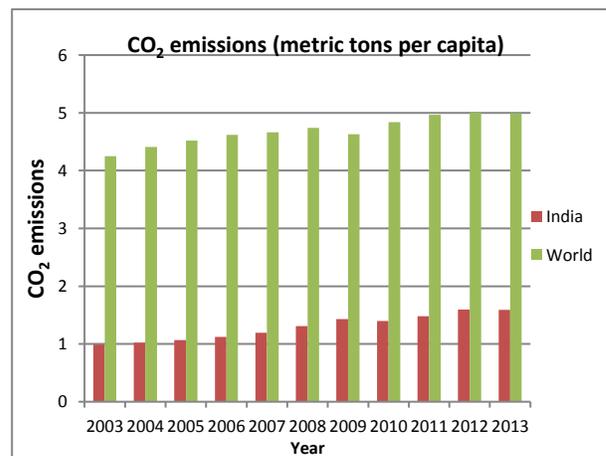


Fig. 1 CO₂ Emissions of India and World

In the piston ring pack, friction is mainly due to the compression ring, especially at the top dead centre and bottom dead centre where boundary lubrication exists. Below Fig. 3 shows the mechanical losses in an IC Engine and significant energy loss due to piston ring assembly.

Emission Standards for Diesel Truck and Bus Engines, g/kWh						
Year	Reference	Test	CO	HC	NO _x	PM
1992	–	ECE R49	17.3–32.6	2.7–3.7	–	–
1996	–	ECE R49	11.20	2.40	14.4	–
2000	Euro I	ECE R49	4.5	1.1	8.0	0.36*
2005	Euro II	ECE R49	4.0	1.1	7.0	0.15
2010	Euro III	ESC	2.1	0.66	5.0	0.10
		ETC	5.45	0.78	5.0	0.16
2010	Euro IV	ESC	1.5	0.46	3.5	0.02
		ETC	4.0	0.55	3.5	0.03

* 0.612 for engines below 85 kW

Fig. 2 Emissions Standards

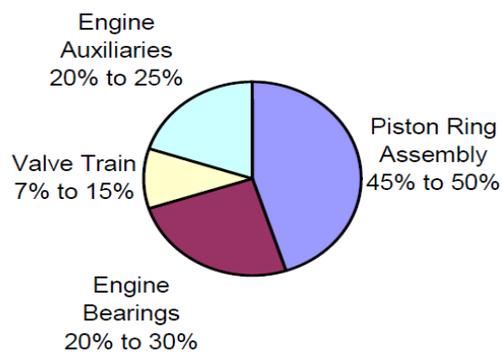


Fig. 3 Mechanical losses of IC Engine

Our main focus is to reduce the losses due to piston rings friction to decrease the emissions of engine.

1.2 Main Functions of Piston Rings

The main task of compression rings is to prevent the passage of combustion gas between piston and cylinder wall into the crankcase. For the majority of engines, this objective is achieved by two compression rings which together form a gas labyrinth. Next to sealing the area between the crankcase and combustion chamber, the piston rings are also used to control the oil film. The oil is uniformly distributed onto the cylinder wall by the rings. Most excess oil is removed by the oil control ring (3rd ring). Temperature management for the piston is another essential task of the piston rings. The major portion of the heat absorbed by the piston during the combustion process is dissipated by the piston rings to the cylinder surface.

1.3 Piston Ring Categories

The compression ring acts as a gas seal between the piston and the liner wall, preventing the combustion gases from escaping down to the crankcase resulting in power loss. The rings have a certain pretension, i.e. they have a larger free diameter than the cylinder liner, which assists the ring in conforming to the liner. The piston Ring with rectangular cross section shown in Fig. 4(a). This ring with its geometrically simple shape performs the necessary sealing functions under normal operating conditions. As in Fig. 4(b), The barrel shaped ring can be used in second piston ring groove. It brings the benefit of reducing friction due to only line contact between ring and liner. As in Fig. 4(c), The Taper faced ring contacts the cylinder bore with its bottom outer edge. This shortens running-in and improves oil scraping. The gas forces acting initially at the running face provide a degree of pressure relief (especially when used in the top groove). Taper faced rings are chiefly installed in the second piston ring groove. As in Fig. 5(a), On the Napier ring the lower edge of the piston ring sliding surface has a rectangular or an undercut recess, which not only seals off the gas, but also acts as an oil scraper. As in Fig. 5(b), The taper faced Napier ring is an advancement of the Napier ring. The oil scraping effect is enhanced by the tapered sliding surface. Keystone rings and half keystone rings are shown in Fig. 6 and Fig. 7. They are used to prevent any carbon deposits in the ring grooves and therefore to counteract any seizing-up of the rings in the ring grooves. Due to higher temperatures and soot formation on diesel engines, the keystone ring is preferably used in the first ring groove, but sometimes also in the second groove [1].

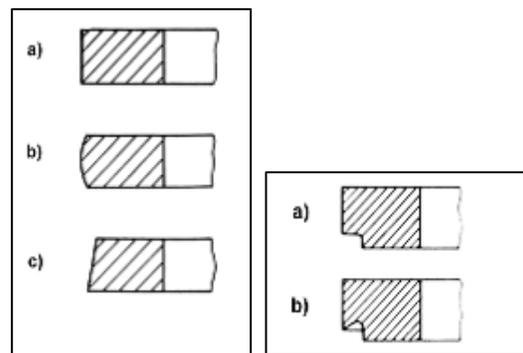


Fig. 4 & Fig. 5 Compression ring cross-section (ISO 6621-1).

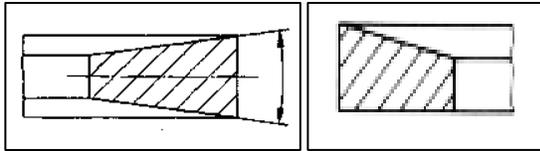


Fig. 6 Keystone ring.

Fig. 7 Half keystone ring (ISO 6621-1).

2 LITERATURE SURVEY

There is never the best piston ring or the best piston ring assembly which can meet all the demands of the different operating conditions, so for different operating conditions different material, different shapes, & different coatings piston rings are used.

The material of the ring should be capable of resisting fracture even in extremity conditions. Material of the ring should be elastic and corrosion resistance to serve its purpose in appropriate way. Ring material should also have good thermal conductivity to conduct heat from piston to the cylinder walls[2]. Material & Shape of the ring should be such that it should withstand the mechanical stresses due to combustion of fuel as well as the thermal stresses due to heat generation in the cylinder. Ring shape should provide minimum friction between ring and liner[2]. Nowadays Coating for ring are being used widely to improve the properties of the piston rings. Normally used coating materials are chromium, molybdenum, titanium and their alloys. Chromium is used where the wear rate of piston ring is high and corrosion atmosphere is present. Molybdenum coating is used where the problem of scuffing is there. Flame spraying process or Plasma Spraying is employed for coating of molybdenum. Molybdenum also gives the advantage of porous structure on the face of the ring resulting in accumulation of lubrication oil on surface permitting the ring to run in extreme operating conditions[1]. Experimental work with new powder compositions for thermal spraying has included molybdenum-nickel-chromium alloys, chromium oxide (Cr₂O₃) with metallic chromium binder, alumina-titania (Al₂O₃-TiO₂), tungsten carbide (WC) with metallic cobalt binder, MoSi₂, CrC-NiCr[2]. As a means of reducing the friction loss, it is effective to decrease the number of piston rings. However, it should be noted that the lubrication condition of the top compression ring probably becomes more severe with a decrease of the ring number since a substantial load of the gas pressure, acting on the top ring, becomes larger[3]. A skewed barrel profile, a reduced axial height and an upward tilted top

ring groove in the piston and a negative static twist in second ring is recommended for friction reduction. For the oil control ring, the use of rings with lower tension was recommended to achieve a reduction in friction[4]. Friction force is considerably affected by the oil starvation. As the average and cyclic change of oil film thickness becomes smaller, the friction force of the piston ring assembly becomes larger noticeably[3].

3 OBSERVATIONS

The experiments are carried out on a computerised test bench coupled with single Cylinder, Kirlosker 4 Stroke, Water cooled, direct injection diesel engine. The engine is flexibility to work at different compression ratio. It is named as variable compression ratio (VCR) test rig. The test rig is available at Institute of Technology, Nirma University. The test rig is equipped with eddy current dynamo-meter (to measure load on engine), crank angle encoder (crank angle measurement), rota-meter (flow measurement) and fuel tank with digital piezo sensor, temperature and pressure sensors etc. First the experiments are carried out on VCR engine with the manufacturer's installed piston rings and then with the new modified piston rings in order to find out the variation in various parameters. At last efficiency of the engine will be calculated & compared in both cases. Result of the engine performance with the old piston rings is as follows:

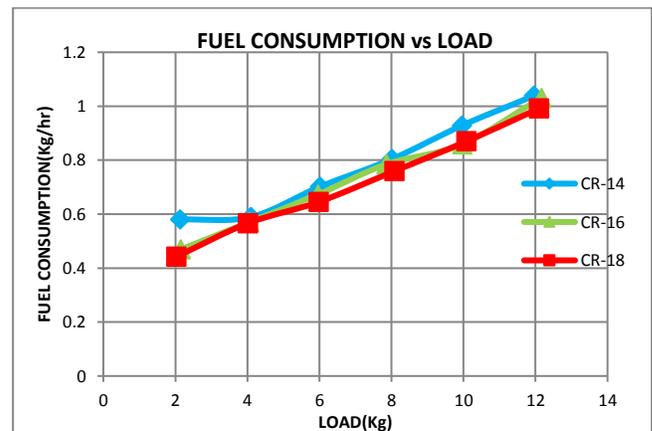


Fig. 8 Fuel Consumption Vs Load

As we can see in Fig. 8, Fuel consumption is increasing as the load on engine increases. At same load as compression ratio increases fuel consumption decreases.

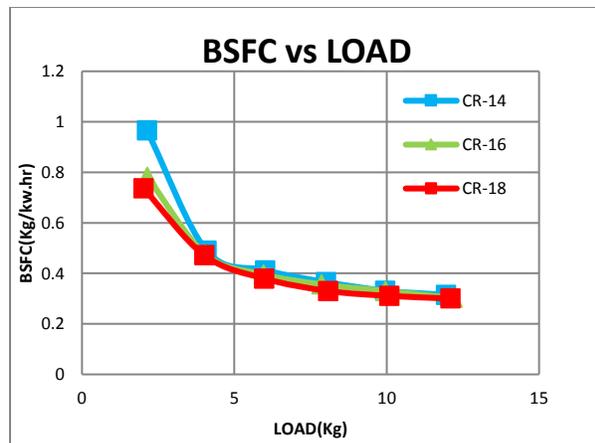


Fig. 9 BSFC vs Load

As we can see in Fig. 9, BSFC is decreasing as the load on engine increases. Also, change in compression ratio does not affect BSFC largely at high loads.

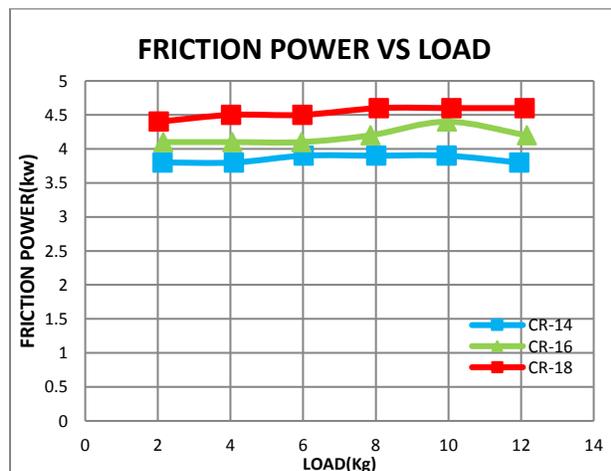


Fig. 10 Friction power vs Load

As we can see in Fig. 10, Friction power more or less remains same as the load on engine increases. At same load on the engine friction power may have higher values in lower compression ratios.

4 CONCLUSION

The Piston ring assembly is a vital component of the internal combustion engine to be focused for improving the performance. As it acts as a seal to restrict the blow by of the combustion gases from cylinder to crankcase and also restrict the excess oil on the cylinder liner walls, thereby increasing the performance as well as decreasing the emissions from the engine respectively. Piston ring assembly accounts for 30-40% of mechanical losses of engine, thus it is necessary to reduce the friction of piston rings to improve the performance of engine. There is a strong need of piston rings which reduces

the friction of engine as well as perform the function of distributing the lubrication oil and scraping the excess oil. It is observed and concluded that by employing Skewed Barrel Profile with a positive twist, Taper napier Profile with negative twist and tapered ring with negative twist in the first, second and third piston rings grooves respectively reduces a considerable amount of friction of piston rings assembly, ultimately reducing the consumption of fuel and thereby reducing the emissions from internal combustion engines significantly.

5 FUTURE WORK

Future work of this project is listed below:

To do the long term endurance test on CI engine using modified piston ring with new coating.

To do the wear, performance and emission analysis and compare the results of this analysis with results of old piston rings.

6 REFERENCES

- [1] MS Motor Service International GmbH_ Piston Rings for Combustion Engines_2nd Edition 01.2010_Article Number 50 003 958-02_ ISBN 978-3-86522-492-7
- [2] Andersson, Peter, Tamminen, Jaana, Sandstrom, Carl-Erik, 2002. Piston ring tribology- A literature survey. Espoo. VTT Tiedotteita Research Notes, 2178. PP 1-108
- [3] Wakuri, Y., Hamatake, T., Soejima, M., Kitahara, T. Piston ring friction in internal combustion engines. Tribology International, Vol. 25, No. 5, PP. 299-308, 1992.
- [4] Grant Smedley, Piston ring design for reduced friction in modern internal combustion engine, <http://dspace.mit.edu/bitstream/handle/1721.1/27129/56844809.pdf>, 2004.
- [5] Kolchin, V Demidov. Design of Automotive Engines. MIR publishers, publ. 1972.
- [6] Durga, V., Rao, N., Boyer, B. A., Cikanek, H. A. and Kabat, D. M. Influence of surface characteristics and oil viscosity on friction behaviour of rubbing surfaces in reciprocating engines. In: Proc. 1998 Fall Technical Conference ASME-ICE, Vol.312, Paper No. 98-ICE-131, PP. 2335.
- [7] Allen Comfort__An Introduction to Heavy-Duty Diesel Engine Frictional Losses And Lubricant Properties Affecting Fuel Economy – Part I
- [8] A. Sonthalia__The Effect of Compression Ring Profile on the Friction Force in an Internal Combustion Engine
- [9] C.Pettavino__Load carrying capacity and friction of a parabolic flat piston ring of finite length
- [10] Akash R. Pandya_Life Cycle Analysis of CI Engine Using Modified Piston Ring Design and Selective Coating.