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A Review Paper on Redesigned Piston Rings to Improve Engine Performance

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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 CO_2 emission. As we know that the government norms are becoming stringent day by day due to increase in percentage of CO_2 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 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. Theutilization 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 CO_2emission. Internal combustion engines such as reciprocating internal combustion engines produceair pollutionemissions, due to incomplete combustion ofcarbonaceousfuel. The main derivatives of the process arecarbon dioxideCO2, water and somesoot— also calledparticulate 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 CO_2 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.

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

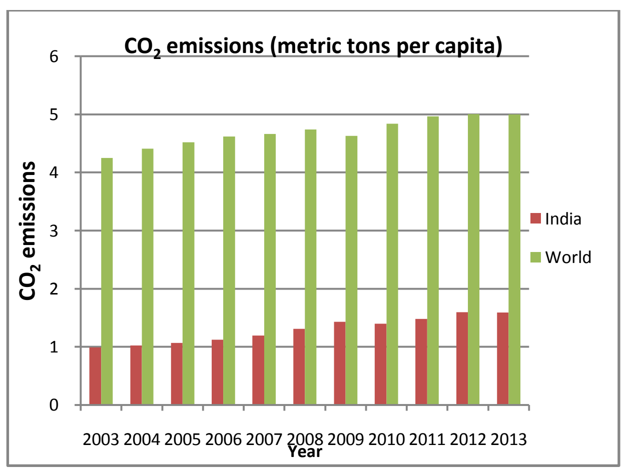

Fig. 1 CO_2 Emissions of India and World

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

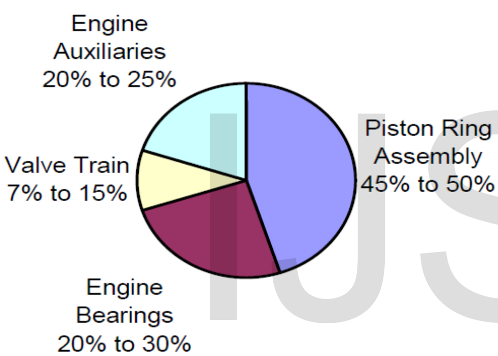

Fig. 3 Mechanical losses of IC Engine

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 contactbetween ring and liner.As in Fig. 4(c), The Taper faced ringcontacts the cylinder bore with its bottom outeredge. This shortens running-in and improves oil scraping. The gas forces acting initially at therunning faceprovide a degree ofpressure 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].

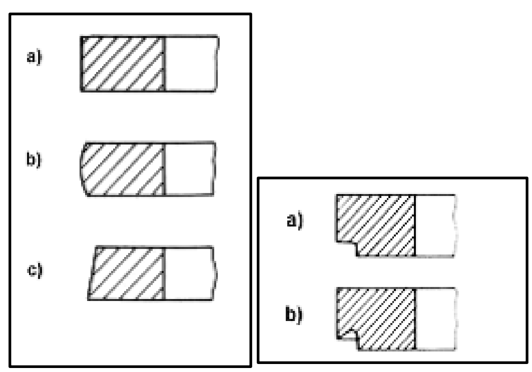

Fig. 4 & Fig. 5 Compression ring cross-section (ISO 6621-1).

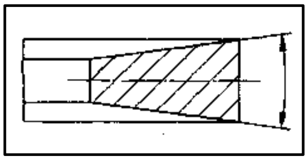

Fig. 6 Keystone ring.

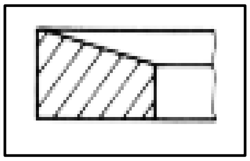

Fig. 7 Half keystone ring (ISO 6621-1).

2 LITERATURE SURVEY

There is never the best piston ring or the best piston ring assembly which can meet all the demands of the diferent operating conditons, 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 sresses due to heat generation in the cylinder. Ring shape should provide minimum friction between ring and lliner[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 molydenum.Molybdenum also gives the advantage of porous structure on the face of the ring rusulting in accumulation of lubrication oil on surface permitting the ring to run in extreme operating conditons[1]. Experimental work with new powder compositions for thermal spraying has included molybdenum-nickel-chromium alloys, chromium oxide (Cr_2O_3) with metallic chromium binder, alumina-titania (Al_2O_3-TiO_2), tungsten carbide (WC) with metallic cobalt binder, $MoSi_2$, 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].

3OBSERVATIONS

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 compressio ratio. It is named as varibale compression ration (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 fin out the variation in various parameters.At last efficiency of the engine will be calaculated &compared in both cases.Result of the engine performance with the old piston rings is as follows:

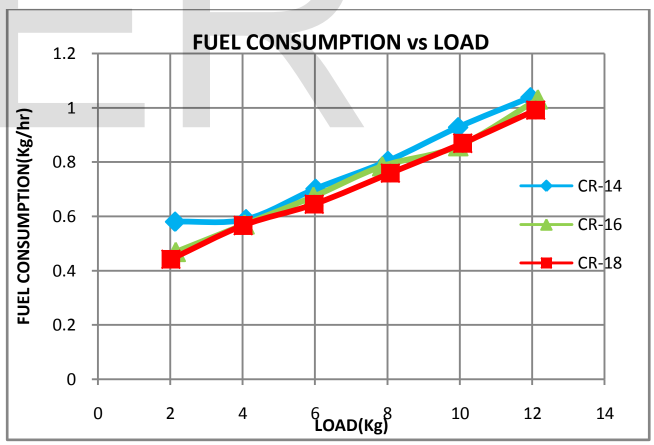

Fig. 8 Fuel Consumption Vs Load

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

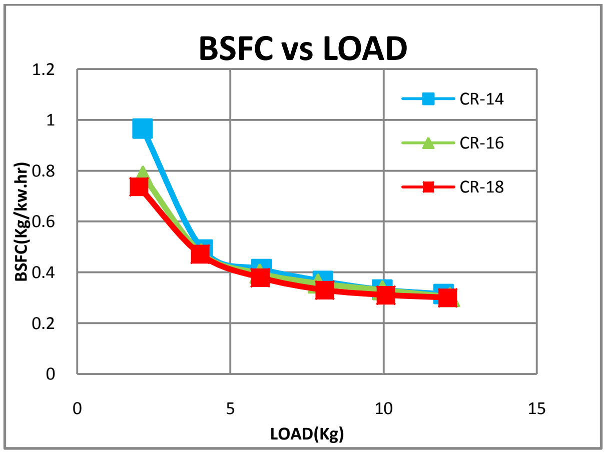

Fig. 9 BSFC vs Load

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

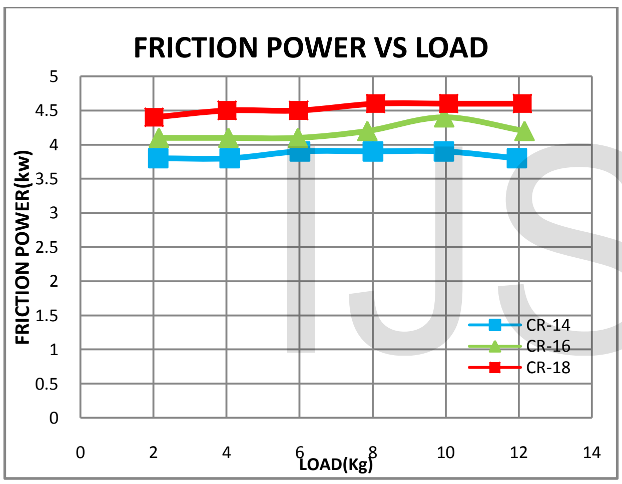

Fig. 10 Friction power vs Load

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 highre values in lower compression ratios.

4 CONCLUSION

The Piston ring assembly is a vital component of the internal combustion engine to be focuused for improving the performance. As it acts as a seal to restrict the blow by of the combustion gases from cylinderto crankcase and also restrict the excess oilon the cylinder liner walls, thereby increasng 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 strong need of piston rings which reduces the friction of engine as well as perform the fuction of distributing the lubrication oil and scraping the excess oil. It is obsereved and concluded thatby 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 withnew coating.
To do the wear, performance and emission analysis and compare the results of this analysis with results of old piston rings.

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