The Effect of Piston Ring Design Modification on Engine Performance Parameters.

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Abstract

The majority of friction in an internal combustion engine occurs between the piston ring pack and the cylinder, which significantly affects the engine's mechanical efficiency. In the piston ring pack, the compression ring is the primary source of friction, particularly at high speeds where boundary lubrication takes place. According to research, altering the cross section of the piston rings can improve engine performance. When typical piston rings are being used, their rectangular cross section generates surface contact with the cylinder liner. The engine's performance weakens as a result of higher friction losses resulting from the friction between the piston ring and the cylinder liner. The difference in pressure at the bottom part of the top ring should be maintained to a minimum so as to avoid friction. Minimizing friction on top rings involves minimizing exposure to high pressure differentials in this field since the compression and combustion processes have an influence on the pressure differential, which will not be altered in the present investigation. This can be made possible by the trapezoidal form of the piston ring. In this present study, we have investigated and compared the engine performance parameters using conventional and modified trapezoidal piston ring design .

Keywords— Piston ring; Trapezoidal; Engine performance; Internal combustion engine

1.Introduction

Improving not just combustion efficiency but also mechanical efficiency in engines can result in improved thermal balance and lower fuel usage. Reduced frictional loss is a good indicator of greater mechanical efficiency, as many engine designers and scientists have noticed. [1] The interactions of piston-cylinder, piston ring-cylinder liner, and piston-piston ring account for 30 to 50 percent of overall friction losses in an IC engine. Even a slight reduction in friction at the piston ring-cylinder liner contact may save a lot of fuel and reduce pollutants. [2,3] The piston rings move around freely in their grooves, and their motions are determined by the force exerted on the piston ring mechanism, which include ring tension from the piston ring's location in the cylinder, fuel gas forces from combustion and blow-by, hydrodynamic force from the ring mass, engine speed, and asperity contact stress between both the ring and cylinder walls.

1.1 Methods for Reducing Friction

Peak pressures inside the cylinder are created in an engine under heavy load circumstances via compression and ignition. The top ring progressively conforms to the lower grooves flank as the pressure in the cylinder increases over the compression stroke, as shown in figure1. If there is no oil in between ring and the liner in this area around TDC of compression/expansion, then the top ring conforms nicely to the bottom groove side. The frictional force operating on the top ring is due to pure boundary lubricating condition, and can therefore be calculated by multiplying the radial load pressing on the rear of the ring by the coefficient of friction:

$$F_f = a_{asp} [(P1 - P2) B2 + W] \quad (1)$$

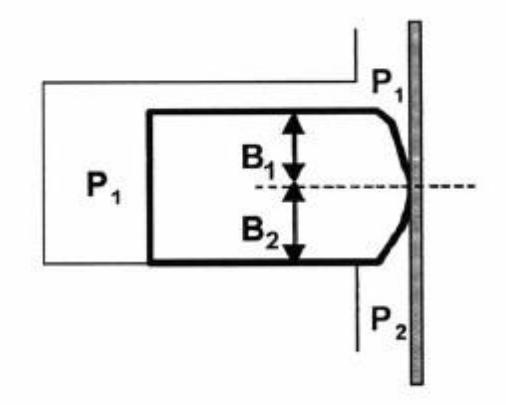

Figure 1 Illustration of the Top Ring near TDC of Compression. [4]

Where, a_{asp} is the coefficient of friction between the ring and the liner, and W is the ring load due to tension. The pressure term usually surpasses the ring load due to tension by at least an order of magnitude because of the high pressures created around TDC of compression. As a result, friction-reduction designs should prioritize lowering the contribution of the pressure differential operating on the bottom half of the top ring. Because the pressure difference is regulated by the compression and combustion processes, which will not be altered in this research, lowering the surface exposure to the high differential pressure is the most effective strategy to minimise top ring friction in this region (i.e. B2). [4] The physical lengths of the region effected by high pressures (i.e. B1 and B2) can also be lowered by manufacturing the top ring of improved cross section. The trapezoidal geometry of the piston ring, which is explained in the following paragraphs, can accomplish this. The region over which the high pressure differential acts is obviously reduced by this design, which decreases the friction created in between top ring and the liner in this region.

1.2 Design of the Piston Ring

Piston rings are subjected to high temperatures and a wide range of stresses. Cast iron or alloy cast iron is used to make them. The ratio of the cylinder diameter to the radial thickness of the piston ring is D/t; the ratio of the difference in between ring lock gaps in the free and working states to the ring thickness is A_0/t; and the ring width is a. Figure 2 depicts a piston ring geometry. Table 1 list the constructional specifications of piston rings used in gasoline and diesel engines.

Table 1 Design data for piston ring [5]

Description	**Equation (mm)**
Radial thickness of compression ring, t	(0.04 – 0.045) D
Piston ring width, a	3 – 5
Difference between free gap and compressed gap of compression ring, A_0	(3.2 – 4.0) t
Radial clearance of compression ring in piston groove, Δt	0.70 –0.95

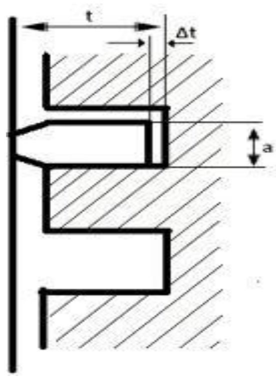

Figure 2 Piston ring diagram

Here, cylinder diameter(D) is taken as around 82.85mm. So from the Table 1, values of different parameters are calculated which are shown in Table 2

Table 2 Values of different parameters of piston ring

Parameter	**Value (mm)**
t	3.4
a	3
A_0	10.88
Δt	0.7

Aside from these figures, the shorter width of a trapezoidal ring is 1.4mm, the length of two inclined sides of a trapezoidal ring is around 1.1mm, and the angles of inclined sides with their respective base sides are about 45°. Figure 3 depicts the suggested trapezoidal piston ring.

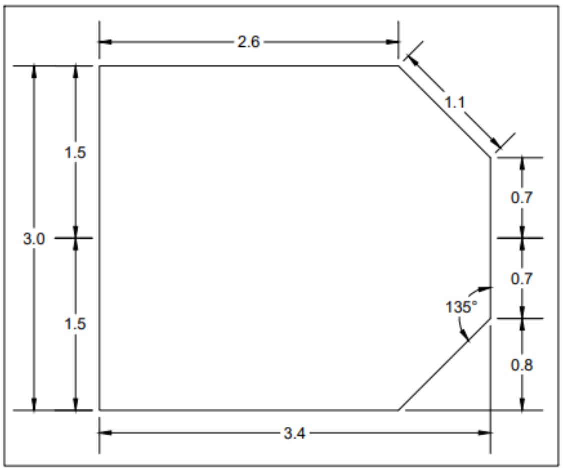

Figure 3 Proposed Trapezoidal Piston Ring

2. Experimental Setup

The testing is carried out on a computerized test setup using a water-cooled single-cylinder Kirlosker 4-stroke direct injection diesel engine. An eddy current dynamo-meter (for monitoring engine load), a crank angle encoder (for determining crank angle), a rota-meter (for measuring flow), and a gasoline tank outfitted with pressure and temperature sensors, as well as a piezo electric sensor are all part of the test rig. All of the sensors are linked to the control panel. On the control panel, you'll find the Dynamometer Loading Unit (DLU). By changing the DLU knob, the load (in kg) may be applied to the engine. The control panel is linked to the device through a USB cable, allowing for the entry of all data. "Engine Soft "is the software used to analyze engine performance. Scholars can use the set - up to look into VCR (Variable Compression Ratio) engine output variable like brake and frictional power, BMEP, brake thermal efficiency and indicated thermal efficiency, specific fuel consumption, mechanical efficiency and volumetric efficiency, and many other things like the A/F ratio, heat balance, and combustion analysis, injection pressure and injection timing at different compression ratios. [6,7]

The structural layout is shown in figure 4. The engine was put through its paces in accordance with Indian regulations, which outline the criteria for repeatability of trials in order to determine the amount of power, performance, and fuel consumption. It also discusses the correction factors that must be applied to the observed data readings in relation to the reference circumstances.

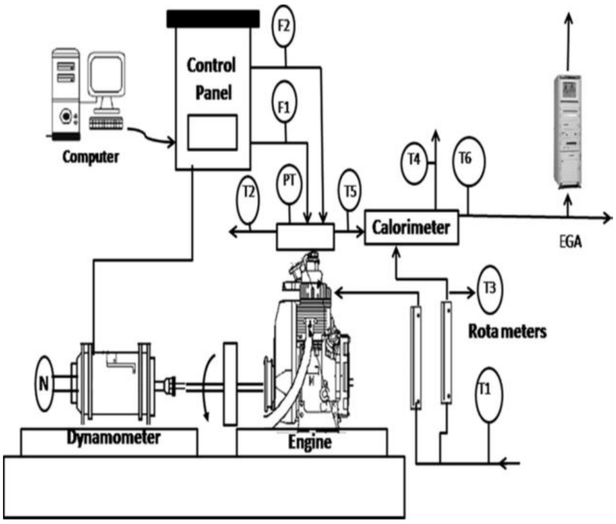

Figure 4 Line diagram of the experimental setup used in the present study. T1 - inlet (engine) water temperature (°C), T2 - outlet (engine) water temperature (°C), T3 - inlet (calorimeter) water temperature (°C), T4 - outlet (calorimeter) water temperature (°C), T5 - exhaust gas temperature before calorimeter (°C), T6 - exhaust gas temperature after calorimeter (°C), F1 & F2 - fuel consumption and air flow measurement, PT - Pressure transducer, EGA - exhaust gas analyzer and N - engine speed measurement. [6,7]

3. Engine Performance During long run endurance test

Various engine parameters are discussed below during long run endurance test with conventional piston ring design and with modified piston ring design.

3.1 Brake thermal efficiency

Brake thermal efficiency, also known as fuel conversion efficiency, is a function of the quantity of heat energy supplied from the fuel. It is used for the determination of the utilization of fuel for mechanical work conversion. It is the ratio of the heat equivalent to one kW hour to the heat in the fuel per B.P. hour. From the graph as shown in figure 5 it is clear that after 256 hours of engine running improvement in brake thermal efficiency with modified piston ring design is about 3% whereas after 512 hours 5% increase, we get at a cost of little bit increase in fuel consumption. The increase in the break thermal efficiency can be explained as follows:

Note that the friction power is found to be decreasing with modified piston ring as compared to conventional piston ring. The reduction on friction power led to increase in break power. Furthermore, the fuel consumption (due to reduction in blow by losses) is found lower with modified piston ring. The overall effect of the same leads to increase in break thermal efficiency.

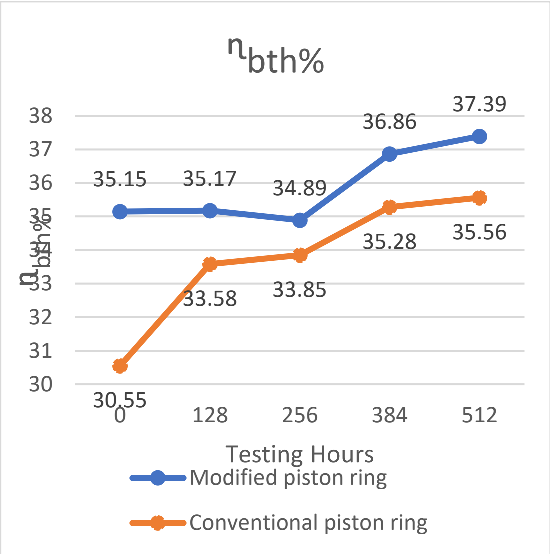

Figure 5 Break thermal efficiency graph

3.2 Specific fuel consumption

Fuel consumption per unit time is important parameters to calculate friction power. Chart as depicted in figure 6 shows that in the beginning there is more difference between modified and conventional piston ring testing. As the hours will increase this difference will reduce with time. After 512 hours modified piston ring set has little bit more specific fuel consumption with respect to conventional one. As stated above the fuel consumption is found lower with modified piston ring. It is interesting to note that the less contact area between the piston ring and the cylinder linear is available in case of modified piston ring. The reduction in the contact area not only reduces the friction power but also helps in reducing the blow by and crevice loses. The reduction in blow by and crevice losses generates more complete combustion with higher peak pressure resulting in reduction in fuel consumption with modified piston ring.

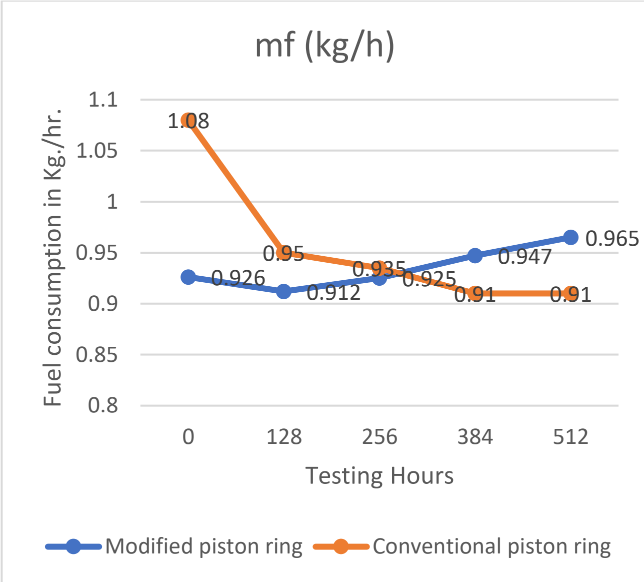

Figure 6 Specific fuel consumption graph

3.3 Brake specific fuel consumption (BSFC)

Brake-specific fuel consumption (BSFC) is a measure of the fuel efficiency. It is the rate of fuel consumption divided by the power produced. It may also be thought of as power-specific fuel consumption, for this reason. BSFC allows the fuel efficiency of different engines to be directly compared. Brake specific fuel consumption is the ratio of fuel consumption in kg/hr to the brake power (kW). So its units are kg/(hr-kW). It is indicative of how much fuel is consumed in producing 3.6*10^6 joules of energy or a power of 1kW for 1 hour. As stated above the modified piston ring results in decease in the fuel consumption and increase in break power output. Thus, the break specific fuel consumption is found to be lesser with modified piston ring as compared to conventional piston ring as depicted in figure 7. The BSFC of modified piston ring is found to be more after 256 hrs of engine operation. This may be due to increase in wear of modified piston ring.

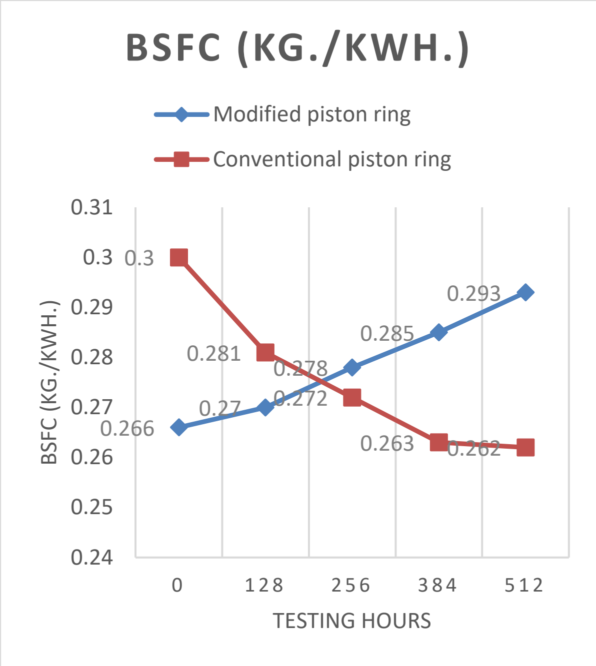

Figure 7 BSFC graph

3.4 Brake specific energy consumption (BSEC)

Brake specific energy consumption is the ratio of energy obtained by burning fuel for an hour to the actual energy or Brake power obtained at the wheels. It is dimensionless. It is indicative how effectively the energy obtained from the fuel is reaching the wheels. BSEC is reciprocal of break thermal efficiency. The results clearly show as depicted in figure 8 that the BSEC with modified piston ring is less as compared to conventional piston ring.

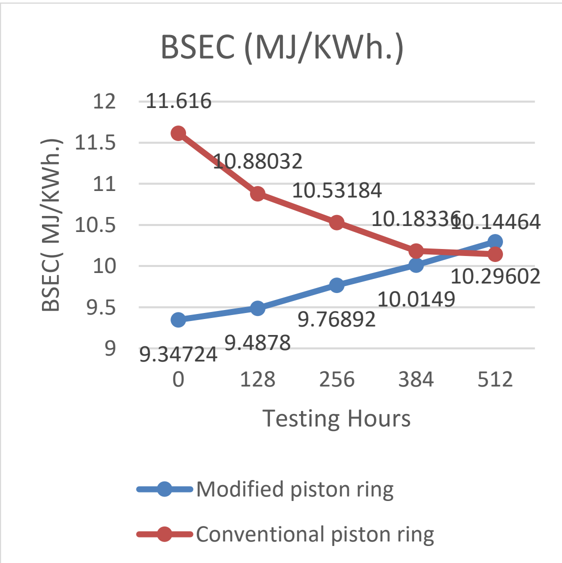

Figure 8 BSEC graph

4. Conclusion

1. The redesigned piston ring reduces fuel consumption while increasing break power output. As a result, the redesigned piston ring has lower break specific fuel consumption than the normal piston ring. The BSFC of modified piston ring is found to be more after 256 hrs of engine operation. This may be due to increase in wear of modified piston ring.
2. The reduction in the contact area of modified piston ring not only reduces the friction power but also helps in reducing the blow by and crevice loses. The reduction in blow by and crevice losses generates more complete combustion with higher peak pressure resulting in reduction in fuel consumption with modified piston ring.
3. The friction power is found to be decreasing with modified piston ring as compared to conventional piston ring. The reduction on friction power led to increase in break power. Furthermore, the fuel consumption (due to reduction in blow by losses) is found lower with modified piston ring. The overall effect of the same leads to increase in break thermal efficiency.

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