STUDY OF TRIBOLOGICAL PARAMETERS ON SI ENGINE – A CASE STUDY

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ABSTRACT

The tribological consideration in the contacts formed by piston ring assembly have attracted more attention over several decades. @ 13-17% of total frictional losses observed in I.C. engine and 35-50% of total friction losses is due to PRA system. This paper reports a set of experiments were carried out on developed experimental setup at laboratory scale to measure PRA friction of multi cylinder 800 cc engine system indirectly by measurement of power consumption by Strip Method. In experiment the fabricated test rig of 800 cc multi cylinder internal combustion engine system with crank mechanism and without gear box is used. . Crank shaft is coupled with induction motor to drive the engine. A.C. motor with variable frequency drive (VFD) is used to vary the engine speed. The temperatures at different locations are measured by RTD temperature sensors. The experimental results and observations are carried out under different operating conditions in speed ranges from 600 rpm to 2400 rpm.

KEYWORDS

Piston Ring Assembly, Friction Losses, Power Consumption

1. INTRODUCTION

The performance parameters which reduce the efficiency of an I.C. engine are different mechanical losses, like direct friction losses, pumping loss, blow losses, valve throttling losses. These are many geometrical parameters and physical parameters which are responsible for the frictional losses, like stroke to bore ratio, cylinder size and number of cylinders, compression ratio, engine speed, engine load, cooling water temperature, oil viscosity, and number of piston rings. It is understood that the piston ring assembly accounts for the larger part of the mechanical losses in the form of friction in the engine. There are various techniques of measuring piston ring assembly friction. In experiment, motorised test rig is used for non fired engine system of multi cylinder 800 cc engine and strip method is used to measure friction in terms of power consumption but in this method the effect of cylinder pressure are not measured and test will not be operating at realistic temperatures. Also, power consumption in different operating conditions are measured by running the PRA system with all three pistons and without second piston (only with two pistons 1&3).

2. PREVIOUS RESEARCH

Mufti and Priest [1] have measured the piston assembly friction losses under fired condition on a single cylinder Ricardo Hydra Gasoline car engine using the IMEP method and found that piston assembly friction found approximately double during power stroke and compression stroke in comparison to suction and exhaust stroke in an engine cycle at different all speeds. Also, they observed that power loss by first compression ring is always found approximately 33% higher than that of second ring at different operating conditions and piston assembly friction losses by both rings also observed about 30-35% of total power losses at all different operating speeds. Hamatake et. al. [2] studied the frictional behaviour of piston ring assembly by varying no. of piston rings and concluded that to reduce the friction losses, decrease the number of rings. Hoshi [3] has experimented on 1300CC 4-cylinder petrol engine at speeds 2000 rpm without load and at 5000rpm with full load by using lubricating oil as SAE 10W30 at constant temperature of 800 ^{0}C and concluded that by changing the piston shape and reducing cross section, friction losses in piston assembly system were reduced by 23% that amounted to 9-11.5% of total friction losses. 3% of total frictional losses reduced by reducing slightly diameters and width of bearing on crankshaft and connecting rod. Estimated total % frictional losses were observed at 2000rpm and at 5000rpm were 21%and 17% respectively. Tateishi [4] has experimented to reduce piston ring friction losses by applying two-ring package instead of the standard three ring packages and by developing low viscosity engine oil, reduction in piston mass, piston ring width and piston ring tension. Reduction of piston ring tension and using two ring packages are effective in reducing piston ring friction and reduction of piston ring friction can contribute to reducing the fuel consumption by several percentages. Wong [5] have done experiments and found that the PRA friction force was found to increase linearly with piston speed, decrease with increasing oil film temperature and slightly increase with gas pressure. Bolander et al.,[6] have developed the numerical model to investigate the effects of surface modifications on the lubrication condition and frictional loss at the interface between a piston ring and cylinder liner and observed that the modified cylinder liner was shown to reduce the cycle-average friction coefficient by 55-65%, while total energy loss per cycle was reduced by 20-40%. Taylor [7] suggested a procedure to calculate PRA friction loss by solving Reynolds equation. The calculation of oil film thickness under the piston rings involves solving Reynolds equation, using the appropriate piston ring profile and taking into account the variable speed of the piston ring as the piston moves from BDC to TDC. It is also necessary to know the gas pressure on either side of the piston ring, the piston ring temperature and the liner temperature at the piston ring position. If all these parameters are known, then the oil film thickness and friction force of the piston ring may be calculated. Noorman [8] measured friction by motoring of an engine by an electric dynamometer and found that motoring friction was found to increase with speed. Ting [9] have used test bench for measurements and showed that PRA friction force was found to increase linearly with the piston speed and found that use of low viscosity oil cause sudden increase in wear at TDC and BDC. Bhatt and Mistry [10] have experimented on 150CC motorized test rig by using different lubricants and operating the the system for speed ranges from 500 to 2000rpm and observed that ring geometry played important role to reduce piston ring assembly friction. Nautiyal et. al.,[11] have studied friction and wear process in piston rings and friction co-efficient were investigated on a modified Bowden-Leben machine using actual segments of piston ring and cylinder liner and found that co-efficient of friction remains more or less constant with increase in oil temperature and large part of top piston ring wear takes place during boundary lubrication around TDC position. Sharma [12] has experimentally studied the various parameters of the engine tribology and experimented with various application of the piston ring geometry at low profile at the piston ring edge and offered a co-relation in the form of equations with a different constant of system.

3. EQUIPMENT AND EXPERIMENTAL METHODS

3.1. Test Rig Specifications

The fabricated test rig of 800-CC multi cylinder internal combustion engine system with crank mechanism, piston cylinder head, and engine lubrication system, with engine cooling system, without gear box is used. Crank shaft is coupled with induction motor to drive the engine. A.C. motor with variable frequency drive (VFD) is used to vary the engine speed. The performance variation is measured in terms of power consumption through multi-functional wattmeter. Temperature (^{0}C) at different nine locations measured through RTD temperature sensors.

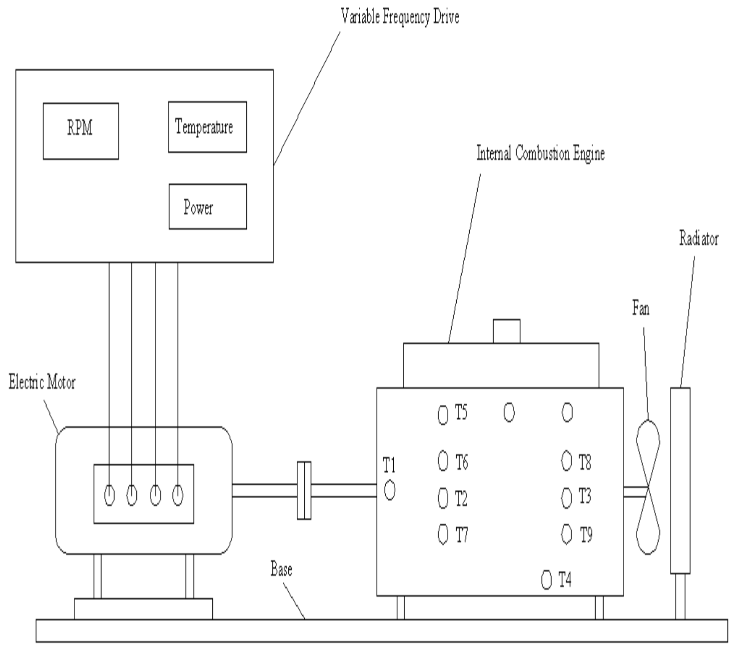

Figure 1. Block diagram of multi cylinder I.C. engine motorized test rig

Table 1. Engine specifications

Type	**4 stroke cycle, water cooled**
No. Of cylinder	3
Cylinder bore size	68.505 – 68.520 mm
Stroke length	72 mm
Piston displacement	796 CC
Compression ratio	8.7 : 1

Table 2. A.C. Motor drive specifications (VFD)

Model number	**VFD – XXXB**
Max. applicable motor output	7.5 KW
Rated output capacity (KVA)	13.4
Rated output current (A)	13.5

3.2. Lubricant and coolant

Lubricating oil - Maruti Genuine Oil (MGO)
Coolant used – Puroguard

3.3. Temperature sensor specifications

PT 100 type temperature sensors ranging from – 0^0C -250 ^{0}C are used.
Locations of Nine Temperature Sensors are as mentioned below which are already shown in figure 1.

- T1 – Bearing temp
- T2 – Cylinder 1 (centre)
- T3 – Cylinder 3 (centre)
- T4 – Oil temp.

- T5 – Spark Plug
- T6 – Cylinder 1 (TDC)
- T7 – Cylinder 1 (BDC)
- T8 – Cylinder 3 (TDC)
- T9 – Cylinder 3 (BDC)

3.4. Experimental methodology

The experimental work is carried out on developed multi cylinder I.C. engine test rig under different variables. i.e., speed, ring geometry. In experimental work the strip method is used. It is generally adopted to get the first impressions about frictional losses of multi cylinder engine (unfired) and also the frictional losses of various components. The set of experiments were carried out under different operating conditions in set of all 3 pistons and set of 2 pistons (without 2nd piston) in speed ranges from 600 rpm to 2400 rpm.
Steps of Experiment
The test sequences to conduct the experiment on Multi Cylinder IC Engine Test Rig are as follows.

(1) First of all select the operating condition and lubricating oil.

(2) Prepare the engine for selected operating condition.

(3) Check the foundation of test rig.

(4) Check all electrical connection of test rig including VFD & watt meter etc.

(5) Switch on the power supply & set the frequency on VFD to required rpm.

(6) Now switch on the VFD, as soon as the VFD is on, the motor will start to operate engine.

(7) Initially the system is to be run for at least 5 to 10 minutes, so that the system get stabilize & the lubricating oil can reach properly up to the surface of piston ring & cylinder liner.

(8) After getting the stable condition of the system, record the actual power consumed by the system, rpm of the system and also the temperature of different nine locations of an engine

(9) Now for the next observation, change the frequency on VFD to change the rpm of the system and allow time to get stabilize the system. Then further record the actual power consumed by the system, rpm of the system and also the temperature of different nine locations of an engine.

(10) During changing the rpm, there is no need to switch off the power.

(11) Repeat the step 5 & 6 for measuring the power consumed for different revolution of the system.

(12) Then switch off the power supply & allow the system to come in rest condition.

(13) Now repeat the same procedure for another measurement

4. RESULTS AND DISCUSSION

The power consumed by the engine was recorded for different operating conditions at different engine speed are plotted in graphical way.

4.1 Power consumption in different operating conditions of PRA system of three pistons

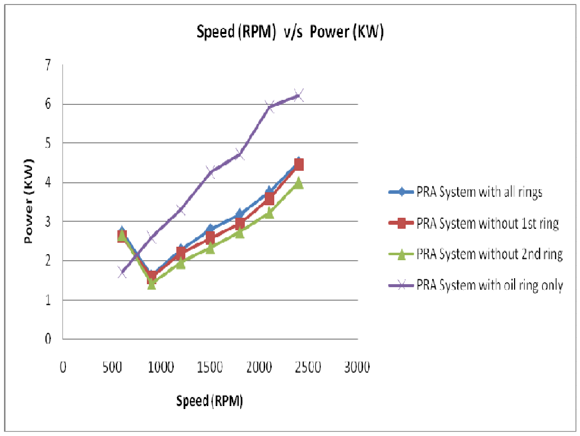

Figure 2. Speed (RPM) v/s Power consumed (KW)

Graph 1 shows power consumed (KW) in different operating conditions of PRA set of three pistons at different speeds in rpm.

PRA system without 1st piston ring

- Power consumption is less as compared to PRA system with all rings at all observed speed.
- The variation in power reduction varies between 2 to 8% in comparison to power consumption value of PRA system with all rings.

PRA system without 2nd piston ring

- Power consumption is less as compared to PRA system with all rings at all observed speed.
- The variation in power reduction varies between 2 to 16% in comparison to power consumption value of PRA system with all rings.

PRA system with oil ring only

- In PRA set with oil ring only, except 600 rpm power consumption is higher as compared to PRA system with all rings for all observed speed.

- The variations in power were observed 27 to 37% higher in comparison to power consumption value of PRA system with all rings except 600 rpm.

4.2 Power consumption in different operating conditions of PRA system of pistons 1&3 (without 2nd piston)

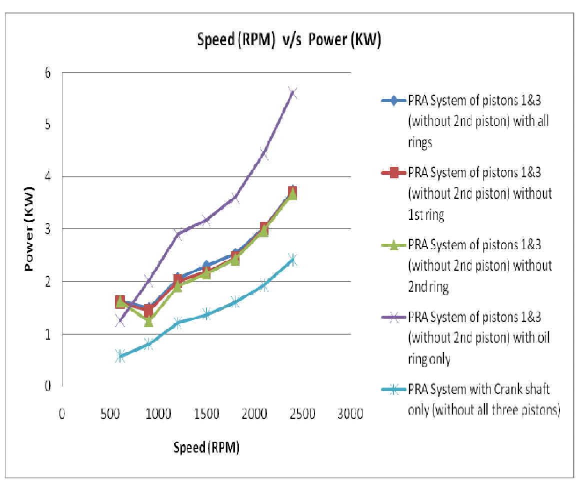

Figure 3. Speed (RPM) v/s Power consumed (KW)

Graph 2 shows power consumed (KW) in different operating conditions of PRA set of pistons 1&3 (without 2nd piston) at different speeds in rpm.

PRA system of pistons 1&3 (without 2nd piston) without 1st piston ring

- Power consumption is less as compared to PRA system of pistons 1&3 (without 2nd piston) with all piston rings at all observed speed.
- The variation in power reduction varies between 1 to 5% in comparison to power consumption value of PRA system of pistons 1&3 (without 2nd piston) with all piston rings.

PRA system of pistons 1&3 (without 2nd piston) without 2nd piston ring

- Power consumption is less as compared to PRA system of pistons 1&3 (without 2nd piston) with all piston rings at all observed speed.
- The variation in power reduction varies between 1 to 12% in comparison to power consumption value of PRA system of pistons 1&3 (without 2nd piston) with all rings.

PRA system of pistons 1&3 (without 2nd piston) with oil ring only

- Except 600 rpm power consumption is higher as compared to PRA system of pistons 1&3 (without 2nd piston) with all rings for all observed speed.
- The variations in power were observed 26 to 33% higher in comparison to power consumption value of PRA system with all rings except 600 rpm.

PRA system with crankshaft only (without all three piston)

- Power consumption increases with speed linearly.

So, from above results, discussion takes place that PRA system with all rings consumes more power than PRA system without 1st and 2nd ring respectively. Also, PRA system without both rings consumes 26-37% more power than PRA system with all rings which is nearer to [1]. It means that maximum frictional losses in PRA system occurs when running the engine without both (1st & 2nd) rings and minimum frictional losses occurs when running the engine with 2 rings only. These results are in line with [2] and [4]. Also, PRA friction force was found to increase linearly with piston speed which is match with results of [5] and [9]

5. CONCLUSION AND FUTURE SCOPE

Referring all the results for the experiment carried out under different operating condition it can be concluded that frictional power loss contribution by individual piston ring varies under different speed. Nature of curve of power consumption of PRA system with is in line with Stribeck curve nature, which means initially the system operates in boundary (at 600 rpm) or mixed lubrication condition (at 900 rpm) and later on (after 900 rpm) mixed to hydrodynamic lubrication condition. Performance effect of change in piston ring geometry can also be experimented and compared with standard set of PRA system performance.

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