A Review on Tribological Wear Investigation of Power Cylinder in Diesel Engine

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Abstract-

As a demand of more efficient and eco-friendly engines is increasing, new technologies are developing. To approach towards the efficient and eco-friendly engines, study of factors that affect the engine’s life and its performance is required. Also the stringent emission norms and increasing demand for engines with higher power density lead to extensive investigation of the parameters that affecting combustion performance. Wear is one of the important parameter, which reduces the life of engine and also it is considered important for the control of oil consumption, emissions, and reduced friction. The tribological performance in IC engine can be understood when friction and wear are considered. This review paper lists the studies made on Cylinder liner, Piston rings interfaces tribological wear investigations. Published data on wear have been collected from various researchers concluded from their experiments and experiences.

Keywords—Wear, IC Engine, Lubrication, Piston, Piston Ring, Cylinder Liner, Friction.

I. INTRODUCTION

Tribology is the science and engineering of interacting surfaces in relative motion. It includes the study and application of the principles of friction, lubrication and wear. Wear is a process of interaction between surfaces, which causes the deformation and removal of material on the surfaces due to the effect of mechanical action between the sliding faces. Also plastic deformation leads to wear; it causes the deterioration of metal surfaces, which is known as "metallic wear". From the view point of triboelement it is very important to know the specific load, speeds and temperatures for the major components of engine like piston assembly, valve train, the journal bearing and lower viscosity engine oil for lubrication. In this paper details of studies made on Cylinder liner and Piston rings interface wear determination from various research papers are listed.

Piston rings are important elements in the internal combustion (IC) engine. Their prime function is to facilitate smooth running of reciprocating part and dynamically seal the distance between the moving piston and the cylinder liner interface to prevent the escape of the combustion gases from the combustion chamber into the crankcase and at the same time to reduce the leakage of the lubricating oil from the crankcase into the combustion chamber. During the running of an IC engine, the hydrodynamic oil film at the interface between the different rings and liner is preferred. Optimum lubricating film reduces both engine wear and friction and enhances engine life [1]. The performance, durability and exhaust emissions are greatly affected by the phenomena of lubrication at the rings and liner. Wear of the cylinder liner is caused to a great extent by the action of the piston rings. As per the author in [1] practical observations and theoretical analyses correlate well in terms of the strongest wear of the cylinder liners taking place in the vicinity of the top reversal point of the top piston ring, where the thermal, chemical, erosive, adhesive and abrasive conditions are the severest. Also high sulphur content of the fuel can increase the proportion of tribochemical wear of the cylinder liner dramatically, particular at low cylinder surface temperatures. High wear of the cylinder liner is furthermore associated with the top reversal point next to top piston ring, and to a less extent with the bottom reversal points of the piston rings. Carbon deposits above the ring pack on the piston may significantly increase the cylinder liner wear near the TDC region. It is also necessary to study the factors influencing reliability and performance along with wear.

The lubricating film of oil allows smooth friction free translatory motion between rings and liner. Of the three rings present top ring is more crucial as it does the main work of restricting gases downwards the crankcase [2]. Boundary lubrication is present at the Top dead centre (TDC) and Bottom dead centre (BDC) of the liner surface. In addition to this, top ring is exposed to high temperature gases which make the oil present near the top ring to get evaporated and decreasing its viscosity, making metal–metal
contact most of the time. Due to this at TDC, excess wear happens on the liner which is termed as Top ring reversal bore wear [2]. This paper explains the studies made on Cylinder liner and Piston rings interface. Published data on wear have been collected from various researchers concluded from their experiments and experiences.

II. METHODOLOGY

The step by step approach used in this paper is listed below and also shown in figure:

1. Study of wear location and Parameters of Piston Ring & Cylinder Liner Assembly Components;
2. Literature Review for Different Methods Related to Wear;

Fig No.1 Methodology of the Review Paper

1. Study of Wear location and Parameters of Piston Ring & Cylinder Liner Assembly Components

Piston Assembly, Valve train, Journal bearing, etc., are the major components which encounters heavy wear. Almost 40% of wear takes place in piston ring and cylinder liner assembly [3]. Boundary lubrication is present at the Top dead centre (TDC) and Bottom dead centre (BDC) of the liner surface. In addition to this, top ring is exposed to high temperature gases which make the oil present near the top ring to get evaporated and decreasing its viscosity, making metal-metal contact most of the time. Thus the locations which are critical from liner wear point of view are shown in Fig.2. The surface finish at liner ID contains fine plateaus which are required for good load bearing capacity and deep valleys required for oil retention. For piston rings wear occurs at ring running face and ring sides. Due to wear of rings ring closed gap, ring radial and axial wall thickness and also tangential load changes. All these parameters and surfaces where wear occurs are marked in Fig.3.[4]
In addition to the conventional methods, advanced methods are used by various authors for wear measurement. The list of the parameters is shown in Table 1. The second column lists various dimensions or parameters and the third column lists the corresponding method used to measure that parameter. The details of all the listed parameters are given in later in this paper.
3. Study of Wear Measurement Methods:

There are various methods used by various authors in their research work to quantify the wear. The various methods and their details are provided in this section.

Conventional Methods:-

A. Gap Between the ring, Axial thickness and radial thickness:

Measurement of the ring gap variation is done by putting the ring in the gauge with nominal bore diameter and value was determined using filler gauge. Measurement of the ring gap is necessary because it will affect Blow By and Lube Oil Consumption (LOC) which will affects wear of the engine. If the gap is too small, the ends of the ring may collide which can lead to the ring breaking, scoring the bore, and eventually lead to complete breakdown. [6]. Radial thickness and axial thicknesses are measured using micrometer.

B. Liner diameter measurement

Liner diameter is measured using dial gauge in conventional method.

Advanced Methods:-

A. Ring Running Face Wear (Qualitative method):

For the observation of the ring running surface in [5] author has used Electron Probe Micro Analysis (EPMA) method. Author has used this method to compare condition of top ring with & without EGR. As shown in figure white vertical streaks on the ring running surface were visible when soot is mixed with the lubricating oil and also when soot is not mixed. [5]
B. Top Ring Wear (Qualitative method):

In [5] author has used running face trace method to compare wear with two types of liners. Fig.7 shows changes of top ring wear in accordance with the engine operating time. Wear of the top ring increases due to EGR when a boron steadite cast iron liner is used. When a pearlite matrix cast iron liner is used, wear of the top ring is less. [5]

C. Liner Localized wear at TDC:

Top ring is exposed to high temperature gases which makes the oil present near the top ring to get evaporated and decreasing its viscosity, making metal-metal contact most of the time. Due to this at TDC, excess wear happens on the liner which is termed as Top ring reversal bore wear as shown in Fig. 4[2]. Measurement of the localized wear at the TDC is done through a graph of the bore surface profile in axial direction with high magnification in relation to a reference line that linked worked and unworked region as shown in Fig.5[6].
D. Measurement of Polished Areas to determine liner wear:

Liner measurement is done with measuring the polished area of liner; this is done by cutting the liner through the diameter in the longitudinal direction. Marking of the polished area from the TDC of the top ring to BDC of the third ring. Measurement of area is as total working areas. The abrasive material will increase the rate of wear of the liner. This is generally caused by insufficient lubrication due to which a large amount of heat is produced and microscopic welding of rings and liner surface takes place. [6]

E. Measurement of Surface Finish:

The Abbott-Firestone curve describes the surface texture of an object. The curve could be found from a profile trace by drawing lines parallel to the datum and measuring the fraction of the line which lies within the profile. It is useful for understanding the properties of sealing and bearing surfaces. The shape of the curve is distilled into several of the surface roughness parameters, especially the Rk family of parameters. Mathematically it is the cumulative probability density function of the surface profile's height and can be calculated by integrating the profile trace. [9] This measurement of abbot curve is used by author in [10] as shown in figure 9.

Fig No.6 Top ring reversal bore wear [2] Fig No.7 Localized Wear of Measurement [6]

Fig No.8 Abbott- Firestone’s Curve[9]
III. SUMMARY

After the detailed study of the published data the following points have been summarized:
1. As per conventional method wear is determined by diameter measurement. As maximum wear of liners occurs at top ring top reversal region and in ring travel zone. Wear of liner can be measured by advanced methods like surface finish measurement and using graph of surface profile.
2. Conventionally wear is measured by measuring closed gap, radial & axial thicknesses. Maximum wear of rings occurs at ring running face and Ring wear can be measured by advanced methods like graph of running face and side’s surface profile.

IV. CONCLUSION

Various quantitative as well as qualitative methods of wear measurement are available in various literatures which help in determining wear of liner and piston more accurately as compared to conventional methods of wear measurements like liner diameter measurement, closed gap measurement, thickness measurements. These methods give more accurate wear measurement and helps in better investigation of wear mechanisms.

V. REFERENCES

[1] Friction and Wear of Tribo-Elements in Power Producing Units for IC Engines- A Review Roop Lal#1, R C Singh*2, Ranganath M S*2, S Majri*3 #1 Assistant Professor,*2 Associate Professor,. *3 Professor,Department of Mechanical Engineering, Delhi Technological University, Delhi, India