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An Overview- Tribological Aspects at the Interface of Piston Ring and Cylinder Liner for Improving the Performance of IC Engine

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Abstract *: The scientists are reluctantly working on tribo-pairs to determine the tribological effects between them under different condition of lubrication. I. C. Engine is one of the major inventions which effects human life of civilization. There are many parts in I.C. engine which have relative motion among them. The most important part is piston ring and cylinder liner. Continuous dynamic loading and motion plays at the interface of them. The intrinsic international norms forced researchers to concentrate on power producing units and alternative source of energy. An overview pertaining to tribological aspects for improving the performance of IC engine has been carried in this paper.*

Keywords : *IC engine, Chemical and mechanical energy, Lubrication, Piston ring pack Face profiles, complex motion.*

I. INTRODUCTION

Internal combustion engine (IC) as shown schematically in Fig. 1 is the most important mechanical invention done by human beings, which has played great role in the industrialization of the globe after world war-II. But, now due to fast depletion of conventional fuel resources and increasing environmental issues, there is worldwide relentless pressure on the researchers to develop ever more fuel efficient and compact IC engines having reduced environmental issues. In the last couple of decades, there have been many studies on the frictional evaluations at the various interfaces in IC engines in order to identify the crucial interfaces of the engine components for minimizing the interfacial frictional losses associated with it.

An Overview- The major portion of fuel energy (i.e. chemical energy) goes as waste in the form of heat. Even, significant portion of chemical energy liberated during the combustion of precious fuel is consumed in the frictional resistance present at the various interfaces of the moving engine components. Fig. 2a illustrates percentage of chemical energy taken away by various modes in a typical IC engine. It can be seen that the portion of chemical energy consumed in friction during mechanical motions in a typical IC engine is considerably large. Moreover, Fig. 2b also provides break ups of frictional losses in a typical IC engine. Due to considerably large frictional losses in piston assembly, this system contributes in more fuel and lubricating oil consumptions and in this way it happens to be a potential source of hydrocarbons and particulate emissions.

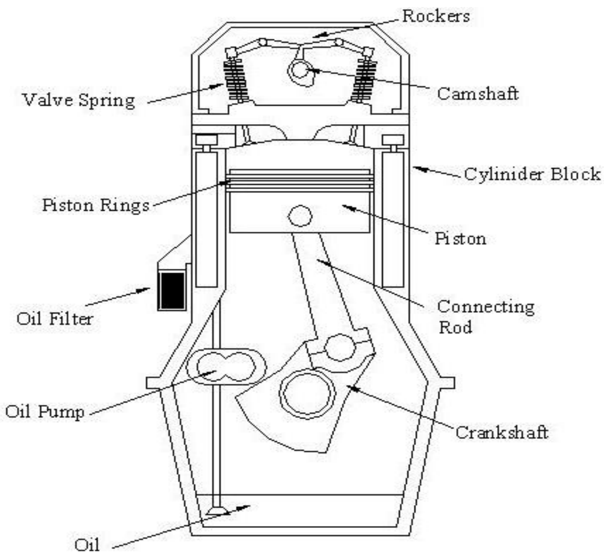
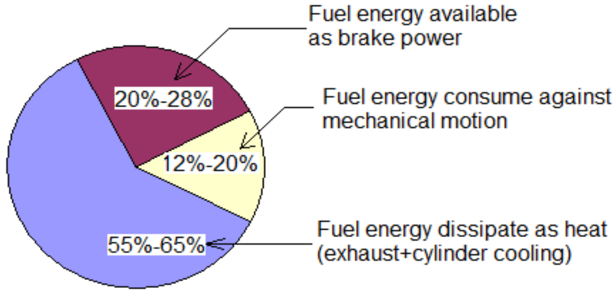
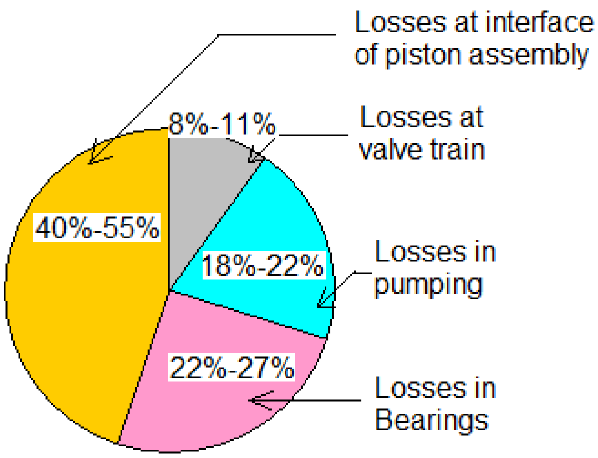


Fig. 1 Vital components of a typical IC engine [1]



(a) Break-ups of fuel's chemical energy



(a) Break-ups of mechanical energy losses

Fig. 2 Chemical and mechanical energy losses in a typical IC engine [1]

Reductions of fuel consumption and emission in an internal combustion engine are largely a function of improved lubrication. Therefore, advanced concepts are now being explored to reduce the friction at various interfaces in an IC engine. The development of smart IC engines and their proper use are of great importance for the national economy, individual and environment. Energy efficient IC engines can save billions of dollars in the case of an industrialized nation. It is worth to mention here that improvements in the tribological performance of interfaces in IC engines can lead to the following benefits:

- Reduced fuel consumption
- Increased engine power output
- Reduced oil consumption
- A reduction in harmful exhaust emissions
- Improved durability, reliability and engine life
- Reduced maintenance requirements and longer service intervals

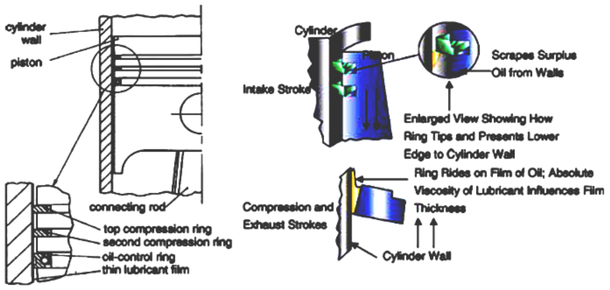
With large numbers of IC engines in use across the globe, even a fraction of improvements in engine efficiency and emission level can have a major influence on the world fuel economy and the environment in a long term.

Piston and Piston Rings - It will be appropriate to say that heart of the reciprocating internal combustion engine is the piston assembly. Figure 1.3 presents photographic view of piston assembly. Piston and piston rings form a critical unit in transforming the fuel energy into useful kinetic energy. The piston ring pack includes the piston rings, which is a series of compression rings and oil ring. The primary role of the compression piston ring is to maintain an effective gas seal between the combustion chamber and the crankcase. The piston rings of the piston assembly, which form a labyrinth seal, achieve this function by closely conforming to their grooves in the piston and interfacing to the cylinder wall. The additional role of the piston rings is to transfer heat from the piston into the cylinder wall and limit the amount of lubricating oil that is transported from the crankcase to the combustion chamber. This flow path is perhaps the largest contributor to engine oil consumption and leads to increase in harmful exhaust gas emissions as the lubricating oil mixes and reacts with the other contents present in combustion chamber.

Fig. 3 Photographic view of piston assembly [2]

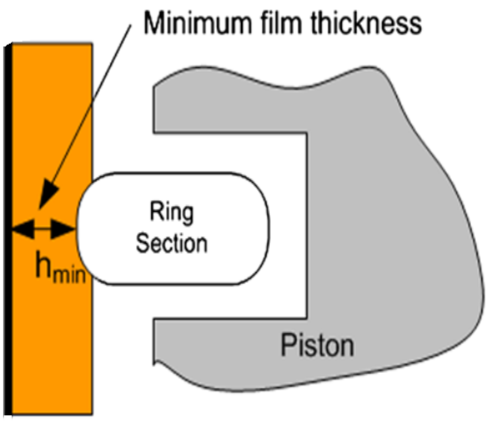
Figs. 4(a) and 4(b) illustrate face profiles and functions of piston rings in an IC engine. Two top piston rings are compression rings. The pressure generated during the combustion pushes the piston rings radially outward, which causes engagement of the entire piston ring face with the cylinder wall. This process helps in gas sealing. The second compression ring, which is known as a scraper ring is designed to assist in the limiting of the upward oil flow in addition to providing a secondary gas sealing. Figure 4 (b) illustrates surplus oil scraping from the cylinder wall by the second compression piston ring. For scraping function, the second compression ring is provided a tapered-faced profile. The bottom piston ring in the piston assembly is known as oil control ring, which has two running faces (or lands) and a spring element to enhance the radial load. The role of this ring is to limit the amount of oil transported from the crankcase to the combustion chamber.

(a) Face profiles of piston rings

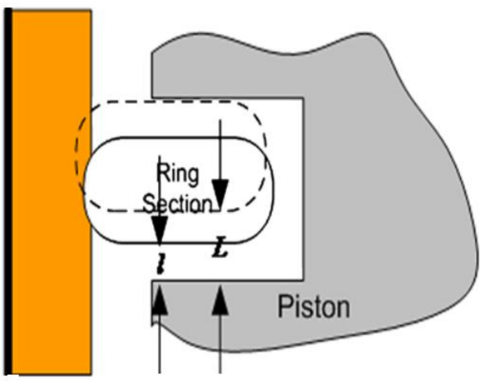


(b) Functions of piston ring

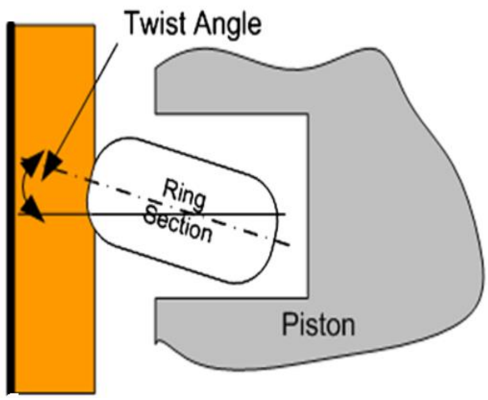
Fig. 4 Face profiles and functions of piston rings [1,3].The piston ring is the most complicated tribological component in the internal combustion engine to analyze because of large variations of load, speed, temperature and lubricant availability. In one single stroke of the piston, the piston ring interface with the cylinder liner wall may experience boundary, mixed and full fluid film lubrication. During the engine cycle the piston itself exhibits a complex motion i.e. transverse motion, axial motion, and secondary motion; as illustrated in Figs. 5(a), 5(b), and 5(c). Such motions result in hydrodynamic/mixed lubrication at the various interfaces in piston assembly. In presence of poor lubrication at the piston skirt and cylinder wall, noise generation may take place due to piston slap.



(a) Transverse movement of piston ring



(b) Primary (axial) movement of piston ring



(a) Secondary motion (twisting) of piston ring

Fig. 5 Movements of piston rings during operation [4]

II. CONCLUSION

It is widely understood that surface profiling and surface topography of mating solids have remarkable influence on tribological behaviors in both dry and lubricated sliding conditions. Though the influences of the micro and nano scale topography are more complex but, at the same time it offers interesting possibilities for friction reduction. The most promising results related to friction reduction may come out with some novel surface profiles in presence and absence of surface texturing. Therefore, in light of stringent federal legislations pertaining to better fuel economy and reduced emissions, there are needs to revisit lubrication and tribological contact design aspects in IC engine for friction reduction. Improving performance of piston assembly from tribological aspects (reducing friction) will have immense influence on fuel saving and controlling the emissions.

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