Automobile Piston Ring Design

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Abstract: ***In IC engine piston ring friction losses account for approximately 20% of total Mechanical losses as reported in the literature. A reduction in piston ring friction would therefore result in higher efficiency, lower fuel consumption and reduced emissions.***

Keywords: Triboligical performance, Lubrication, Heat Dissipation, Material

1. Introduction

Advances in modern engine development are becoming more and more challenging. Piston ring frictional losses account for approximately 20% of the total mechanical losses in modern internal combustion engine. Reduction in piston ring friction would therefore result in neither efficiency, lower fuel consumption and reduce emission. The goal of this study is to develop low friction piston ring design to improve engine efficiency, without affecting oil consumption, blow by, wear and cost. Main part of the study on the basis, the lubrication of the piston ring has been an important research matter for many years because it is extensively accepted. The piston ring pack in an internal combustion engine typically consists of three circular rings located in grooves in the piston. The rings move with the piston along the cylinder liner during engine operation. The primary function of piston is to maintain an effective gas seal between the combustion chamber and crankcase. The reciprocating motion of piston ring in cylinder creates drastic change in the pressure, the combustion event generates large amount of heat. The second function of piston ring liner assembly is to transfer this heat from the piston in to the cylinder wall. These can be effective by considering alloy materials which may lead to prolong life of the cylinder liner and piston. The third function of piston ring assembly is to limit the amount of oil that transported from the crankcase to the combustion chamber by oil control ring.

2. History

In the early steam engines no piston rings were used. The temperatures and the steam pressures were not as high as the corresponding parameters in today's internal combustion engines, and the need for considering thermal expansions and clearances was smaller. Increasing power demands required higher temperatures, which caused stronger heat expansion of the piston material. This made it necessary to use a sealant between the piston and the cylinder liner to allow a decrease in the clearance in cold conditions, i.e.

3. Ring Categories

Piston rings form a ring pack, which usually consists of 2–5 rings, including at least one compression ring. The number of rings in the ring pack depends on the engine type, but usually comprises 2–4 compression rings and 0–3 oil control rings. For example, fast speed four-stroke diesel engines have 2 or 3 compression rings and a single oil control ring. The oil control rings used in diesel engines are two-piece assemblies and spark ignited engine oil control rings may be three-piece assemblies as well.

3.1 Types of Rings

The compression ring acts as a gas seal between the piston and the liner wall, preventing the combustion gases from trailing down to the crankcase. The rings have a certain pre-tension, i.e. they have a larger free diameter than the cylinder liner, which assists the ring in conforming to the liner. The cylinder gas pressure acts on the back-side of the ring, especially on the top ring, pressing it against the liner. The ring force distribution depends on the face form. With a rectangular face profile the force is higher than with a barrel-shaped face, as the compression pressure is able to act on the face-side of the barrel-shaped ring and thus counteract some of the force owing to ring pre-tension.

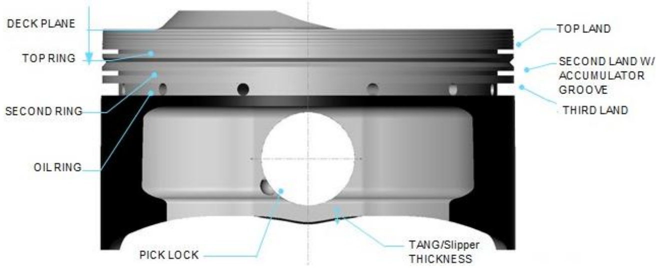

Figure 1:

In addition to the task of the compression rings to seal off the combustion chamber from the crankcase, there needs to be some mechanism to distribute the oil evenly onto the liner. The number of oil control rings in a ring pack is one or two. Normally a single oil control ring is sufficient but on occasions a second ring may be required.

The scraped oil may run through the possible gap between the liner wall and the piston skirt. With the latter alternative, the oil is forced in front of the oil control ring. The oil control rings may have a coil spring inserted, as the pretension of the ring is not sufficient in all instances. The additional force on the oil control rings causes them to have the most extreme lubrication conditions, even though these are the rings that control the oil film.

4. Piston Ring Coating

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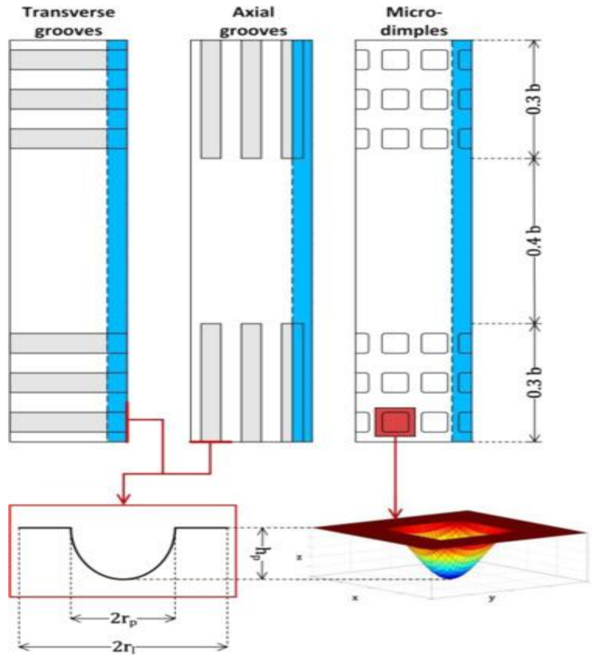
A piston ring material is chosen to meet the demands set by the running conditions. Furthermore, the material should be resistant against damage even in emergency conditions. Elasticity and corrosion resistance of the ring material is required. The ring coating, if applied, needs to work well together with both the ring and the liner materials, as well as with the lubricant. As one task of the rings is to conduct heat to the liner wall, good thermal conductivity is required. Grey cast iron is used as the main material for piston rings (Federal Mogul, 1998).From a tribological point of view, the grey cast iron is beneficial, as a dry lubrication effect of the graphite phase of the material can occur under conditions of oil starvation. Furthermore, the graphite phase can act as an oil reservoir that supplies oil at dry starts or similar conditions of oil starvation.

4.1 Texture Patterns

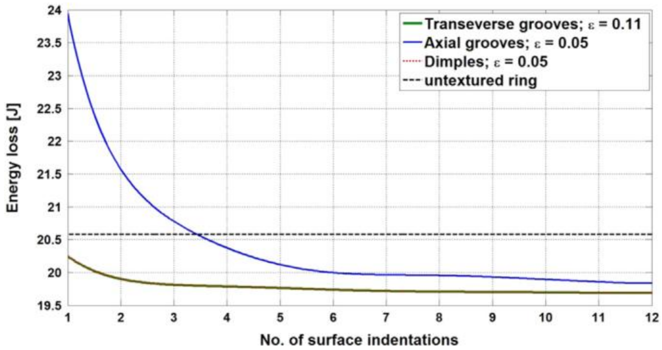
The sliding contact between a piston ring and a cylinder liner hosts a variety of different friction mechanisms during one working cycle of the engine. Owing to the variations in load, speed and counter surface effects, the lubrication conditions in a ring/liner contact are strongly transient, which is reflected by variations in the friction, and wear, behavior.

The ring friction is determined by the ring load, the surface properties and the lubrication conditions as determined by the sliding velocity and the viscosity and availability of the oil. The ring load comprises the ring pre-tension and the gas forces acting on the back-side of the ring. Experiments by Takiguchi and co-workers with tworing and three-ring pistons have shown that the number of rings influences the frictional behaviour of the ring pack, but that the total tension of the piston rings in the ring pack finally determines the friction losses.

The maximum friction force, which occurs under conditions of mixed lubrication in the vicinity of the TDC, has been found to decrease with increasing oil viscosity, while the friction pressure which is strongly affected by the hydrodynamic lubrication conditions between the TDC and BDC locations, has been found to increase with an increase in the viscosity of the lubricating oil. Reservoir provided by the graphite phase of the material. .



Texture pattern	No. of surface indentation per unit length	Aspect ratio	Diameter or width (μm)	Depth (μm)
Transverse grooves	7	0.11	32.14	3.53
Axial grooves	12	0.05	18.75	0.9375
Micro-dimples	12	0.05	18.75	0.9375



The frictional behavior of the piston, piston ring and cylinder liner can be expressed in several different ways, depending on the purpose of the tribological analysis. The most detailed analyses comprise friction curves, in which the (i) coefficient of friction, or (ii) the friction force is plotted with respect to either (iii) the piston stroke, or (iv) the angular position of the crankshaft. Friction curves of any of the above-mentioned type serve for tribological analyses of the lubrication conditions, and the probability for wear, in the ring/liner or piston/liner contact.

5. Results

Transverse grooves that are perpendicular to the sliding direction results in maximum energy savings (Fig. 5). The energy saved by transverse grooves is more than that of a square dimple pattern. By contrast, axial grooves have a negative effect if not properly optimized. The feasible zone (combination of geometrical parameters) for the usage of axial grooves to minimize energy loss is very small. Energy loss in transverse grooves and micro-dimples lies below the

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energy loss in axially textured grooves, and untextured ring for all textures per unit length. Hence, in transverse grooves and micro-dimples, the aspect ratio influences energy loss more than the texture diameter.

The effect of area density on interface performance was found to be minimal. The efficiency of micro-dimples slightly improves and approaches that of transverse grooves because area density increases in the circumferential direction. Although the reduction of energy loss caused by micro-dimples increases with area density, this reduction essentially remains low.

The friction force for the entire engine cycle of optimized transverse grooves, axial grooves, and micro-dimples. Transverse grooves cause less hydrodynamic friction relative to axial grooves and micro-dimples. This finding shows the reduction in instantaneous friction force of the textured PRL interface with reference to an untextured ring. Fiction force decreases substantially at mid strokes for a textured PRL interface. Transverse grooves, axial grooves, and micro-dimples cause a 7.91%, 3.39%, and 1.475% reduction in friction force, respectively. Micro-dimples show good performance at stroke ends when the lubrication enters into the boundary regime. Micro-dimples were also found to provide better frictional performance at high loads and low velocities at the beginning of the expansion stroke. However, this variation in performance in different lubrication regimes occurs near dead ends. Therefore, the influence of this variation remains insignificant to energy loss because of the low velocity at dead ends. Moreover, usage of modern engine oils result in formation of tribo film at dead ends, thus, reducing the boundary friction and wear.

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Author Profile

Tom K Thomas received the B- Tech. degrees in Mechanical Engineering from St Joseph’s College of Engineering and Technology in 2017.

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