Piston Rings: A review

Dr.Shailesh Mani Pandey
Assistant Professor, MED
Delhi Technological University, Delhi-110042
Email-shaileshmanipandey@dce.ac.in

Abstract

Piston rings are heart of engine and development of piston rings are continuously going on. In this article we tried to cover all major types of piston rings along with their manufacturing methods. The material of the piston rings has also been reported in this review article

Introduction

The discovery of fire and wheel by early humans remain the two most important advances in the history of mankind. The invention of internal combustion engines, arguably, comes in at a very close third. A wide spectrum of our day to day activities depend on work extracted from the chemical energy of fuels via these engines ranging from electricity to transportation. Even a large number of industries are based solely or partially on internal combustion engines.

Due to its widespread use, a seemingly small wastage of energy (via leakage of combustion gases) or material (by wear of reciprocating parts) in each engine is magnified on the larger scale thus calling for ways to minimise any kind of wastage. An important invention was made in 1854 by John Ramsbottom in this regard when he showed dominance of piston rings over hemp packing hitherto used in internal combustion engines. His design is the forerunner for practically any type of one-piece resilient piston ring in existence. [1]

Falling in line with all the other major innovations, the piston rings have an inherent shortcoming. While preventing loss of pressure by leakage of expanding gases, they need to be in perpetual contact with the cylinder liner thereby resulting in friction and wear of liner and rings themselves (accounting for about 50% of total frictional losses). [2] Currently, the accepted practice is to swap the lining or the ring with a fresh one as and when they surpass the limit of acceptable wear. Piston rings, based on their position and functions, are usually classified as follows: [3]

Compression Rings

The main purpose of compression or pressure rings, as the name suggests, is to seal in the pressure from the combustion side so that there is minimal leakage of expanding gases and maximum utilisation of combustion pressure. Compression rings are usually situated in the topmost groove on the piston, however, exceptions exist on account of different designs. Another major function of piston rings is to dissipate the heat from piston to cylinder wall.

Intermediate Rings

Intermediate or secondary rings usually help by retaining enough oil to lubricate the top compression rings as well as help them with sealing the combustion chamber.

Oil Control / Scrapper Rings

Oil control rings control and maintain the thickness of oil film present on cylinder walls. These rings scrap the excess oil splashed on the cylinder walls and send it back to the crankcase, hence are also known as scapper rings. Oil rings make an almost oil-tight seal between the piston and the cylinder liner.

In addition to this, piston rings also help the piston withstand heat, shock, fatigue, wear, maintain shape and prevent corrosion. [1]

Piston Ring Design

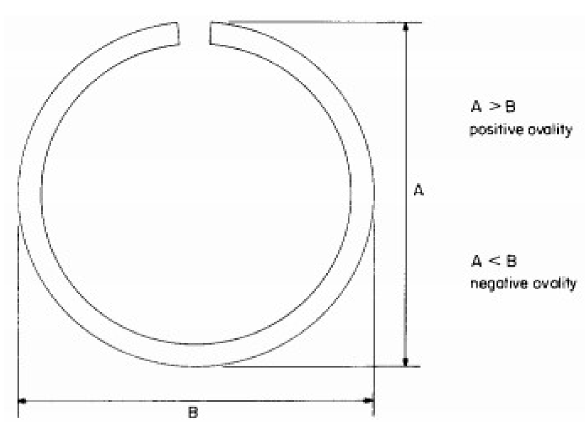

Fig 1. Ovality of piston ring

Piston rings are designed to have either 'positive ovality or negative ovality. High speed petrol engines usually have rings with positive ovality since this condition has a damping effect on the vibration of the ring, thus reducing ring flutter. If rings having excessive negative ovality are used, then blow-by past the ring can be high with a subsequent loss in performance and possible wear. Low and medium speed diesel engines impose lower inertia forces on the rings and hence the ring vibration tends to be less. [1]

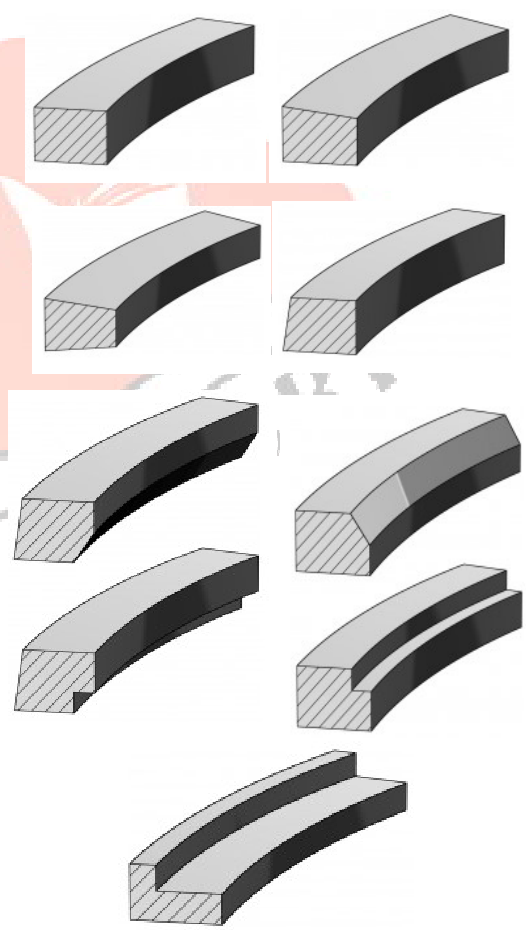

Fig 2. Piston ring profiles. [4]

In addition to ovality, a wide range of ring profiles is also in use. These profiles in themselves reflect scientific advances and have slight advantages over each other on a case to case basis. Some of the most widely used ring profiles are- rectangular, tapered, internally bevelled or tapered, any combination of taper face with internal bevel or taper, keystone, half-keystone and L-shaped.[5]

Piston Ring Manufacturing

Casting

A variety of casting techniques such as centrifugal casting, static pot casting or general casting may be used to manufacture piston rings cheaply either in groups or individually. However, this method limits the minimum thickness of the rings that can be produced.

Powder Metallurgy

Piston rings of less than 2mm thickness can be manufactured at a high rate of ~300 per minute using powder metallurgy. Even though the setup cost is relatively higher, wastage is considerably low and the setup is profitable in long run.

Machining

Piston rings are cut and turned to size and later ring profile is milled to required shape using appropriate machine tools.

Piston Ring Coating

Ring coating is a different topic unto itself. Rings are coated either to improve corrosion resistance and increase shelf life or to improve wear resistance and increase total operating life. Popular wear resistance coating materials have been discussed in the next section.

Wear Resistant Coatings

Chromium Plate

Chrome plating is most commonly used coating on piston rings. Chromed rings take longer to run-in as compared to other rings. Ring and linear wear are considerably reduced by a factor of 2 to 3 if chrome plated rings are used against cast iron liners, which happens to be a widely adopted solution. However, under extreme temperature, the rubbing face of chromium tends to soften and scuffing may occur. Hence, molybdenum and chromium/molybdenum allow electroplates have been developed. [1]

Sprayed Molybdenum

This coating is particularly used in USA and has greater resistance to scuffing than chromium. Molybdenum is usually inlaid into the ring, by flame or plasma spraying, of which, the flame sprayed variant is in widest use. The major limitation is that molybdenum is prone to oxidation at 500º and at 730ºC, the oxide evaporates. Under consistent high temperature operation (such as high rated diesel engines), the coating may detach from the substrate. [1]

Sprayed Chromium

This coating, being used as an inlay, is believed to have better scruff resistance and improved wear life as compared to its electroplated counterpart. Fe30%Cr has also been used as plasma sprayed coating and found to have very good wear resistance. [1]

Composite coatings

A large number of composite or alloy sprayed coatings are being tested, mostly based on carbides and oxides of metallic matrix. Generally sprayed using PVD, these composite coatings provide high resistance to wear and abrasion. Only molybdenum/chromium/nickel alloy and chromium oxide are equivalent to molybdenum for scruff resistance. [6]

It is highly likely that in near future, we will have tailor-made coatings depending on the cost constraint and usage made by mixing the right amount, size, distribution and type of hard particles in a suitable matrix.

References

[1] Taylor B.J., Eyre T.S., A review of pistons and liner materials, pp-79-85, (1979)

[2] Zabala B., Igartua A., et al, Friction and wear of piston ring/cylinder liner at TDC, Tribology International (2017)

[3] Patel P.D., Hirapara B.B., et al, A technical research on piston ring coating of single cylinder 4s SI engine fuelled with CNG, IJSTE, pp-270-271 (2015)

[4] Marine insight-Guidelines-Types of piston rings and ring maintenance.

[5] Kori Handbook, Federal-Mogul Corporation (2008)

[6] Scott D., Smith A.I., Tait J. And Tramain G.R., Wear 33, pp-293-315 (1975)

[7] Ciulli E, A review of internal combustion losses part 1 (1992)

[8] Patel Rachana A., Niralgikar Kirti H., A review of wear in piston ring of IC Engine, IJERT (2015)