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Tribological Effects on Piston Rings Due to Different Filler Materials

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ABSTRACT

The purpose of this study was to study the effect of chromium addition on tribological performance of piston rings. The composites fabricated by liquid stir casting technique with different weight fraction. Piston rings wear was carried out using reciprocating tribometer. The results showed that addition of chromium improve the wear resistance and wear rate decreased with an increment in a normal load. The wear rate was found 0.333mg/min for 5% and 0.267 mg/min for 10% chromium addition at 3 N and 0.267mg/min for 5% and 0.133 mg/min for 10% chromium addition at 6 N respectively.

Keywords : Piston Rings, Cylinder Liner, Thermal Conductivity

I. INTRODUCTION

Problem Statement

The functions of a piston ring are to seal off the combustion pressure, to distribute and control the oil, to transfer heat, and to stabilise the piston. Piston rings for current internal combustion engines have to meet all the requirements of a dynamic seal for linear motion that operates under demanding thermal and chemical conditions. In short, the following requirements for piston rings can be identified.

- ✓ Low friction, for supporting a high power efficiency rate.
- ✓ Low wear of the ring, for ensuring a long operational lifetime.
- ✓ Low wear of the cylinder liner, for retaining the desired surface texture of the liner.
- ✓ Emission suppression, by limiting the flow of engine oil to the combustion chamber.
- ✓ Good sealing capability and low blow-by for supporting the power efficiency rate.
- ✓ Good resistance against mechanical-thermal fatigue, chemical attacks and hot erosion.
- ✓ Reliable operation and cost effectiveness for a significantly long time.

Increasing power demands required higher temperatures, which caused stronger heat expansion of the piston material so a material with good coefficient of thermal conductivity is preferred. Piston rings are used in two strokes and four stroke reciprocating internal combustion engines which are widely used in the automobile industry, pumps, compressors, railway engines, aerospace application etc.

Overview of Material

Typical piston rings materials are light alloys, cast iron, nodular cast iron, and alloyed steels [62]. The piston rings for high-speed engines are primarily made of aluminium silicon alloys. This study is about the material for piston rings with ZA27 alloy as a base material

With three fillers Graphite, Nickel and Chromium where composition of chromium is varied and other fillers are kept constant. Varying composition of chromium to study its effect on Tribological parameters is the core idea of this study.

II. LITERATURE REVIEW

Johansson et al [1] study suggests that Fuel consumption is an extremely important parameter for the automotive industry today. Anticipated emission legislative demands in combination with a rising oil price are true motivators. In engines the piston system is the largest source of frictional losses, accounting for about 50% of the total frictional losses, thus it is important to optimize. Apart from frictional losses the piston system is a large consumer of lubricating oil, a considerable contributor to the total amount of particulate emissions (PM).New materials, coatings and high-tech machining processes that previously were considered to be too expensive and therefore only used in complex applications are today becoming more affordable. It is important to develop reliable test methods to study these new concepts. The reciprocating tribometer at Volvo Technology has been updated to better evaluate the frictional difference between material combinations/surfaces; it is possible to evaluate a number of operational parameters in each experiment. The components that were studied were a piston ring running against a cylinder liner. Friction, wear and change in surface morphology were studied in the experiments. It is shown that for the introduced DoE based tribometer test the interaction of dynamic viscosity, velocity and contact pressure can be studied within one experiment. When grey cast iron is used with thermally sprayed PVD coating (CrN) then friction coefficient, tribological wear will decrease and surface roughness will increase.

Kapsiz et al [2] has reported an experimental study of tribological characteristics of cylinder liner (CL)/piston ring (PR) pair. Reciprocating wear process parameters are optimized for minimum weight loss and friction based on mixed L16 Taguchi orthogonal design with three process parameters, sliding velocity, applied load and oil type. It is observed that sliding velocity have the most significant influence on both weight loss and friction characteristics of CL/PR pair. The interaction of sliding velocity and oil type has some significant influence on weight loss of piston ring. In our study we have varied only one reciprocating wear process parameter for study and keeping others as constant.

Grabon et al [3] carried some tests on reciprocating tribometer tester. The construction of tribological tester allows measuring the friction force between specimen and counter-specimen. Tribological behaviours of cylinder liners with and without oil pockets were compared. Specimens were cut from plateau honed cylinder liners made of grey cast iron. Counter-specimens were cut from grey cast iron piston rings. A special tool acted as a hammer to form additional dimples on the liner surfaces. Theareadensity of oil pockets was about 13%. Specimen surfaces had dimples with average depths about 5 mm and diameters in the range 0.15–0.2mm. Two batches of tribological tests were carried out, in regimes of full and starved lubrication. Friction tests were conducted at three mean sliding speeds: 0.44, 0.66 and 0.88m/s. Experiments were performed with normal loading the range 50–300N, starting from the lowest load. Normal load increased in a step wise manner after 2m in at each load, until the maximum load was reached. Using the results of this literature we decided the parameter values range.

Ghasemi et al [4] had experimented that Plastic deformation of the matrix during the wear process results in closing the graphite flakes. In this study, the relationship between the deformation of the matrix and the closing tendency of flake graphite was investigated, both qualitatively and quantitatively. Two representative piston rings, which belonged to the same two-stroke marine engine but were operated for different periods of time, were studied. Initial microstructural observations indicated a uniform distribution of graphite flakes on unworn surfaces, whereas worn surfaces demonstrated a tendency towards a preferred orientation. Approximately 40% of the open flakes of the unworn surfaces were closed during sliding, which may result in the deterioration of the self-lubricating capability of cast iron. Moreover, flakes within the orientation range of 0 to 301 relative to the sliding direction showed a maximum closing tendency when subjected to sliding. The closing tendency gradually decreased as the angle increased, approaching a minimum between 30 and 701. A slight increase in the closing tendency was observed for flakes with orientations between 70 and 901. A similar trend was observed on both rings. This study helped us decide graphite's effect on wear properties as a filler material.

Lima. Et al [5] had done FEA of piston ring material with coating. a series of finite element analyses was conducted to analyse the stresses in thin film-coated piston rings under contact loads. The actual normal and tangential pressure observed during a complete four-stroke gasoline engine cycle (720°) was used as input to load an axisymmetric film/substrate mesh. Four values of coating thickness were analysed (from 20 to 100 μm) and, for each one, five values of elastic modulus (from 144 to 578 GPa) were considered. The systems were compared based on the stress distribution, particularly in terms of the intensity and position of the peak stresses in the film and at the film/substrate interface. Results show that (a) in terms of radial stresses in the ring, the stiffer (or thicker) the film, the lower the compressive stresses at the interface immediately under the film-sleeve contact, and the higher the tensile stresses deeper at the ring, while (b) in the coating, the more compliant the material, the more compressive the axial stresses observed. This paper added excellent information about mechanical and physical behaviour of piston ring material under requisite loading conditions.

Yuan et al[6] had performed experiments on Reciprocating tribometer and their research aims to obtain the piston ring tribological characteristics of a free-piston engine. Mathematical models of piston ring seal and lubrication were established based on thermodynamic equation and hydrodynamic lubrication equation. The lubrication performances of the piston ring were simulated; the effects of the piston motion to piston ring lubrication process were analyzed compared with a corresponding conventional engine. Results show that seal working time of free-piston ring is longer than conventional engine's during a cycle time, but the leakage loss is lower. Moreover friction forces and friction work of piston ring in two engines are almost equivalent, but the peak friction power of free-piston engine is larger than crankshaft engine. This research helped us in a better understanding of lubrication for piston rings.

With the help of above references we tried to improve certain properties of piston ring material such as lubrication by adding graphite , wear resistance by keeping ZA27 as base material , thermal and mechanical strength increased by using nickel. To study the effect of chromium with the above composition we carried out several tests and analysed them.

III. CONCLUSION

As we increase the percentage of chromium added from C0(1.03 %) to C1 (2.06 %)the coefficient of friction increases slightly but overall the coefficient of friction remains significantly less.

The variation of temperature as observed in both the samples is minimal which indicates steady temperature along with good thermal conductivity which is a result of adding chromium.

The wear resistance properties are enhanced of ZA27 alloy by using nickel as a filler material.

The research work is showing that as we increase the amount of chromium filler from C0 toC1 the wear resistance of ZA27 alloy with three fillers nickel, chromium and graphite has increased hence the wear rate decreases. This will directly affect the life of the piston rings which is a major issue. Graphite is self-lubricating filler which helps in oil starvation conditions for piston rings.

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