Evaluation of a Piston Ring Coating on the Oscillation Wear and Friction with use of Unique Pre-Screening SRV Instrumentation

Dr. Raj Shah, Philip Iaccarino, Vincent Colantuoni

Koehler Instrument Company, Inc. Holtsville, NY

ABSTRACT

In an engine, the piston group accounts for approximately 50% of frictional losses, contributing to significant fuel inefficiencies. With market demands for higher and higher fuel performances, the piston ring only increases in its load. With the use of a cost-effective Schwing, Reib, Verschleiss (SRV) instrument, the friction, wear, and load carrying capacity can be pre-screened, to determine which components perform better in an engine. By further understanding the piston-cylinder-contact assembly, engineers and scientists can further improve the piston ring and cylinder liner interaction.

The recently advanced SRV laboratory technique can also be used as a tool to study and solve various tribological problems. It is a diverse model for evaluating the friction and wear properties of greases, lubricants, coatings, additives, and other materials. Additionally, the SRV instrument is in compliance with many ASTM, ISO, and DIN testing standards. As a result of its versatile application, the SRV has the ability to be implemented in many practical setups. This paper will dwell into detail of how this technique can be used for evaluating a variety of piston ring coatings.

OBJECTIVES

SRV measures the following in the test system:

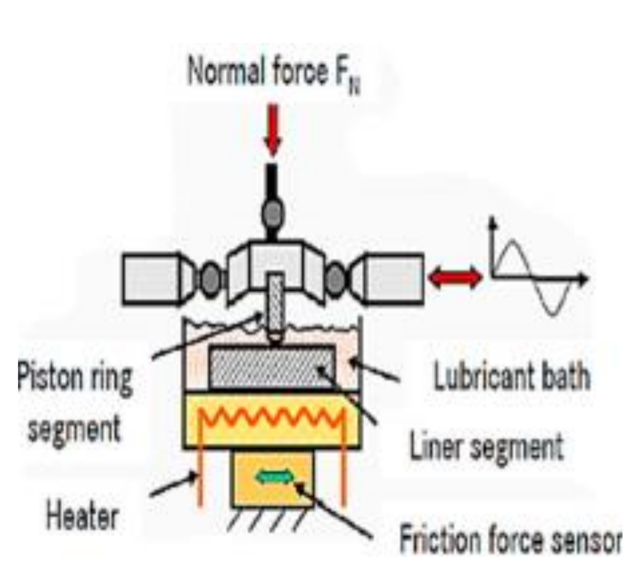
- The physical interactions between a lubricant and two specimens in a loaded contact in either rotational or linear oscillatory motion.
- The upper specimen oscillates in a linear path on the lower stationary specimen at a specified frequency, stroke length, load, temperature, and test duration.
- The frictional force imparted to the lower specimen is measured continually and the coefficient of friction (COF) is automatically calculated and recorded throughout the test.
- If both specimens are metallic, the electrical resistance between the two can be measured as an indication of the film strength of the lubricant.
- After testing, the specimens can be examined under a microscope and the wear scars measured. Nonmetallic specimen including various plastics and ceramic materials can be tested on the SRV.
- In this poster, the SRV instrumentation is used to assess the efficacy of various piston ring coatings. This is done by measuring the coefficient of friction of the piston ring contact and the ring mass loss.

SRV TEST SET-UP

Three piston ring coatings were tested with the SRV instrument:

1) Chromated 126 = Chromium Plated
2) CrN-TiN 1º Group 127 = PVD multi-layer TiN-Ti-CrN-CrN coating
3) NIPCO + Si_3N_4 128 = Electroless nickel-phosphorous coating with dispersed Si_3N_4 particles

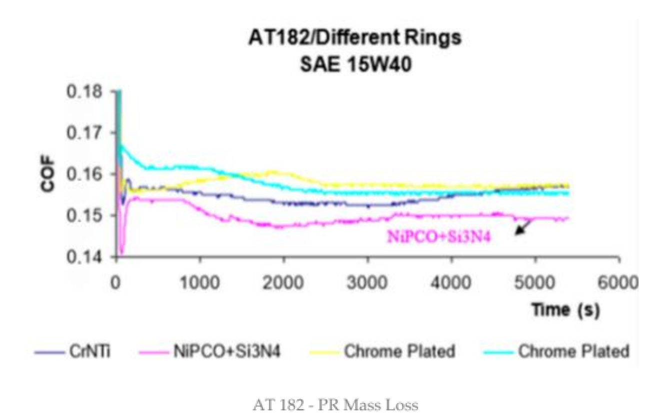
A schematic of the SRV test is shown below, as well as the test parameters used for the coatings.



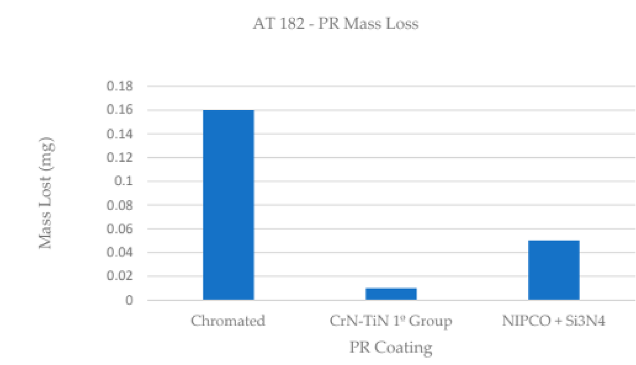
Parameter	Condition Setting
Load	300 N
Contact Pressure	10 MPa
Test Time	5400 s
Frequency	50 Hz
Stroke	3 mm
Linear Speed	0.3 m/s
Temperature	200°C
Lubricant	SAE 15W-40

RESULTS AND DISCUSSION

The coefficient of friction of the piston ring contact was monitored for each coating over the 5400 s test time with a 300 N applied load. Additionally, the mass of the ring assembly was measured before and the test for each coating, and the mass loss was determined.



Coefficient of friction for each piston ring, across the 5400 s test time



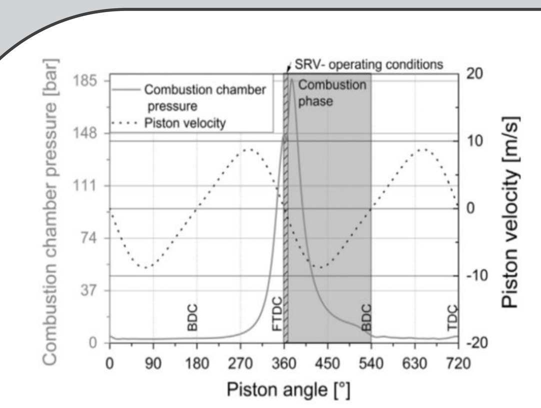
Mass loss for each ring, before and after the SRV tests

Summary of Average COF and Ring Mass Loss for each Coating

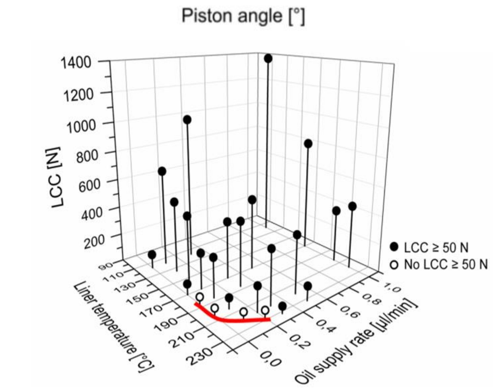
Piston Ring	Average COF	Ring Mass Loss (mg)
Chromium Plated	0.158	0.16
CrN-TiN 1º Group 127	0.156	0.01
NIPCO + Si_3N_4	0.151	0.05

It is clear the chromium plated coating performs the worst, as it has the highest average COF and highest ring mass loss. A higher COF indicates that there is more energy dissipated in the piston ring, and is undesirable for piston ring lubricants. Higher ring mass loss indicates more wear in the ring assembly, which is also undesirable. The CrN-TiN 1º and NIPCO + Si_3N_4 performed the best. The NIPCO + Si_3N_4 coating has a lower average COF, but a higher ring mass loss when compared to the CrN-TiN 1º coating. The best coating will depend on the needs of the tribosystem – whether a lower COF is desired or a coating with better wear resistance is desired.

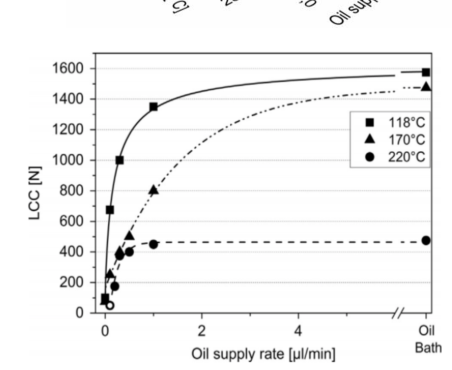
LOAD CARRYING CAPACITY OF AL-SI-CYLINDER LINERS IN THE MERCEDEZ BENZ SRV-TEST



Combustion chamber pressure and piston velocity versus piston angle of the piston assembly from simulation of an actual Mercedes 4-cylinder passenger car diesel engine (147kW) at 1600 rpm and full load.



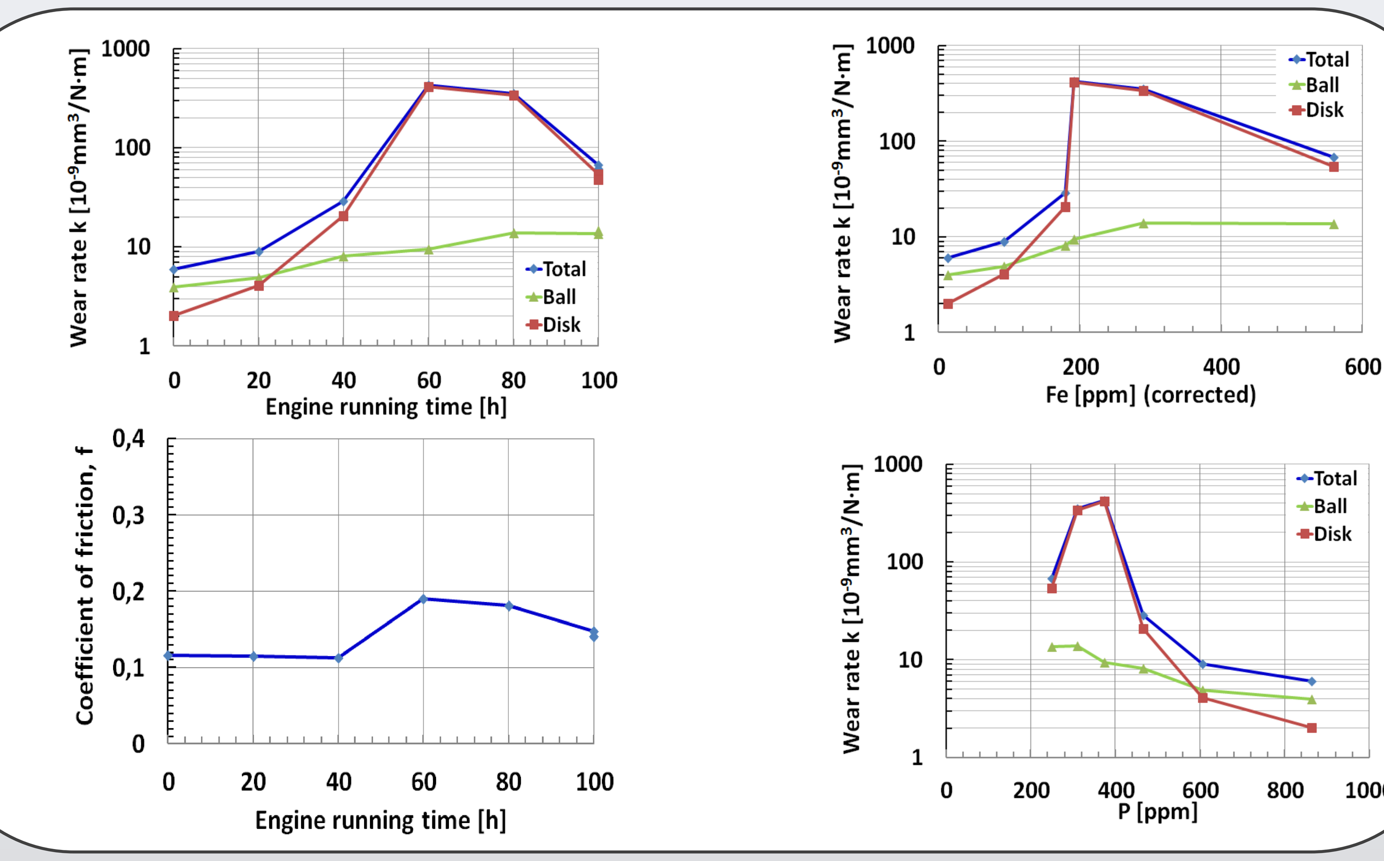
LCC dependency on liner temperature and oil supply rate.



LCC for three different linear temperatures of 118°C, 170°C and 220°C

ASTM D6425 AT 150°C (OIL SAMPLES FROM SEQUENCE IIIG TEST)

"Cliff" testing aims to identify in engine or gear tests the induction time or off-set point ("cliff") after which wear and friction increased and failure occurred. Explanations for friction and wear increased as well as failures, which occurred during engine tests, can be derived from SRV® testing of oil samples taken or collected at different engine test times and correlating these with their friction, wear and EP data in respect to depleting curves for specific additives or other oil properties.



The developed test can be used as a method to evaluate wear, scuffing, and friction behavior of different combination of ring coatings, linear materials, honings, and engine oils. The test parameter needs to adjusted very carefully to the real engine situation where the temperature and oil supply rates are reflected in the real engine.

CONCLUSIONS

The SRV is a versatile instrument to assess many parameters in a tribosystem. The instrument's set-up can mimic that of a practical real-world tribosystem. Therefore, it excels at determining friction and wear properties of many lubricants, greases, coatings, and other contacts. From the experiments highlighted in this poster, the SRV is effective is analyzing friction and wear characteristics of a piston ring coating. The instrument was able to determine that the CrN-TiN 1º Group 127 and NIPCO + Si_3N_4 coatings were the best performing coatings, depending on the desired needs of the tribosystem. Along with the SRV's versatility for tribological experimentation, the instrument also complies with various ASTM, ISO, and DIN methods and specifications.

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ACKNOWLEDGEMENTS

Koehler Instrument Company, Inc. 85 Corporate Drive Holtsville, NY 11742 (631) 589-3800
rshah@koehlerinstrument.com, philip.iaccarino@stonybrook.edu, vcolantuoni@koehlerinstrument.com