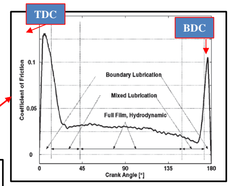
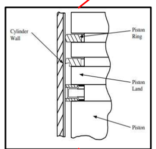
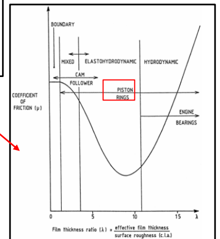
Motivation & Background

- Piston rings – provide sealing between the combustion chamber and crankcase to minimize oil and fuel transfer
- Boundary Lubrication at BDC and TDC (high load, low speed, high COF) – asperity contact, higher wear, reduced sealing ability
- Excessive wear of piston ring-cylinder liner contact leads to increased oil consumption and blowby of combustion gases into the crankcase
  - Potential risk of explosion in Hydrogen IC Engines (H_2ICE) due to dissolved Hydrogen in oil.
- **Objective** – To investigate the wear preventive performance of engine lubricants under boundary lubrication in different environments (H_2 in particular)



Lubrication regimes during piston expansion

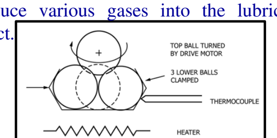




Stribeck Curve for Automobile Components

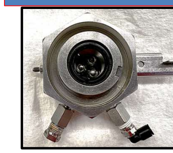
Four-Ball Wear Test - Overview

- Four-Ball Wear Test is used to evaluate the wear performance of a lubricant
  - A steel ball is rotated against three lubricated stationary balls under a specified load, speed, operating temperature, and time (pure sliding) (ASTM D-4172)
  - Wear preventive ability of the oil is evaluated by measuring the wear scars generated on the stationary test balls
    - Smaller the wear scar, better the lubricant is at preventing wear
- **Modification** – Ball cup was modified to introduce various gases into the lubricated contact.

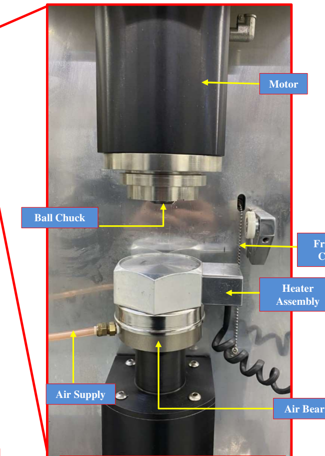


Schematic of a 4-Ball Wear Tester

Falex Variable Drive 4-Ball Wear Tester



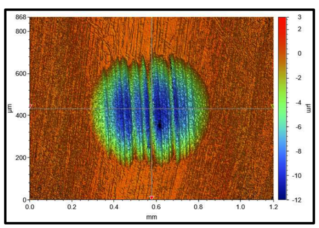
Sealed Ball Cup with Pipe Fittings

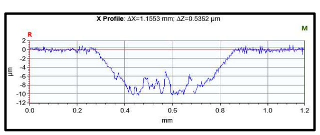


Four-Ball Tester – Testing Area

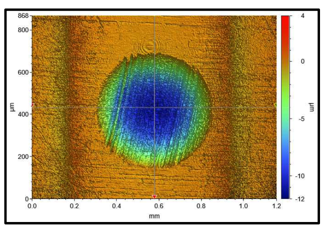
Four-Ball Wear Test – Results

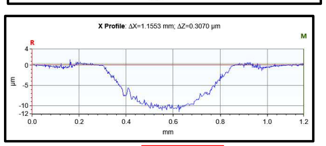
Wear Scar – Optical Profilometry (125 ºC)



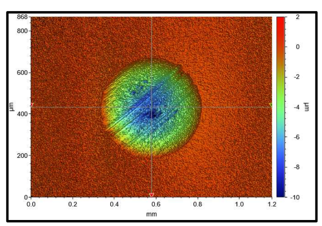


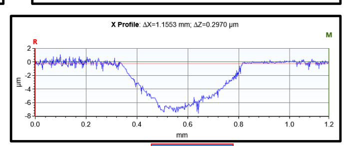
Air





Nitrogen



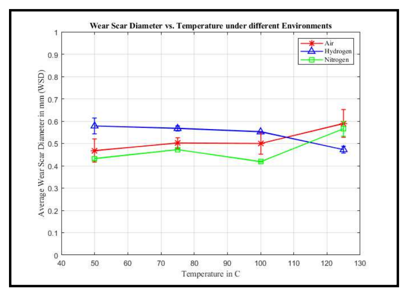


Hydrogen

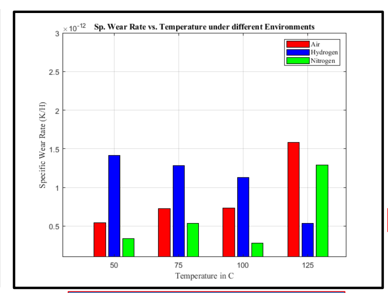
Unwrapped X Profiles of Wear Scars generated on stationary balls at 125 ºC

Four-Ball Wear Test – Results

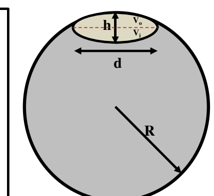
Variation of Wear Scar Diameter and Specific Wear Coefficient with Temperature



Variation of Wear Scar Diameter with Temperature under different environments



Variation of Specific Wear Coefficient with Temperature under different environments



Wear Volume representation

For the convex wear volume, from geometry,

- $V_o = \frac{1}{6}\pi h_o\left(\frac{3}{4}d^2 + h_o^2\right) \rightarrow$ *Outer volume*
- $V_i = \frac{1}{6}\pi h_i\left(\frac{3}{4}d^2 + h_i^2\right) \rightarrow$ *Inner Volume*

- Results indicate that the wear scar diameter and specific wear rate for the three different environments do not follow a uniform trend with respect to temperature
- From 50 to 100 ºC, wear scar in Hydrogen environment is the largest, while that in Nitrogen environment is the smallest, with Air exhibiting intermediate behavior
- At 125 ºC the wear scar in Hydrogen environment is smaller than that in Nitrogen