Fabricating, Analyzing and Testing Four-Ball Lubricant Testing Machine

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Abstract— The Four Ball Lubricant Testing Machine provides an advancement of the anti-wear and extreme pressure properties of lubricants to be used in machine operations. This machine is widely used, the ASTM standard tests are well known in the industry and used as a reference by many lubricant formulators. Lubricant testing and oil condition monitoring provides quality and condition assessment of lubricants and oils used in engines and other expensive machinery and systems. Lubricant quality control testing includes lubricant analysis programs for large, high-value engines and drive-trains, turbines, ships, trains, generators, offshore platforms, and other highly valuable machinery.

Keywords: Four-Ball Lubricant Testing Machine, ASTM

I. Introduction

Lubrication can be defined as the application of some materials between two objects moving relative to each other to allow smooth operation as much as necessary. It is known since ages that oils and greases reduce the friction between sliding surfaces, by filling the surface cavities and making the surfaces smoother. Action of liquids/greases known as lubrication. In other words, lubrication is a process by which the friction and wear rates in a moving contact are reduced by using suitable lubricant. Lubricant is a substance introduced between relatively moving parts to reduce friction (μ = 0.1 to 0.0001) and wear rate. The progress in scientific research indicated that reduction in friction occurs due to decrease in adhesion component of friction compared to abrasion component of friction. Almost every relatively moving component in an assembly requires lubricant.

II. Literature review

1) Oxidation of the lubricant appears to increase wear by decreasing the effective concentration of ZDP [3].
2) Individual wear tests at a variety of speeds and loads failed to distinguish any performance difference between the oils selected at most of the speed/load combinations [3].
3) Boundary lubrication apparently plays an important role in the wear portion. The reference oils can be separated according to their boundary lubrication effectiveness under certain load/speed combinations [1].
4) The junction temperature rise has been determined, using a chemical reaction rate correlation between static and dynamic runs [2].
5) The catalytic aspect of metal surfaces in chemical reactions under boundary lubrication, at least in paraffinic mineral oils, appears to be insignificant [2].
6) To calculate a wear volume, it is usually assumed that the wear occurs only on the stationary balls. The missing material is assumed to come from spherical segments of the stationary balls that correspond to the net volume occupied by the rotating spherical ball that fits into the wear scar [4].
7) Early studies either focused expressly on the temperature effect [5] or interpreted the film failure results as a consequence of the breaking of the physical or chemical bonds between the lubricant molecules or atoms and the substrate.
8) To focus on the mechanical aspects of film failure, recent work [6] has been directed toward the measurement of the maximum shear stress sustained by a lubricating film prior to failure.

Development of Four-Ball Testing Method

III. Scope

This test method covers the determination of the load carrying properties of lubricating greases. Two determinations are made:

1) Load-Wear Index.
2) Weld Point, by means of the Four-Ball Extreme-Pressure (EP) Tester.

IV. Significance and Use

1) This test method, used for specification purposes, differentiates between lubricating greases having low, medium, and high level of extreme-pressure properties. The results do not necessarily correlate with results from service.
2) It is noted that lubricating greases that have as their fluid component a silicone, halogenated silicone, or a mixture comprising silicone fluid and petroleum oil, are not applicable to this method of test.

V. Apparatus four-ball extreme-pressure lubricant tester

It is important to distinguish between the Four-Ball EP Tester and the Four-Ball Wear Tester. The Four-Ball Wear Tester can be used under a variety of test conditions at loads up to 490 N (50 kgf). The Four-Ball EP Tester is designed for testing under more severe conditions and lacks the sensitivity necessary for the Four-Ball Wear Test.

A. *Standard Four-Ball Wear Tester includes:*

– ½ HP Single Speed Motor, 1,200 rpm
– Mechanical Loading System
– (Lever Arm and Weight Hanger, 60 kg. max load)
– Test Duration Timer
– Ball Assembly and Fixtures
– Ball Cup Disk Adapter
– Ball Holding Cup

VI. Procedure of Performing Test

1) Bring lubricant to be tested.
2) Completely fill the ball pot with the lubricating grease to be tested, avoiding the inclusion of air pockets.
3) Imbed the three steel test balls in the grease. Place the lock ring carefully over the three balls and screw down

the lock nut securely .Scrape off the excess grease pushed onto the lock nut.

4) Press one ball into the ball chuck and mount the chuck into chuck holder.
5) Examine the ball chuck carefully before each run. The chuck is continually subjected to wear and seizure and should be replaced when it will not fit into the ball chuck-holder tight enough to support its own weight, or if the ball seat shows signs of seizure.
6) Install the ball pot assembly on the test apparatus in contact with the fourth ball. Place the mounting disk between ball pot and thrust bearing.
7) Place the weight tray and weights on the horizontal arm in the correct notch for a base test load.
8) Release the lever arm and gently apply the test load to the balls, making certain the ball pot assembly and mounting disk are centered. If the optional friction-measuring device is used, connect the calibrated arm on the ball pot to the indicator spring by means of the clip and wire, placing clip and indicator support over the numbers which correspond to the applied load.
9) Shock-loading should be avoided as it may deform the balls permanently.
10) Start the motor and run.
11) The time for the apparatus to “coast” to a stop is not considered.
12) Remove the load from the balls by raising the lever arm and locking it in raised position. If the friction-measuring device is used, remove clip and wire. Remove the ball pot assembly; remove the chuck and discard the ball.
13) Measure the scar diameter of test balls as follows:
    Option A— Remove the lock nut and release the test balls. Clean the balls with Stoddard solvent and then n-heptane, and wipe dry with soft cloth. Place the individual balls on a suitable holder and by means of a microscope, measure to the nearest 0.01 mm the scar diameters both parallel (horizontal) and normal (vertical) to the striations in the scar surface of one of the three test balls.
    Option B— Retain the balls in the ball pot. Wipe excess grease from the balls and ball pot. Wash the ball surfaces with Stoddard solvent and then n-heptane. Using a microscope, measure to the nearest 0.01 mm the scar diameters both parallel (horizontal) and normal (vertical) to the striations in the scar surface of one of the three test balls. Measurement by microscope of the scar diameters on all three balls rather than one ball as outlined in Options A or B may be made if the operator so desires.
14) Record for load the average scar diameter Discard the balls. If the average scar diameter is not more than 5 % from the compensation scar diameter, repeat the test at the next higher load and again compare scar diameters. Continue this procedure until the last non-seizure load is determined.
15) If the measured scar diameter for the load is more than 5 % from the compensation scar diameter, the next run is made at the next lower load .Continue this procedure until the last non-seizure load is determined.
16) When the optional friction-measuring device is used, the last non-seizure load is detected by a gradual transverse movement of the indicating pen.
17) Make additional runs at consecutively higher test loads recording the measured scar diameter and discarding test balls, until welding occurs. Make a check run at this point. If welding does not occur on the check run, then repeat the test at the next higher load until welding is verified.
18) Shut off the motor immediately to prevent damage to the tester. Excessive wear or seizure of the ball and ball chuck may result if caution is not observed. Welding may be detected by any or all of the following: If friction-measuring device is used, a sharp transverse movement of the indicating pen.(2) Increased noise level of motor.(3) Smoking from the ball pot.(4) A sudden drop in the lever arm.

VII. CALCULATIONS AND REPORTS

1) Corrected Load—Calculate and record for each applied load between the last nonseizure load and weld point using the equation:

Corrected load, kgf $=LD_h/X$

Where:

L = applied load, kgf, that is, total weight applied (tray and weights) multiplied by lever arm ratio,

D_h = Hertz scar diameter, mm, and

X = average scar diameter, mm.

2) Load-Wear Index—Calculate and report the Load-Wear Index (formerly Mean-Hertz Load) in kilograms-force using the equation:

Load-Wear Index, kgf = A/10

Where:

A = sum of the corrected loads determined for the ten applied loads immediately preceding the weld point.

3) Formula is used for finding out the Minimum Scar Diameter (MSD) as follow:

– Minimum Scar Dia. = (Horizontal (Parallel) Reading+ Vertical (Normal) Reading)/2
– M.S.D. = Average Readings in mm/2

VIII. RESULT ANALYSIS

SL.NO.	PARAMETERS	SAE 20	SAE 40	SAE 90
	TIME (t) sec.	10	10	10
	APPLIED LOAD (W) kg.	50	80	100
	TEMPERATURE $(T)^0$c.	30	30	30
	MINIMUM SCAR DIAMETER (MSD) in mm.	0.5950	0.9570	0.9830

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