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The Standard Test Method for Measurement of Extreme Pressure Properties of Various Lubricating oils by Using Four Ball Extreme Pressure oil Testing Machine.

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Abstract:—As per the American Society of Testing Materials (ASTM-D-2783), the standard test method for measurement of Extreme Pressure (E.P.) properties of lubricating oils by using Four Ball Extreme Pressure Oil Testing Machine (F.B.E.P.O.T.M.) plays an important role in oil industry while selecting such oils as a lubricating media for testing various types of E.P. lubricating oils. Lubricating oils are needed to reduce frictional losses as well as to support working load and avoid metal to metal contact between the components working together for obtaining desired functions in machines.This F.B.E.P.O.T.M is utilized for finding the load carrying capacity and weld point of different types of lubricants/Oils fluids. Extreme Pressure (E.P.) properties like-Load wear Index ,Weld Point, Non load are the basis of differentiation of Lubricating oils having low, medium and high level of extreme pressure properties.
In this paper we find out or Evaluate Tribological (E.P.) properties i e. of load carrying capacity and weld point or various oils or lubricants used for various purposes.
It's necessary to form a lubricating fluid film of low shear strength, then it is possible to decide the film breaking strength in other words load carrying capacity of oil can be calculated.

Key Words:—AND TEST VARIABLES: - The F.B.E.P.O.T.M., Load, Pressure, Temperature, Speed, Lubricants, Grease, Alloy Steel Balls etc.
Purpose:—The F.B.E.P.O.T.M. is used to test wear preventive, E.P.Properties (i.e. Load carrying capacity and weld load) of lubricating oils.
Specimen:—S.K.F.Balls of 12.7 mm Diameter with following materials (i) Cr. Alloy Steel, (ii) EN31 etc.

I. INTRODUCTION

Lubrication, a constituent of tribology, is one of the powerful means of reducing frictional resistance of surface having relative motion under load. It includes both Hydrodynamic and hydrostatic lubrication utilizing either liquids or gasses as lubricants. It has been established since long those surfaces of the bodies are never perfectly smooth. It is due to these corrugations that friction arises. However smooth the surfaces may be seen, friction still exists between them.
The ability of a lubricant to allow rubbing surfaces to operate under load without scoring, seizing, welding or other manifestation of material destruction is an important lubricant property. This property is called film strength or load-carrying capacity, and many devices have been designed to measure it under controlled laboratory conditions. In general these devices embody rubbing test specimens operating under variable measurable loads. The test machines differ as to speeds, geometry of test specimens, load ranges, temperature ranges and test materials. The lubricating oils are selected considering the various operations condition like temperature rise, working load, normal working temperature; Extreme conditions etc. lubricating oils are categorized by either composition or end use. The academics like to characterize oils on the basis of differences in their composition and properties. They are divided in two groups –mineral oils and vegetable or animal oils, but consumers prefer terminology that reflects the use of the lubricant. Since specific end uses require certain properties end use terms serve also to identify those properties. The terms or names given below have been selected on the basis of their common acceptance and usage. 1) Extreme Pressure (EP) oils, (2) Compound oils, (3) Detergent oils (4) Synthetic oils (Fluids).

II. FOUR BALL EXTREME PRESSURE OIL TESTING MACHINE (F.B.E.P.O.T.M.)

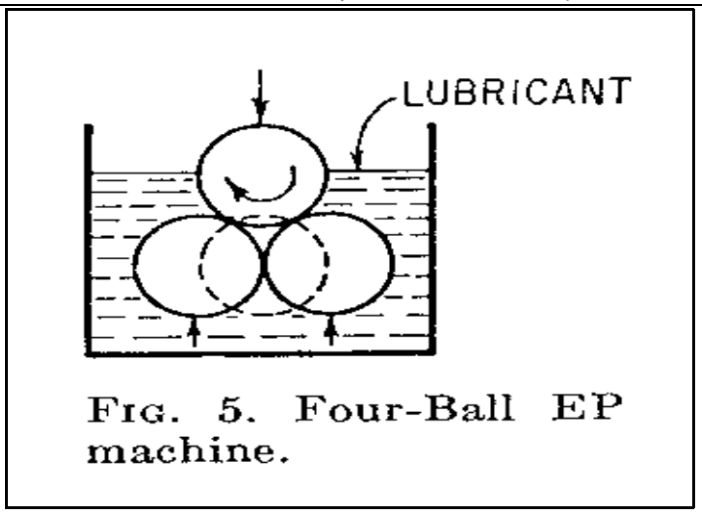

FIG. 5. Four-Ball EP machine.

Fig. 1. Four–Ball EP Machine

DATA FOR TEST:-

1) Test Specimens: - Four ½ inch Dia. SKF Balls, Cr-steel.

2) Load: - 10 to 800 kg (981 N to 7848 N) on lever arm.

3) Speed: - 1,800 rpm.

Three of the balls are clar in contact as in an equilateral triangle (See Fig.1. Four-Ball EP Machine). The fourth ball is held in a rotating chuck a... ...ouches each of the stationary balls. Load is applied through a lever system, which pushes the three stationary balls upward against the rotating ball the test lubricant covers the stationary balls. Tests are run at various loads and for specified periods of time. After the test, the stationary balls are marked with wear scars, the appearance of which indicates the load- carrying capacity of the test lubricant.

Since the original machine was invented, it has gone through an evolution until it approximates the specifications given in the article, one of the early methods of use aimed at determining the initial load causing seizure. Form this evolved the seizure delay method. A complex method of use which involved weld loads, seizure delay, and scar areas (P-WI Method) was later developed. Many additional descriptions of the machine and test methods are available in the literature. The mean hertz load test method is described in Federal Test Method Standard 791, method 6503.

III. FOUR BALL E.P. TEST

The determination of the load carrying capacity of a lubricant in kilogram applied to a system of four steel balls in the form of a tetrahedron.

3.1. FOUR BALL E.P. TEST: (ASTM D2783):–

In the ASTM D 2783 Four Ball EP test (Four ball wear test) steel ball of the same size and metallurgy are used (Cr. Alloy steel material for balls, Dia.12.7 mm) (See Fig. 2-F.B.E.P.Tets) Three steel balls which are immersed in the industrial gear lubricant being tested, are locked in to a test cup . A fourth steel ball that is held in place in a rotating chuck is place on top of the three steel balls locked in the test cup. The fourth steel ball is rotated at a speed of 1770 rpm and subjected to a series of 10 second duration's at increasing loads until welding of the steel balls occurs. At the end of each 10 second test, the ball in the chuck is discarded and the other three balls are taken from the cup to examine the diameter of the wear scar. These wear car diameter to calculate the load wear index. New steel balls are used with each load applied.

The loads are applied in stepped series with the first load being 6 kilograms of force (kgsf). The loading series used is 6,8,10,13,16,20,24,32,40,50,63,80,100,126,160, 200,250,315,400,500,620 and 800 kgsf.

If welding dose not occurs at 800 kgsf, the lubricant is reported as having a weld point of + 800 kgsf.

3.2. TEST PROCEDURE:-

A series of 10 second runs is made at pre-selected and successively higher loads until welding of the four balls occurs (See Fig.2.Four Ball EP Test). The work sheet data collected from the determination of the load scar curve are used in calculations under the mean Hertz load formula for the determination of the E.P value.

Two measurements are made of the wear spots on each of the three lower balls, and the average scar diameter readings are plotted to establish the load scar curve and the weld point.

Due to the accuracy of result that it gives, it can be also used for. Research and Development institutes.

The various Advantages of this (F.B.E.P.I.T.M.) machine are:-

1. The construction is quite easy to understand.
2. The balls used in this testing machine are easily available and of low cost.
3. The range of temperature for testing Oil is quite large 18^0C to 35^0 C.
4. Large variety of oils are tested by this Machine.

5. As measurement of scar on the balls under microscope is very easy so by comparing from table we can easily predict the load carrying capacity of given oil.

IV. RIG TEST (EXPERIMENTAL SETUP

The four ball machine is a standard rig test for the evaluation of Extreme Pressure (E.P.) properties of a Lubricant, in this machine Vertical spindle rotates a chuck between a speed of 1200 rpm to 1800 rpm, in which a steel ball of 12.7mm diameter. [With (i) EN 31- C-0.9 to 1.2%, Mn.- 0.3 to 0.7%, Cr-1 to 1.6%,Ni-Nil % OR (ii) Alloy Steel – C-0.53%, Mn-0.58%, Cr- 0.48%, Si - 0.05%, P-0.027% and Fe-Balance and VHN hardness of 670 (Average) were used test specimen.] is fitted below it three identical balls are clamped together tightly in a cup filled with Lubricant (5ml) to be tested.

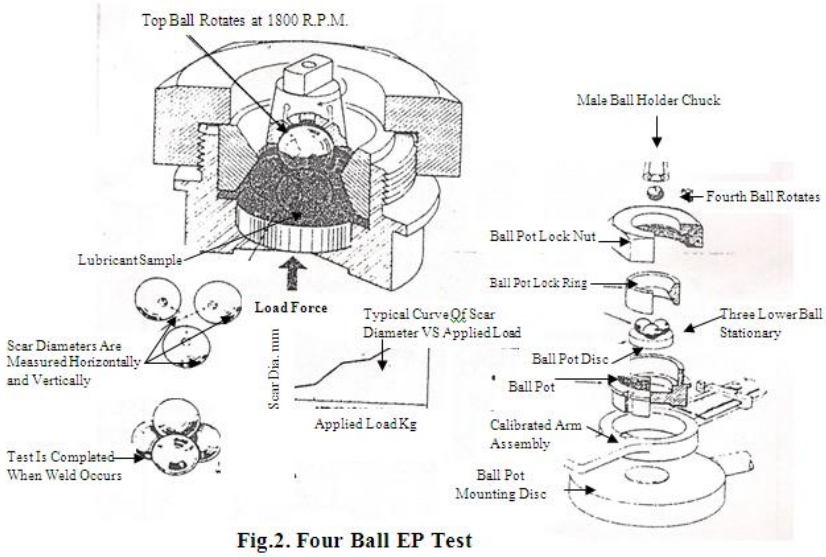

Fig.2. Four Ball EP Test

The cup is mounted on a thrust bearing which automatically centers the top ball held in the chuck. Thus, the load is evenly distributed over three points of contact between the top rotating ball and the underlying three stationery balls. The loads in the range of 20 kg to 40 kg. (OR 549 N to 3479 N) are applied on the thrust bearing by suspending lever arm with the temperature control within range of 18^0C to 35^0C.

The rotation of the driving spindle causes a friction torque, which is recorded on a rotating drum. The duration of the test is 60 Seconds.

To evaluate the EP activity of the additives a number of test were performed until the welding point was reached. The wear scars were optically measured and the other parameters were calculated by the standard method.

V. RESULTS

The F.B.E.P.O.T.M. is used to find out load carrying capacity and weld loads (Points/Regions) of different types of lubricating Oils by using this F.B.E.P.O.T.M.we tested various lubricating oils (i.e. SAE-20,SAE-30,SAE-40, SAE-68, SAE-90,SAE-120 & SAE-140) For finding out their load carrying capacity & weld loads. Under various loads & their various parameters for time duration 10 seconds. See following table No.1.

The following Fig.4.shows the graph plotted Minimum Scared Diameter (MSD in mm) Versus Applied Load (W in kg) is shown between for various regions up to weld point. and Fig.5. Shows Pressure (P) kg/cm^2 Versus Temperature (T)^{0}C. In the graph (See Fig. 4) it is shown that the various regions with applied load W, assumed that load 25 to 50 kg LNSR, load 50 to 150 kg – ISR, load 150 to 350kg – IMSR, load 350 to 375 kg – JBWR and load 375 to 390 kg – WR Formula is used for finding out the Minimum Scar Diameter (MSD) as follow

$$\text{Minimum Scar Dia.} = \frac{\text{Horizontal (Parallel) Reading (HR) + Vertical (Normal) Reading (VR)}}{2}$$

$$\text{M.S.D.} = \frac{\text{Average Readings}}{2} \text{ in mm.}$$

After that test conducted for various oils SAE 20 to SAE 140 and it is found that the following results for various parameters. (i.e. LNSR, ISR, IMSR, JBWR & W.R.) Or Tabulated below (See table 1)

i.e. Result Table.

(i) LNSR- Last Non Seizure Region
ii) ISR - Initial Seizure Region
(iii) IMSR- Immediate Seizure Region
(iv) IBWR- Just Before Weld Region.
(v) WR - Weld Region

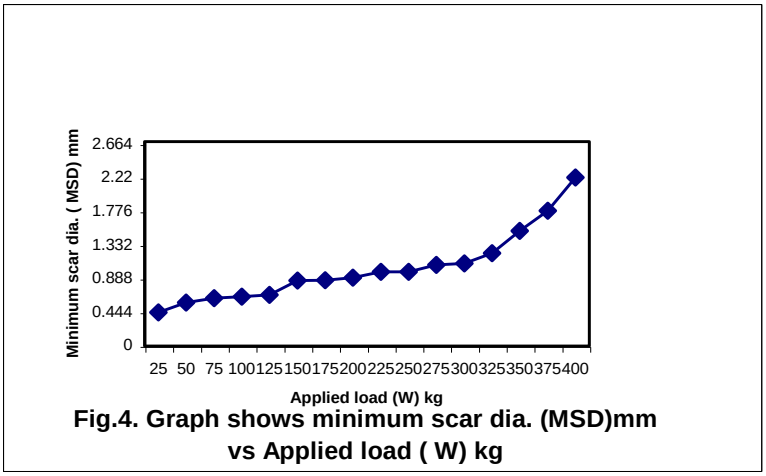

Fig.4. Graph shows minimum scar dia. (MSD)mm vs Applied load (W) kg

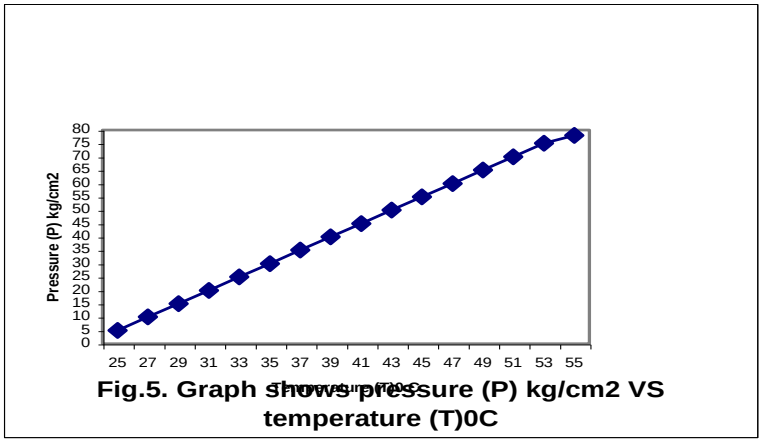

Fig.5. Graph shows pressure (P) kg/cm2 VS temperature (T)0C

VI. CONCLUSIONS

Four Ball Test (F.B.E.P.O.T.M.) shows limited application in determining the EP activity of wear based fluids for metal working processes.

It is also observed (or finally concluded) that if Pressure or Applied Load increases the Minimum Scar Diameter, Weld Load and Temperature also increases.

Due to this simple test procedure of this F.B.E.P.O.T.M. is widely used in oil industries as well as in Research and Development (R & D) Institutes.

We finally resulted that, weld load and temp. For various oils is as follows:-

1) Oil SAE-20 - Weld load is 390 kg at 55^0c Temperature.
2) Oil SAE-30 - Weld load is 400 kg at 56^0c Temperature.
3) Oil SAE-40 - Weld load is 410 kg at 65^0c Temperature.
4) Oil SAE-68 - Weld load is 425 kg at 67^0c Temperature.
5) Oil SAE-90 - Weld load is 450 kg at 73^0c Temperature.
6) Oil SAE-120 - Weld load is 475 kg at 80^0c Temperature.
7) Oil SAE-140 - Weld load is 500 kg at 85^0c Temperature

TABLE. 1. RESULT TABLE.

SR. NO.	PARAMETERS	SAE 20	SAE 30	SAE 40	SAE 68	SAE 90	SAE 120	SAE 140
1.	**PRESSURE (P) kg/cm^{2}At**							
	(i) L.N.S.R.	5	10	15	15	20	20	25
	(ii) I..S.R.	10-25	15-30	20-35	20-35	25-40	25-40	30-45
	(iii) I.M.S.R.	30-70	35-70	40-75	40-75	45-80	45-85	50-90
	(iv) J.B.W.R.	75	75	80	80	85	90	95
	(V) W.R.	78	80	82	85	90	95	100
2.	**APPLIED LOAD (W) kg, At**							
	(i) L.N.S.R.	25	50	75	75	100	100	125
	(ii) I.M.S.R.	50-125	75-150	100-175	100-175	125-200	125-200	150-225
	(iii) I.M.S.R.	150-350	175-	200-375	200-375	225-400	225-425	250-450
	(iv) J.B.W.R.	375	375	400	400	425	450	475
	(v) W.R.	390	375 400	410	425	450	475	500
3.	**TEMPERATURE (T)^{0}c At**							
	(i) L.N.S.R.	25	28	31	32	35	36	39
	(ii) I.S.R.	27-33	30-36	33-39	34-40	37-43	38-44	41-47
	(iii) I.M.S.R.	35-51	38-52	41-59	42-63	45-69	46-76	49-79
	(iv) J.B.W.R.	53	54	63	65	71	78	80
	(v) W.R.	55	56	65	67	73	80	85
4.	**TIME (t) sec. At**							
	(i) LN.S.R.	10	10	10	10	10	10	10
	(ii) I.S.R.	10	10	10	10	10	10	10
	(iii) I.M.S.R.	10	10	10	10	10	10	10
	(iv) J.B.W.R.	10	10	10	10	10	10	10
	(v) W.R.	10	10	10	10	10	10	10
5.	**MINIMUM SCAR DIAMETER (MSD) in mm At**							
	(i) L.N.S.R.	0.4440	0.6890	0.8570	0.8740	0.9430	0.9760	1.0825
	(ii) I.S.R.	0.5750 0.6760	0.7315 0.9750	0.8970 1.0865	0.9225 1.1885	1.0560 1.3055	1.0745 1.3055	1.1805 1.4575
	(iii) I.M.S.R.	0.8660 1.5230	1.0285 1.5790	1.2280 2.132	1.2570 2.1625	1.3500 2.4445	1.3825 2.6100	1.4850 2.7875
	(iv) J.B.W.R.	1.7870	2.0295	2.2400	2.4080	2.6056	2.6300	2.9680
	(v) W.R.	2.2275	2.2325	2.2915	2.5875	2.6115	2.6950	3.2910

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