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Rheological Study of Virgin and Used Lubricant Oils

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Abstract—*Lubricating oil used in vehicles engine are need to be changed after particular time intervels because engine oil pollutes due to metal wear, pollutants from the environment , some times already existing contamination in oil. In order to determine overall lifetime of oil one should know various parameter such as wear elements, pollutants, viscosity , acid number, base number, amount of engine wear, oil consumption, operating condition and element correlation coefficient. Available engine oils are hydrocarbons like poly alpha olefin (PIO), poly internal olefin blended with additives to enhance the properties like anti wear corrosion resistance. The best performance engine oil is important in two aspects: 1) the economy 2) in terms of its effect on engine life. The study indicates that the combustion condition and deposit formation are the predominant cause of wear. Process for the development of an automotive lubricant are selection of a base stoke, evaluation of additives followed by formulation of the lubricating oil with best trade-off in performance and cost. Oil analysis of various samples utilize include variety of chemical and physical laboratory bench test to evaluate the components in virgin oil (before any use) and oil after use for certain periods(after every 6 hours of running condition).From this study will be helpful in monitoring and maintaining vehicles and machine engines.*

Keywords: *Automotive lubricating oil, metal wear, acid number, base number, additives*

1. INTRODUCTION

For many years, lubricant inspection and testing has been used to help diagnose the internalcondition of oilwetted components and to provide valuable information about the lubricant serviceability. Oldmethods used for this purpose included such simple procedures assmelling used oil for the sourodor of excess acid, chcecking visually for obvious signs of contamination or placing a small drop of sample on absorbent paper to detect contaminates and monitor additive effectiveness. Modern day analysis sin built on these early efforts. Oil analysis test proceres are established and reviewed by such agencies as the International Standards Organization, the American Society of Testing Materials and the Society of Automotive Engineers. Today, little doubt remains that comprehensive oil analysis program is a very valuable tool. The study indicates that the combustion condition and deposit formation are the predominant cause of wear. Process for the development of an automotive lubricant are selection of a base stoke, evaluation of additives followed by formulation of the lubricating oil with best trade-off in performance and cost. Oil analysis of various samples utilize include variety of chemical and physical laboratory bench test to evaluate the components in virgin oil (*before any use*) and oil after use for certain periods(*after 150 hours of running condition*).From this study will be helpful in monitoring and maintaining vehicle.

2. TREND OIL ANALYSIS

All oil analysis programs are designed to be performed as a trend analysis. This is a regularly scheduled set of samples over a span of time. A trend is a unique history of what is happening to a unit within its specific application. To etablish a trend, at least two samples are needed.

All the test data on a sample is relevant to:

1. Hours or mileage on the oil

2. With time, the oil is accumulating more and more detectable metals

3. What would be normal readings for an engine with 10, 000 miles on an oil drain would be high readings on an engine with 1, 000 miles on an oil drain

4. Time on the engine itself

5. Each system has a life span and there will be differences in results along the way. One oil sample, taken after a failure, does not show the history of how the failure developed or how long it existed. Only a trend can do this. With failure analysis it is very difficult to reconstruct what caused the problem. The test data for an oil sample will sometimes fail to support the problem or failure when the service is used as a onesample failure analysis. Lubricating oils consist of a base of mineral or synthetic oil and several substances added in order to enhance different properties of the product. Some of these

additives are salts of organic acids and metals such as calcium, barium, magnesium, and zinc. Depending on the additive and the characteristics of the oil, metal concentrations range typically from 0.2 to 2g/L. This determination is carried out, according to standard methods from the American Society for Testing and Materials (ASTM), by means of either in datively coupled plasma optical-emission spectrometry (ICPOES) or flame atomic absorption spectrometry(FAAS). These techniques are also used for the determination of wear metals in used lubricating oils, which is an activity carried out within predictive/proactive maintenance schemes of large engines and lubricated machinery. From the analytical point of view, lubricating oils are a difficult matrix due to their high viscosity and hydrophobicity, which precludes direct introduction to standard nebulizers employed in ICP-OES and FAAS, as well as dilution with aqueous solvents. Thus, instrumental determinations usually require a dilution with organic solvent, for instance xylene, methyl-isobutyl ketone, or kerosene. The samples are prepared by weight to avoid undesired volume uncertainties due to the viscosity of the oil. A wear metal profile is often prepared for each engine. Impending component failure will be indicated by a rapid increase in wear metal concentration, or the sudden appearance of a metal. The metal type and concentration may also indicate to the analyst and engineers which part of an engine is failing. It has been found that each type has its own generation mechanism involving a specific wear process. Color is an important feature in wear debris analysis. If the shape and texture allow one to differentiate the wear particles according to their prehistory of formation, color may help to define debris composition. Composition of wear particles is determined by the materials of the worn surfaces, contaminants and products of tribo chemical reactions. In lubricated metallic contacts we most often meet steel, copper, lead, tin, chromium, silver and titanium- contained particles. Ferrous oxides found in the lubricants usually can be divided into two groups: red or black oxides. Examination of color allows one to define the source of particle generation and the severity. These particles consist of metallic and non-metallic matter. The metallic particle is a wear condition that separates different size and shapes of metallic dust from components like all type of bearings, gears or coupling. When implemented correctly it provides tremendous information on machine under operation. Yet, it is frequently excluded from oil analysis programs because of its comparatively high price and a general understands of its value. The test procedure is lengthy and requires the skill of a trained analyst.

2.1 SOME OF THE SPECIFIC USES OF OIL ANALYSIS INCLUDE

Noting progressive wear in order to repair damaged parts before they become emergency breakdowns.Detection of corrosive acids**,** coolant**,** fueldilution and other oil conditions which are caused by engine problems that could become major failures.Planning of needed repairs based upon the noted progression of an abnormal wear pattern**,** which can lead to more effective equipment utilization and fewer emergency repairs.Oil Analysis provides useful records when handling warranty problems**,** resale of equipment**,** detection of abuse and evaluation of new oils**,** oil filters and air filters.

3. LITRETURE REVIEW

Noln et al. (1990) described that in larval phases of aquatic organisms that is open to toxic substances contained in used oil that can build up plankton and other tiny organisms due to the food chain and finally reach human beings as contaminants elevate the food chain, consumed used-oil-contaminated water range from mild symptoms of increasing the toxic compounds in the liver to complete impairment of body functions and in the end death. When applied the waste lubricating oil to soil, degrades significant contamination of the surrounding soil and groundwater. This degradation is because of bacteria and fungi which can degrade the components of used lubricating oil. Mueller Associates (1987) pointed out that one pint of used oil can create an acre-sized slick on water; as little as 35 parts per million will appear as a thin film. When dumped into water, used oil increases the high biological oxygen demand as its hydrocarbons decompose. This removes oxygen that is necessary for healthy animal and plant life. Brown et al. (1985) and Wakeham and Carpenter (1976) described that hydrocarbons, such as well branched alkanes and PAHs with three or more rings, are moved in soil runoff to surface water and inhabit out of the water column into the residue where they may keep on for many years. Contaminants that make used oil management more problematic are heavy metals and chemical additives. When leaded gasoline was the predominant vehicle fuel, lead was present at high levels in used oil because of piston blow-by. Other heavy metals commonly present in used oil include cadmium, chromium, arsenic and zinc These may arise from wear on the metal engine parts or from their inclusion in oil additives (Franklin Associates, 1985). Low molecular weight PAHs and volatile compounds, such as the mono-aromatics and various halogenated alkyl substances, comprise the largest fraction of WCOs lost by volatilization (Metzler and Jarvis, 1985) and (Stephens et al., 1981) Oil applied to road surfaces was lost by volatilization in the initial 15- to 30-day period following application (Surprenant et al, 1983).Baranowski (1982) reported that most common impurity in used oil is water which may result from leaky engine seals, condensation or coolant contamination. Brinkman, and Dennis, (1982) reported that as the EPA has gradually reduced the lead content in gasoline, the presence of lead in used oil has decreased correspondingly, from an average of 21, 000 ppm to 500 ppm. Canil et al. (1982) have described that dirt in the oil can result from worn seals, abrasion and erosion in the engine and adhesive wear. These two impurities are readily separable from the oil. Simple heating drives off the water, while mechanical filtration removes dirt particles. Mackenzie and Hunter (1979) reported that diaromatics are lost through natural weathering at once when waste crankcase oil becomes adsorbed to particulate matter.

4. METHODOLOGY

The oil samples of Castrol and Shell of Grade 15w40 are taken. They are then put in Dynamometer and run for 16 hours each at different loading. First at normal loading that is 700 rpm for 5 hours. Then at Half load for the next 3 hours. At Full load for next 4 hours. At last again at normal loading for 4 hours.The used oil is the taken from it and taken for testing of viscosity and density.

4.1 METHOD DESCRIPTION

For comparative study of the engine oils 2 engine oils of same grade were brought. These engine oil were then run in the engine for the following time & load specified Engine oil time load :By running these oil samples at above specified criteria the used oil were retained from the engine.

4.2 WORKING PROCESS

A engine is used in this process, which was connected to dynamometer. The dynamometer was used to measure the power output & apply the loading to the engine according to the given loading said. After running the engine for the stipulated time , the used oil were retained for further analysis of the change in various properties of the engine.

4.3 Working Principle

Dynamometers are used to provide simulated road loading of either the engine (using an engine dynamometer) or full powertrain (using a chassis dynamometer). In fact, beyond simple power and torque measurements, dynamometers can be used as part of a test bed for a variety of engine development activities, such as the calibration of engine management controllers, detailed investigations into combustion behavior, and tribology.

4.4 Testing Method

4.4.1 Viscosity Test: Viscosity is a measure of the resistance of a fluid which is being deformed by either shear stress or tensile stress. In everyday terms (and for fluids only), viscosity is "thickness" or "internal friction". Thus, water is "thin", having a lower viscosity, while honey is "thick", having a higher viscosity. Put simply, the less viscous the fluid is, the greater its ease of movement (fluidity). This is done by rheometer.

4.4.2 RHEOMETER

A rheometer is a laboratory device used to measure the way in which a liquid, suspension or slurry flows in response to applied forces. It is used for those fluids which cannot be defined by a single value of viscosity and therefore require more parameters to be set and measured than is the case for a viscometer. It measures the rheology of the fluid. There are two distinctively different types of rheometers. Rheometers that control the applied shear stress or shear strain are called rotational or shear rheometers, whereas rheometers that apply extensional stress or extensional strain are extensional rheometers. Rotational or shear type rheometers are usually designed as either a native strain-controlled instrument (control and apply a user-defined shear strain which can then measure the resulting shear stress) or a native stress-controlled instrument

4.4 PROCEDURE

Pour liquid into measuring cup (CC17/QC- LTD) up to a mark of 5ml.Put measuring probe (CC17) inside cup and Rheolab QC with coupler. The RheolabQC can carry out measurements with controlled shear rate (CSR) or controlled shear stress (CSS). Shear rate control is more frequently used because the shear rate is often known from the application. For each type of measurement you can select to measure a range (’Ramp’) or a single point (’Const’). Select the required measurement type from the list. You can select measurements for CSR between shear rate and rotational speed; for CSS measurements you can select between shear stress and torque. Speed and torque are raw value from the instrument; the range is given in the technical data. Shear rate and shear stress are calculated from speed and torque using the measuring system factors.

1. The input of measurement parameters (’Program Input’) is done in one step for a single point measurement and in two steps for a ramp. The time value given under ’Time’ is the complete measurement duration. Enter the number of measuring points (’MeasPt’) and the constant value or the start and end value for the set variable. Please note that the duration of one measuring point needs to be at least 0.5 s.
2. If you frequently measure samples with similar names it may be useful to preset the beginning of the sample name to make sample name entry easier Under ’Save to Memory’ you select whether the measurement results should be stored to the instrument’s memory (’Save On’) or not (’Save Off’). The instrument can store up to 100 measurements. The stored measurements can be transferred to a computer using the Rheoplus Software or the RheolabQC Data export software

4.5 Density Test

DENSITY is a physical property of matter, as each element and compound has a unique density associated with it. Density defined in a qualitative manner as the measure of the relative "heaviness" of objects with a constant volume.

4.6 DENSITY METER

4.6.1 Procedure

1. The oil sample is poured into the density probe column upto the brim using a funnel
2. Then the column is sealed by plastic cap
3. The probe is then set to check the density using the control buttons
4. Press the OK button when asked for temperature setting
5. Again press OK button to get the reading

9.1 DENSITYTEST RESULTS:CASTROL-15W40 (FRESH)

Table 1

D	T	D-15
0.8485	22.09	0.8541
0.8487	22.08	0.8538
0.8486	22.09	0.8537
0.8484	22.08	0.8535
0.8478	22.08	0.8529
0.8475	22.08	0.8526
0.8475	22.08	0.8526

Mean Density=0.8486

2. SHELL-15-W-40 FRESH OIL

Table 2

D	T	D-15
0.8705	22.06	0.8755
0.8714	22.05	0.8733
0.8728	22.05	0.8777
0.8736	22.05	0.8785
0.8735	22.06	0.8784
0.8734	22.06	0.8783
0.8733	22.06	0.8782
0.8732	22.07	0.8782

Mean Density=0.87

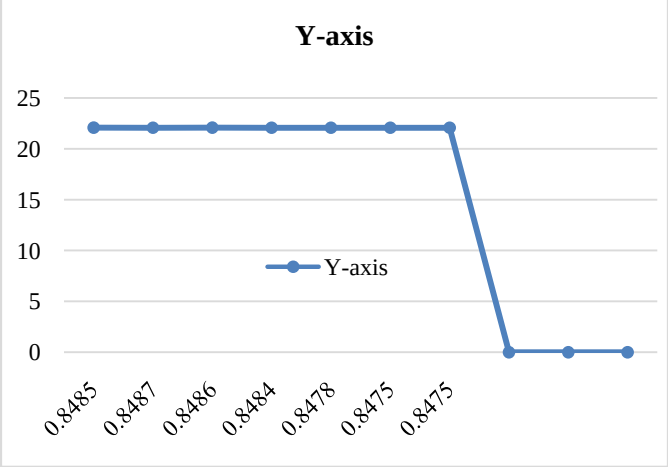


Fig. 1: Density variation of Castrol 15-W-40 Fresh

CASTROL-15-W-40 USED (AFTER RUNNING)

Table 3

D	T	D-15
0.8601	22.02	0.8651
0.8605	22.02	0.8655
0.8614	22.03	0.8664
0.8628	22.04	0.8678
0.8619	22.06	0.8669
0.8614	22.07	0.8664
0.8613	22.09	0.8663
0.8611	22.09	0.8661

Mean Density-0.8628

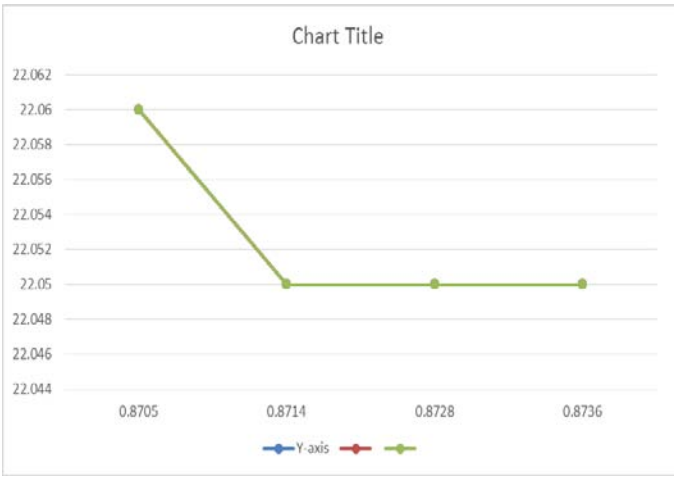


Fig. 3: Density variation of Shell 15-W-40 Used

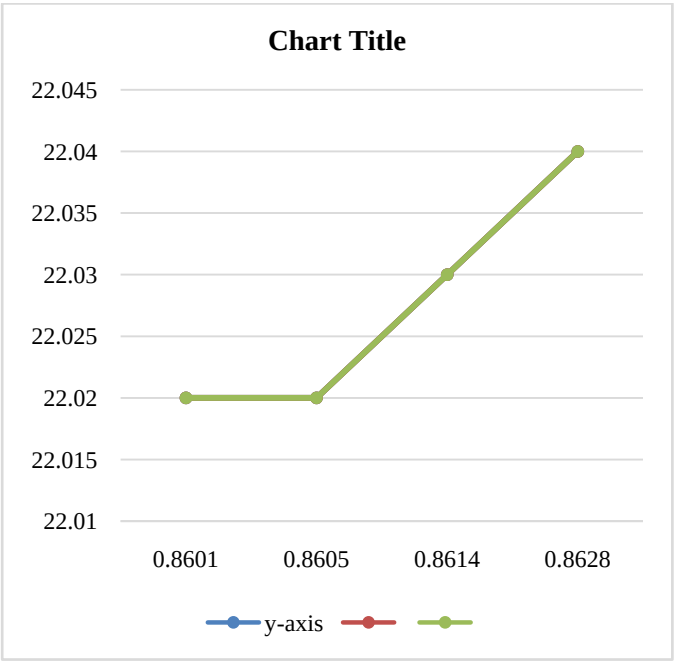


Fig. 2: Density variation of Castrol 15-W-40 Used

4. SHELL 15-W-40 USED (AFTER RUNNING)

Table 4

D	T	D-15
0.8805	22.06	0.8854
0.8804	22.08	0.8853
0.8803	22.10	0.8852
0.8802	22.11	0.8851
0.8501	22.13	0.8851
0.8799	22.14	0.8849
0.8796	22.14	0.8846
0.8796	22.15	0.8846

Mean density= 0.8796

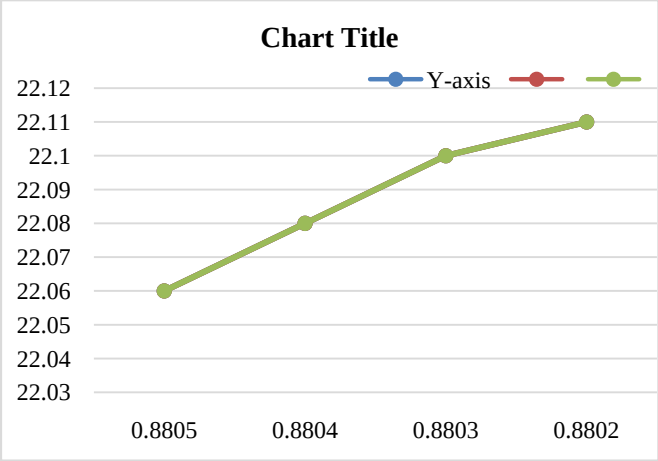


Fig. 4: (Density variation of shell 15-W-40 Used

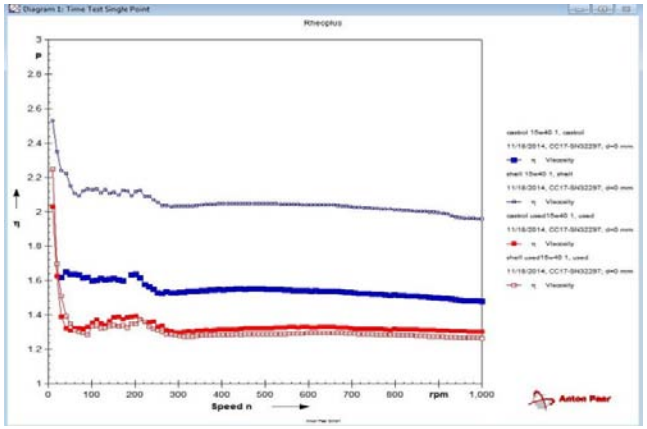
5. VISCOSITY TEST RESULTS

SHELL FRESH:15-W-40 Table-1

Meas. Pts.	Timet Timet	Viscosity	Shear Rate	Speed	Torque
	[s]	[P]	[1/s]	[rpm]	[mNm]
1	36	1.03E+07	5.44E-07	4.25E-07	0.00728
2	72	2.53	12.9	10.1	0.0424
3	108	2.35	25.8	20.2	0.0789
85	3, 060	2	1, 090	848	2.83
93	3, 350	1.98	1, 190	929	3.05
94	3, 380	1.97	1, 200	939	3.08
100	3600	1.96	1280	1000	3.25

CASTROL USED 15-W-40 Table-3

Meas . Pts.	Time	Viscosity	Shear Rate	Speed	Torque
	[s]	[P]	[1/s]	[rpm]	[mNm]
1	72	2.03	12.9	10.1	0.0341
2	108	1.62	25.8	20.2	0.0545
3	144	1.39	38.8	30.3	0.0699
95	3420	1.31	1210	949	2.06
100	3600	1.3	1280	1000	1.6



SHELL USED:15-W-40 : Table-2

Point No	T	Viscosity	Shear Rate	Speed	Torque
	[s]	[P]	[1/s]	[rpm]	[mNm]
1	72	2.25	12.9	10.1	0.0378
2	108	1.69	25.8	20.2	0.0569
3	144	1.51	38.8	30.3	0.0761
79	2, 840	1.29	1, 010	788	1.68
100	3600	1.26	1280	1000	1.2

CASTROL FRESH 15-W-40 Table-4

Meas. Pts.	Time	Viscosity	Shear Rate	Speed	Torque
	[s]	[P]	[1/s]	[rpm]	[mNm]
1	72	2.12	12.9	10.1	0.0356
2	108	1.71	25.9	20.2	0.0576
3	144	1.62	38.8	30.3	0.0815
4	180	1.65	51.7	40.4	0.111
91	3280	1.5	1160	909	2.6
92	3310	1.49	1180	919	2.28

6. FUTURE SCOPE

This study allows us to select the type of oil according to different conditions of engine.And a further study on this will allow us to find the wer metals by doing the atomic adsorption spectroscopy (AAS) also find the acidity and basicity value by finding the Acid No. and Base No.

7. CONCLUSION

1. We have analyse the density and viscosity changes in two samples of fresh and used oil.
2. As per the standards we had run the engine oils on different loads as per the ASTM.
3. Density in Castrol oil decreases from 0.8628 to 0.8486 gm/cm^3. Density in Shell oil decreases from 0.8799 to 0.8732 gm/cm^3. The density didn't vary much.
4. Viscosity in the Castrol oil decreases from 1.7 to 1.3 (poise).Viscosity in Shell oil decreases from 2.0 to 1.34 (poise). And as per the standard results it varies a little.

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