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FEASIBILITY TEST TO REUSE THE DEGRADED AUTOMOBILE LUBRICANT

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Abstract- *The modernization and mechanization of the rapidly changing world has led to a notable increase in the number of vehicles which in turn demands the exploitation of lubricating oil. This oil unfortunately nonrenewable has led to oil crisis recent time which have brought to notice a striking fact that this petroleum based fuels will be available neither in sufficient quantities nor at reasonable price in near future. This has revived interest in recycling lubricating oils so that it can be used again. This study describes an evaluation carried out to study the recycling of used lubricating oil which has contributed immensely to the level of environmental pollution. This study informs about the evaluation of lubricating characteristics (mainly viscosity, density and flash point) of used and recycled lubricants in SI and CI engines vehicles and the evaluation of viscosity degradation rate at approximately every 500 km running. It has been found that for the same kilometers running viscosity degradation rate is much more in CI engine than SI engine vehicles. From the brief comparison of the properties between used and recycled lubricating oil, by recycling process properties can be upgraded to maximum value and SI engine recycled oil is quite better than CI engine recycled oil. This study identifies a method by which the used oil is adequately recycled for reuse in other applications. The cost of recycling is relatively low compared its production from crude oil. It is also observed that when 500 ml of used oil is recycled appropriately then 450 ml can be regained for SI engine vehicles and 400 ml for CI engine vehicles. This recycled oil can be used in any type of machineries excluding vehicles.*

Keywords: Lubricating oil, Degradation, Recycling, Viscosity, Density, and Flash Point.

1. INTRODUCTION

The system that provides a continuous supply of oil between moving faces during engine operation make a viscous film known as the lubricant. It lubricates and cools the components of power transmission while eliminating impurities, neutralizing chemically active products of combustion, transmitting forces, and damping vibrations. The main purpose of lubricants is to grease moving parts to lessen friction and wear and tear by providing smooth, trouble free performance for increased length of time. Typically lubricants contain 90% base oil and less than 10% additives [1]. Lubricants are added to fuels like gasoline which has low lubricity. Sulfur impurities in fuels also provide some lubrication properties, which have to be taken into account when switching to a low-sulfur diesel. Biodiesel is a popular diesel fuel additive providing additional lubricity. Non-liquid lubricants include grease, powders. Dry lubricants such as graphite, molybdenum disulfide and tungsten disulfide also offer lubrication temperature up to 350°C [2]. Recycling or refining is an energy-efficient and environmentally beneficial method of managing used oil. Less energy is required to produce a gallon of re-refined base stock than a base stock from crude oil. Again by recycling used oil can be processed to new lubricating oil, which can be used again [3].

2. AUTOMOBILE LUBRICATION SYSTEM

Automobile lubrication system is used to smooth the moving parts of the automobile to reduce friction and wear and tear by providing trouble free performance for a longer span of time. A lubricant is a blend of base oils and performance enhancing additives as required by engine, gear box and other functional areas. Automotive engines are generally lubricated with petroleum base oils that contain chemical additives to improve their natural properties. Synthetic oils are used in gas turbines and may be used on other engines [4]. Probably the most important property of oil is the viscosity which indicates the measure of force required to move one layer of the oil film over the other. If the viscosity is too low a protecting oil film is not formed between the parts. With a high viscosity too much power is required to shear the oil film and the flow of oil through the engine is retarded. Viscosity tends to decrease as temperature increases. Viscosity index (VI) is a number that indicates the resistance of oil, changes in viscosity with temperature. The smaller the change in viscosity with temperature, the higher the viscosity index of the oil. The lubricating system supplies clean oil cooled to the proper viscosity to the critical points in the engine where the motion of the parts produces hydrodynamic oil films to separate and support the various rubbing surfaces. The oil is pumped under pressure to the bearing points while sliding parts are lubricated by splash and oil mist. After flowing through the engine the oil collects in the oil pan or sump which cools the oil and acts as a reservoir while the foam settles out. Some engines have an oil cooler to remove additional heat from the oil.

3. PROPERTIES OF LUBRICANTS

Viscosity is the main properties of lubricating oil. Again, density, flash points are also used to maintain lubricant properties.

3.1 Density

Density is defined as an object mass per unit volume. It is denoted by 'ρ' (the lower case Greek letter rho). Density is also defined as its weight per unit volume, although this quantity is more properly called specific weight. Different objects usually have different densities.

Mathematically, density is defined as mass divided by volume, which is expressed as:

$$\rho = m/v \quad (1)$$

Where,

ρ= density, kg/m^3

m = Mass, kg

V = Volume, m^3

From equation (1) mass density must have units of a unit of mass per unit of volume. As there are many units of mass and volume covering many different magnitudes there are a large number of units for mass density in use. The SI unit of kilogram per cubic meter (kg/m^3). Again, 1Kg/m^3 =0.001 kg/l.

3.2 Viscosity

Viscosity is the property of a fluid that determines its resistance to flow. It is an indicator of flow ability of fluid. Lower the viscosity greater the flow ability. It is mainly due to the forces of cohesion.

3.2.1 Dynamic or Absolute Viscosity

The dynamic or absolute viscosity can be expressed like

$$\tau = \mu\,(du/dy) \quad (2)$$

Where,

τ =F/A= shearing stress, N/m^2

F= Force, N

A=Area, m^2

Equation (2) is known as the Newton's Law of Friction.

In the SI system the dynamic viscosity units are N s/m^2, Pa.s or kg/m.s

Where,

1 Pa.s = 1 N s/m^2 = 1 kg/m.s

3.2.2 Kinematic Viscosity

Kinematic viscosity is the ratio of absolute or dynamic viscosity to density - a quantity in which no force is involved. Kinematic viscosity can be obtained by dividing the absolute viscosity of a fluid with its mass density.

The kinematic viscosity can be expressed like

$$\nu = \mu / \rho \quad (3)$$

Where,

μ = absolute or dynamic viscosity, Pa.s

ρ = density, kg/m^3

In the SI-system the theoretical unit is m^2/s or commonly used Stoke (St).

Where,

1 St = 10^4 m^2/s

Since the Stoke is an unpractical large unit, it is usual divided by 100 to give the unit called Centistokes (cSt).

Where,

1 St = 100 cSt

1 cSt = 10^6 m^2/s

3.3 Viscosity Index (VI)

The VI scale was set up by the Society of Automotive Engineers (SAE). The temperatures chosen arbitrarily for reference are 100 and 210 °F (37.8 and 98.9 °C). The original scale only stretched between VI=0 (worst oil, naphthalene) and VI=100 (best oil, paraffin) but since the conception of the scale better oils have also been produced leading to VIs greater than 100. VI improving additives and high quality base oils are widely used nowadays, which increase the VIs attainment beyond the value of 100. The Viscosity Index of synthetic oils ranges from 80 to over 400.

The viscosity index can be calculated using the following formula:

$$VI=100x(L-U)/(L-H) \quad (4)$$

Where, VI indicates the viscosity index,

U = kinematic viscosity at 40^0 C, cSt

L & H= Constant values based on the kinematic viscosity at 100^0 C available in an ASTM D2270 table.

3.4 Flash Point

The flash point is the lowest temperature to which a lubricant must be heated before its vapor when mixed with air then will ignite but not continue to burn. The oil flashes because a flammable mixture results when it is heated sufficiently causing vapors to emerge and mix with oxygen in the air. The flash point temperature of oil corresponds roughly to a vapor pressure of 3-5 mm Hg. When a small flame (ignition source) is applied to the oil's surface, this vaporous mixture will burn momentarily and then extinguish if the critical temperature has been reached.

4. METHODOLOGY

Recommended engine oil for both SI & CI engine vehicles is "Mobil SAE 20W50" [5]. It is necessary to change engine oil after running every 4000 and 5000 kilometers for SI and CI engine vehicles respectively.

4.1 MEASUREMENT OF DENSITY

Density of lubricating oil generally is measured by means of a density bottle and digital weight meter (Fig.1.0). At First density bottle is cleaned and dried, then density bottle weighted.

Fig. 1: Digital weight meter for density test

After that, density bottle is filled with lubricating oil (below or equal 25 ml each) and weighted again. Then weighted mass found. By dividing the mass of each oil test by the volume of the density bottle required density is measured.

4.2 MEASUREMENT OF VISCOSITY

Saybolt universal viscometer is used to measure viscosity of lubricating oil. This Viscometer consists of an oil tube fitted at the top with an overflow cup and the tube is surrounded by a belt. The out flow capillary tube is filled to the bottom of the oil tube which is made of stainless steel or of hard and corrosion resistant materials. The receiving flask is marked to hold 60 cc of the sample. The lower end of the outflow tube is enclosed in a larger tube sealed by means of cork which acts as a closed air chamber and prevents the flow of oil (Fig. 2).The use of a loop string to withdraw this cork is recommended. Here a thermometer is installed to measure the temperature of the oil as well of the bath. The bath is heated to the required temperature using an electrical heater. Oil used in this instrument should first be strained through a 100- mesh sieve and excess of oil overflow at the top should be removed by means of a suitable pipette. The outflow time is recorded by making use of a stop-watch. The results are normally expressed as Saybolt universal seconds (SUS).

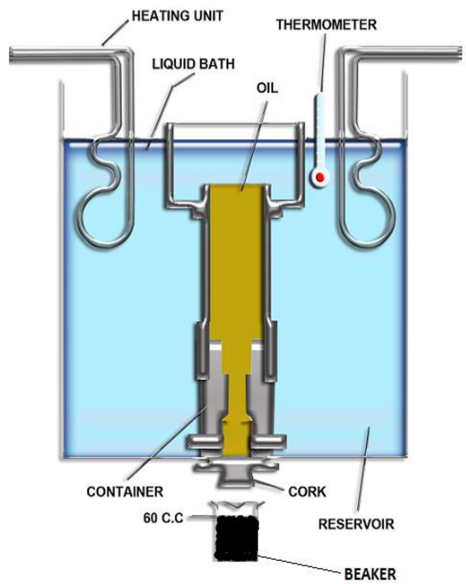

Fig. 2: Sectional view of Saybolt universal viscometer

There are several precautions to be observed in connection with this viscometer. The level of bath liquid must be above of the overflow rim of oil tube and any oil used to test or cleaning should be strained before its use. The oil heated to the required temperature and some of it poured through the clean tube. The cork is inserted tightly enough to prevent air leakage, but mot reaching out flow tube. Stirring the oil in the container and also of the bath should be constant during the entire time of the test [6]. Adequate stirring and control should be provided for bath so that, the temperature of the test sample will not vary not more than 1.5^0C. After the bath and oil in the container have reached the required temperature oil tube thermometer is withdrawn then excess oil in the over flow cup is pipetted out. So the level of the oil in the overflow cup is below the level of oil in the tube. The cork is then dexterously withdrawn and the time of the flow of 60 cc of the oil is recorded. The liquid in the surrounding bath is kept under constant stirring during the entire test. The ratio of the dynamic viscosity and the mass density is known as kinematic viscosity and is denoted by ν. The following formula [7] used to determine kinematic viscosity at centistokes (cSt) unit for approximate Saybolt universal seconds (SUS):
For SUS values between 32 seconds to 100 seconds
Kinematic viscosity,

ν= (0.22xSUS)–(195/SUS) cSt (5)
For SUS values greater than 100 seconds
Kinematic viscosity,
ν= (0.22xSUS)–(135/SUS) cSt (6)
Now, the absolute viscosity is given by
$\mu = \nu*\rho$ (7)
Where,
μ = absolute viscosity, pa.s
ν = kinematic viscosity, m^2/s
ρ = density of oil, kg/m^3

4.3 MEASUREMENT OF FLASH POINT

The flash point was developed for the purpose of determining the fire hazard of fuels and oils being stored or transported. A combination of other tests such as viscosity, viscosity index, and specific gravity flash point can help reveal both the quality of the crude oil from which the lubricant was derived and the quality of the refining process. The flash point can also identify whether the base oil was a wide or narrow single cut or whether it represents a blend of two fractions (two base oils of different viscosities mixed together).

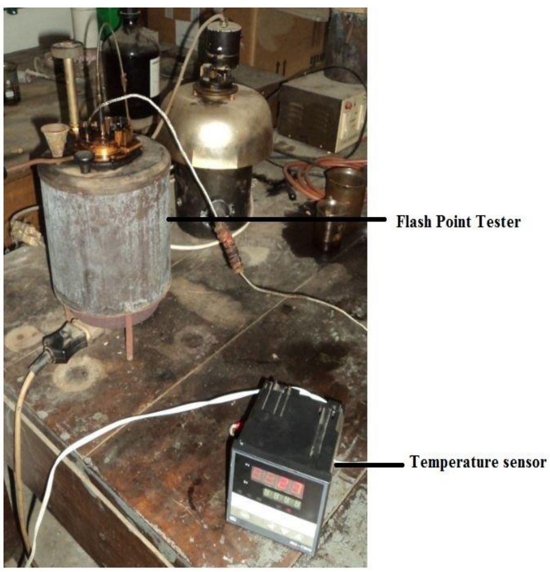

Fig. 3: Flash point tester with temperature sensor

The flash point may give some indication about the volatility and the content of the most volatile components of the test oil [8]. The flash point tells about the volatility of the oil. Unlike mineral oils that start to evaporate long before their flash points are reached and some synthetics do not evaporate until they begin to decompose (destructive distillation). Hence flash points of these synthetics can range much higher than those of mineral oils of conventionally refined similar viscosities. The flash point tester accurately determines the lowest flash point temperature of fuels, lubricating oils and homogenous liquids or liquids containing suspended solids as well as liquids that tend to form a surface film during testing (Fig.3). Flash point tests are simply conducted by mounting the flash cup filled with sample into the test position. Every liquid has a vapor pressure which is a function of that liquid's temperature. As the temperature increases vapor pressure increases. As the vapor pressure increases, concentration of vapor of the flammable liquid in the air increases. Then temperature determines the concentration of vapor of the flammable liquid in the air. A certain concentration of vapor in the air is necessary to sustain combustion and that concentration is different for each flammable liquid. The flash point of a flammable liquid is the lowest temperature at which there will be enough flammable vapor to ignite when an ignition source is applied. Then required flash point indicated by temperature sensor.

4.4 RECYCLING OF DISPOSED ENGINE OIL USING BLEACHING EARTH

4.4.1 DEGRADED OIL COLLECTION

During the servicing period of automobile lubrication system disposed oil has been collected from oil pan after opening oil plug. Then disposed oil stored in a clean vessel to remove other soluble impurities and to maintain room temperature. Then 500 ml of used engine oil was measured in a beaker.

4.4.2 WATER TREATMENT

25 ml of (5% of used oil)) water was measured in a separate 50 ml beaker. Then 500 ml of use oil and 25 ml of water were mixed in a pan. This mixture of used oil and water blended, 10 to 15 minutes for proper mixing of water into oil. At the end of the water treatment step oil was allowed to settle 1 hour to form sediment at the bottom of the pan. After this period oil was properly sediment and decanted into another pan while the residue sludge at the bottom of the pan was discarded.

4.4.3 BLEACHING

The oil in the pan was then subjected to bleaching. Then 30 to 35 % of bleaching earth [9, 10] was introduced into the oil and the mixture as continuously stirred for 10 to 15 minutes. At the end of the bleaching step bleached oil was again allowed to settle 5 to 6 hours to form sediment at the bottom of the pan.

4.4.4 HEATING OF BLEACHED OIL

Then bleached oil was placed on a regulator hot plate. Then the temperature was maintained at 90^0 C to 100^0C.

4.4.5 COOLING AND SEDIMENTATION

During this stage oil was allowed to cool and sediment in the pan for 20 to 24 hours and decanted into another pan while the residue at the bottom of the pan was discarded.

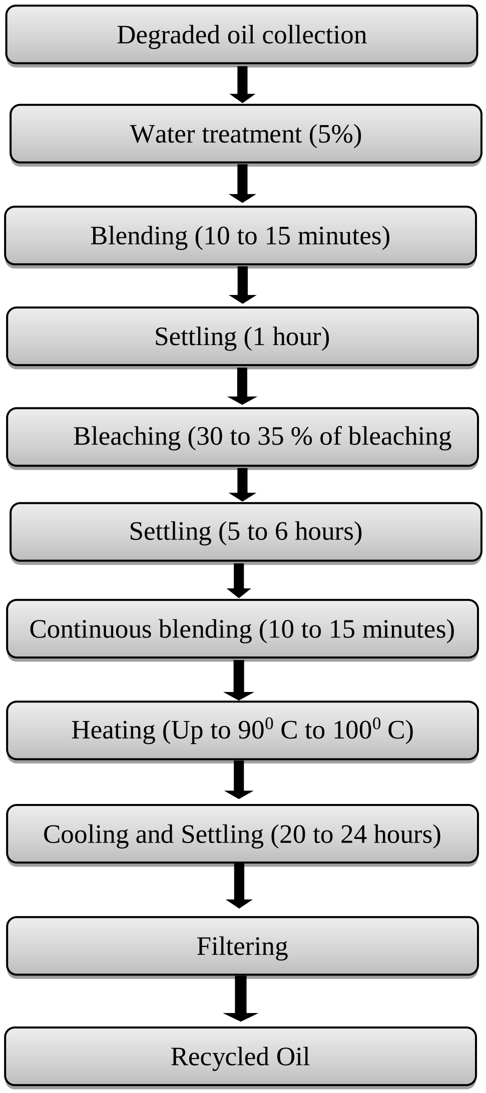

Fig. 4: Flowchart for recycling of degraded engine oil

4.4.6 FILTRATION

Then sediment oil was finally filtered using a filter cloth. The filtrate was collected in a filtration flask and observed to be clear while the residue (filter cake) which was discarded. Then finally recycled oil found.

5. RESULT

5.1 DENSITY ANALYSIS FOR RECYCLED OIL

Fig.5 shows density increased from 0.756 kg/l to 0.831 kg/l and 0.792 kg/l to 0.839 kg/l (1kg/m^3=0.001kg/l) for recycled oil from disposed CI and SI engine oil respectively. Again density degradation rate is higher in CI engine oil than SI engine oil.

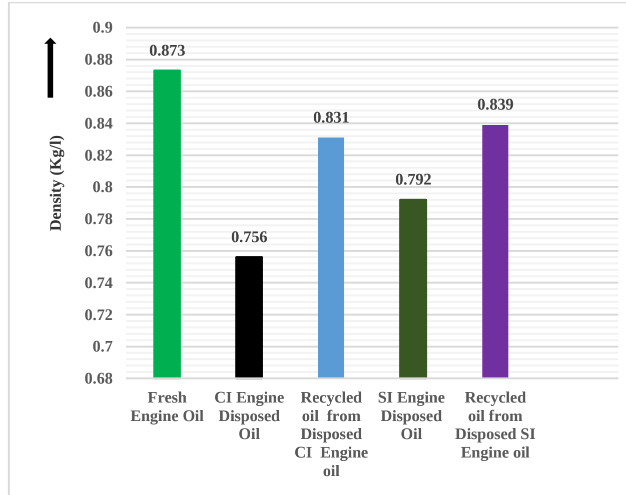

Fig. 5: Change of density from disposed oil to recycled oil at 15^{0}C temperature

5.2 VISCOSITY ANALYSIS FOR RECYCLED OIL

Kinematic viscosity up gradation of disposed CI and SI engine oil at 40^{0}C and 100^{0}C temperatures are shown in bar chart in Figs. 6 and 7 respectively. At 40^{0}C temperature, kinematic viscosity upgraded from 34.36 cSt to 113.26 cSt for recycled oil from disposed CI engine oil and 63.56 cSt to 115.91 cSt for recycled oil disposed from CI engine oil (Fig.6). Again, kinematic viscosity increased from 4.8 cSt to 12 cSt for recycled oil from disposed SI engine oil and 7cSt to 13 cSt for recycled oil disposed from CI engine oil at 100^{0}C temperature (Fig.7).Though viscosity upgrade rate is higher in CI engine oil than SI engine oil but viscosity of degraded and recycled SI engine oil is better than CI engine oil.

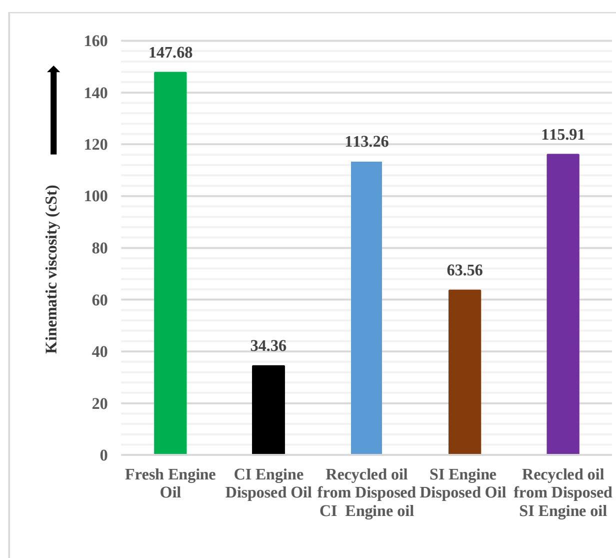

Fig. 6: Change of kinematic viscosity from disposed oil to recycled oil at 40^{0}C temperature

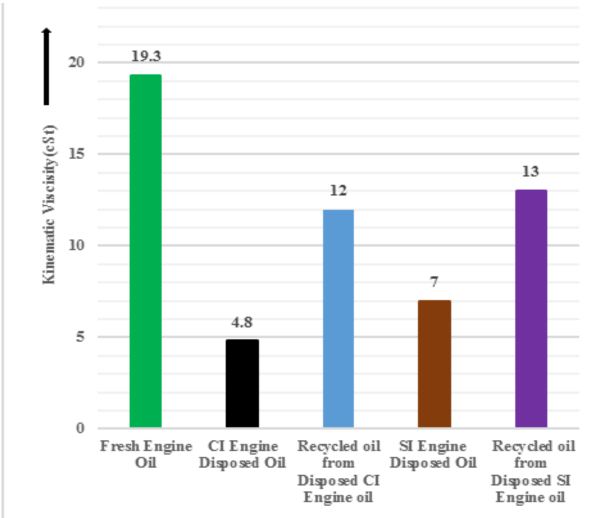

Fig. 7: Change of kinematic viscosity from disposed oil to recycled oil at 100^0C temperature

6.0 DISCUSSION

This study mainly emphasis on properties (viscosity and density) of lubricant, properties degradation rate and a recycling process to upgrade the properties so that disposed lubricant can be used for another application. Viscosity falls randomly at increasing temperature and kilometers running whereas density degradation rate is quite proportional. Viscosity of disposed oil is improved 53.42% and 35.60% through recycling process for CI and SI engine respectively at 40^0C temperature. By recycling process density can be upgraded to a few extents both for SI and CI engine vehicles. Though the properties of recycled oil are upgraded but the color of the recycled oil remains unchanged due to improper mixture of reagents and additives. The recycled oil can be used for other machineries excluding as engine oil.

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8. NOMENCLETURE

Symbol	Meaning	Unit
τ	Shearing Stress	N/m^2
μ	Absolute or Dynamic Viscosity	Pa.s
ν	Kinematic Viscosity	m^2 /s
ρ	Density	kg/m^3
St	Stoke	-
P	Poise	-
PTFE	Poly Tetra Fluoro Ethylene	-