# Evaluation of Performance Parameters of Blends of Soybean Based Oils with Additives as Lubricant in CI Engine

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***Abstract - Lubricants act as an antifriction media, facilitating smoother working, reducing the risks of undesirable frequent failures and maintaining reliable machine operations. Presently, the depletion of the world's crude oil reserves, increased oil prices and the global concern to protect the environment against pollution, exerted by lubricants and their uncontrolled disposal have brought renewed interest in the development and use of nature friendly lubricants derived from alternative sources. Vegetable oils already used as lubricant since ancient time. The suitability of vegetable oils as lubricant is mainly influenced of its composition, stabilization towards oxidation and pour point. The addition of suitable anti-oxidant is believed significantly enhanced the stability of vegetables oil. Therefore the modification of vegetable oil structure is necessary to enhance its performance as a better lubricant. This paper is an evaluation of performance of CI engine using blends vegetable oils with additives as lubricant.***

***Keywords- Antifriction media, Stabilization, Oxidation, Pour point, Blends vegetable oils.***

## 1. INTRODUCTION

### 1.1Bio-lubricants

**S**ignificant interest is focused on improving environmental friendliness, reliability, durability, and energy efficiency in the automotive and machinery industries. Developing new technological solutions, such as introducing lightweight materials, less harmful fuels, controlled fuel combustion, and more efficient exhaust gas after treatment, are possible means to decrease environmental problems brought by vehicles and machines. High pressure gases and high temperature expansion resulting from combustion in an internal combustion (IC) engine apply direct force to the components of engine-like pistons, thus moving the components over a certain distance and transforming chemical energy into useful mechanical energy. The increasing oil prices, the depletion of the crude oil reserve in the India, and the demand to protect the environment against pollution caused by lubricating oils and their uncontrolled spillage have renewed interest in developing and using alternative lubricants. Bio-lubricant oils are perceived as alternatives to mineral oils because they possess certain natural technical properties and they are biodegradable. Compared with mineral oils, vegetable oil-based bio-lubricants generally exhibit high lubricity, high viscosity index (VI), high flash point, and low evaporative losses. Both boundary and hydrodynamic lubrications can be obtained from bio-lubricants because of their long fatty acid chains and the presence of polar groups in the structure of vegetable oil [1].

### 1.1 Sources of Bio-lubricants

.More than 350 oil-bearing crops are known, among which, only palm, soybean, sunflower, coconut, safflower, rapeseed, cottonseed, and peanut oils are considered as potential alternative biolubricants. Oil content statistics of some non-edible and edible oil seeds

| Noedible species | Oil content (% of volume) | Edible species | Oil content (% of volume) |
|---|---|---|---|
| Jatropha | 40–60 | Rapeseed | 38–46 |
| Neem | 30–50 | Palm | 30–60b |
| Karanja | 30–50 | Peanut | 45–55 |
| Castor | 45–60 | Olive | 45–70 |
| Mahua | 35–50 | Corn | 48 |
| Linseed | 35–45 | Coconut | 63–65 |
| Moringa | 20–36 | – | |

***Table 1.1***

Table 1.1 shows the oil content statistics of some non-edible and edible seeds [1]. Moreover, other non-edible oils such as jatropha, neem, and karanja have received worldwide interest

**1.1.8.**

| Edible Vegetable oils | Density ($Kg/m^3$) | Kinematic viscosity at 401C($mm^2/s$) | Oxidation stability 110 1C, h | Cloud point 1C |
|---|---|---|---|---|
| Palm | 875 | 5.72 | 4.0 | 13.0 |
| Sunflower | 878 | 4.45 | 0.9 | 3.42 |
| Coconut | 805 | 2.75 | 35.4 | 0 |
| Soybean | 885 | 4.05 | 2.1 | 1.0 |
| Linseed | 890 | 3.74 | 0.2 | _3.8 |
| Olive | 892 | 4.52 | 3.4 | – |
| Peanut | 882 | 4.92 | 2.1 | 5.0 |
| Rape seed | 880 | 4.45 | 7.5 | _3.3 |
| Rice bran | 886 | 4.95 | 0.5 | 0.3 |

**Bio-lubricants in India**

The annual estimated potential of bio-lubrication is about 08 million tones per annum.[1] Wild crops cultivated in the wasteland also form a source of bio-lubrication production in India and according to the Economic Survey of Government of India, out of the cultivated land area; about 175 million hectares are classified as waste and degraded land.[1] Table 1.2 below depicts the annual production of non edible oil seeds in India.[1]

**Annual Production of Non edible Oil Seeds in India**

| Type | Production(MT) | Oil % |
|---|---|---|
| Palm | 450 | 35-45 |
| Palm | 500 | 30 |
| Karanja | 200 | 27-39 |
| Kusum | 80 | 34 |
| Pilu | 50 | 33 |
| Ratanjot | - | 30-40 |
| Jaoba | - | 50 |
| Bhikal | - | 37 |

**Table 1.3**

### 1.2 Properties of Biolubricants

Biolubricants have many valuable and useful physicochemical properties

#### 1.2.1 Viscosity:

Viscosity is the most important property of oil. It indicates resistance to flow, and is directly related to temperature, pressure, and film formation. High viscosity indicates high resistance to flow and low viscosity implies low resistance to flow

#### 1.2.2 Viscosity Index:

The VI indicates changes in viscosity with changes in temperature. A high VI indicates small changes in temperature, whereas a low VI indicates high changes in temperature. Vegetable oil-based biolubricants have higher VI than mineral oils, which ensures that biolubricants remain effective even at high temperatures by maintaining the thickness of the oil film. Hence, biolubricants are suitable for a wide temperature range.

#### 1.2.3 Pour Point:

Pour point is the lowest temperature at which oil flows or pours. Pour point is an important factor. Vegetable oil-based bio-lubricants have lower pour points than mineral oils, thus providing excellent lubrication for cold starts.

#### 1.2.4 Flash Point and Fire Point:

Flash point is the lowest temperature at which a lubricant must be heated before it vaporizes. When mixed with air, a lubricant will ignite but will not burn. By contrast, fire point is the temperature at which the combustion of a lubricant continues. Flash and fire points identify lubricant volatility and fire-resistance properties. Both factors are important for transportation and storage requirements. Vegetable oil-based bio-lubricants have higher flashpoint than mineral oils, thus considerably reducing the risks of fire in case of a lubricant leak, and providing safety on shop floors.

#### 1.2.5 Cloud Point:

Cloud point is the temperature at which solids dissolve in oil. Wax crystallizes and becomes visible when temperature drops. To prevent clogging of filters, temperature must be maintained above the cloud point.

#### 1.2.7 Oxidation stability:

Oxidation stability is the ability to exhibit resistance toward oxide-forming tendency, which increases when temperature rises. The most significant contributors to oxidation include metal surfaces, temperature, contaminants, pressure, agitation, and water. A low oxidative stability indicates that oil oxidizes rapidly during use if it is untreated, becoming thick and polymerizing to a plastic-like consistency.

#### 1.2.9 Anti-wear properties:

Lubricants are satisfactory for low-speed and low-pressure applications. Boundary lubrication occurs when oil viscosity is insufficient to prevent surface contact. Anti-wear additives pro-vide a defensive film at contact surfaces to reduce wear. Vegetable oil-based bio-lubricants have better anti-wear properties than mineral oils.

**1.2.10 Biodegradation of Bio-lubricants:**

Biodegradability is the capability of a material to be decayed by microorganisms .A lubricant is classified as biodegradable if its percentage of degradation in a standard test exceeds a certain marked level. Vegetable oils exhibit better biodegradability than mineral oils and others, as shown in Table 3.

**Bio-degradability of some base fluids**

| Types of fluids | Biodegradability (%) |
|---|---|
| Mineral oils | 20–40 |
| Vegetable oils | 90–98 |
| Esters | 75–100 |
| Polyols | 70–100 |
| Trimelliates | 0–70 |

**Table 1.4**

**1.3 Vegetables Oils as Bio-lubricants**

**1.3.1 Soy bean oil based lubricants:**

.A review study1 showed that all bio-based fats, oils, and their derivatives had better lubricities than diesel fuel. Rapeseed oil2 has been studied as additive with base oil. Masjuki et al3 observed better performance of palm oil based lubricating oil in terms of wear, and that of mineral oil based lubricating oil in terms of friction. Stefanescu et al4 compared lubricating capacity of rapeseed oil to that of usual min-eral oil. Studies are reported5 on chemical and physical modifications, as well as additives, on soya bean oil (SBO) to change oil characteristics, and properties, broadening potential industrial applications. An experimental study on sunflower oil as lubricant showed that viscosities increases with increase in oxidation time in general and peroxide index reduces (2%), for additive ascorbic acid has a positive effect on oxidation while hydroquinone doesn't have a positive effect6. Esters of SBO7 yield better results compared to crude SBO as a fuel in diesel engine. Though, esters of vegetable oils are having plenty of advantages over crude vegetable oils required for a good lubricant, suitability study of esters of vegetable oils as crankcase lubricant is yet to be carried out. In this paper, tri-bological, corrosion and field studies on various SBO formulations were carried out and results were compared with mineral oils based lubricants. Suitability of all SBO formulations was analyzed as crankcase lubricants by conducting ASTM tests.

**1.4 Objectives of study:**

The objective of this research is to investigate the effect blending of soya bean oil, palm oil and additive as lubricants of its VI, pour points, flash points, kinematic viscosity, etc. on CI engine with different parameter.

## 3. EXPERIMENTAL SETUP

**3.1 Experimental Setup**

A four cylinder four stroke diesel engine has been used to carry out experimental investigation.

**3.1.1 Engine Specification:**

**Table 3.1**

| | |
|---|---|
| Make & Model | Mahindra Engine MDI-3200 |
| General Details | Four stroke, Four cylinder, Vertical, Compression Ignition, Water cooled, Direct injection. |
| Oil Quantity | Max 5 Liter, Min 4 Liter |
| Firing Order | 1-3-4-2 |
| Lubricating Oil | SAE 20 / SAE 40 |
| Max. Power | 10 B.H.P.@ 1500 rpm |

### 3.1.2 Experimental Set-up:

Figure 3.1Experimental Set-up

### 3.1.3 Electronic Controller Device:


**Figure 3.3**

### 3.2 Measurement and Instrumentation of Physical-Chemical Properties

#### 3.2.1 Viscosity

**Figure 3.4 Redwood Viscometer**

Redwood viscometer apparatus are widely used in Petroleum Laboratories, Industries, Oil Refineries, Educational Institutions, Research Organizations for standardization and determines the Viscosity of Petroleum products, which flows in a Newtonian liquid except cut back Bitumen's and road oils at the set temperature, They confirm to requirement of IP 70. Two adaption of Redwood Viscometers are available. Redwood Viscometers No. I for liquids having Redwood Flow 20 seconds to 2000 Seconds and Redwood Viscometers No. II exceeds 2000.The complete outfit comprises hemmer tone finish, copper/Stainless steel bath with drain plug, electrical heating arrangement, Suitable to operate at 220 Volts 50 Hz AC mains Or gas heating arrangement with silver plated oil cup with precision stainless steel jet, ball value, cover, thermometer clip, stirrer and suitable stand with leveling screws. The sample required to be tested, is to fill in to the required level as indicated by the gauge in a cup having a Stainless Steel jet fixed in the bottom. The temperature is maintained during the test by heating the liquid in a bath surrounding the cup, and the flow time for 50 ml of the sample is measured.

#### 3.2.3 Cloud and Pour Point:

**Figure 3.5 Cloud and Pour Point meter**

This is made as a specified by IP-15, ASTM-D-97/57 & IS-1448-1970 the pour point is the lowest temperature at which the oil will just fail to flow. The apparatus consists of a main cooling bath made of stainless steel sheet and stand unit with drain plug and cover with provision for fitting thermometer and a filling aperture for adding freezing mixture. A glass jar for containing oils, jacket, disc and gasket as specified are also provided.

### 3.2.4 Flash and Fire Point:

**Figure 3.6 Flash and Fire point Meter**

The apparatus is used for determination of Flash Point & Fire Point of Petroleum products except fuel oil with open flash 800 °C as per specification IP 36/57, IS 1448(P:69) 1969 and ASTM-D-92-67. The apparatus consists of a cup heating plate to specific dimensions thermometer clip and test flame attachment with swivel joint for passing over liquid surface in the prescribed manner, heater is controlled by means of different types of regulators fitted to the apparatus suitable for operation on 220 Volts AC mains.

### 3.2.5 Rotary Bomb Oxidation Test (RBOT):

**Figure 3.7 Rotary Bomb Calorimeter**

Rotary bomb oxidation tests (RBOT) of all the oil formulations are carried out in presence of copper catalyst at 150 ◦C in dry conditions as per ASTM Test Method D-2272. In the RBOT test, the vessel is sealed, charged to 90 psi pressure with oxygen, and rotated axially in a constant temperature oil bath set at 150 ◦C. The pressure in the bomb is continuously recorded. The RBOT time is the time at which the pressure of the bomb has dropped by 25.4 psi.

### 3.2.6 Pressure Differential Scanning Calorimerty (PDSC) Method:

**Figure 3.8 Pressure Differential Scanning Calorimeter**

The PDSC experiments use a computerized DSC 2910 thermal analyzer from TA Instruments (New Castle, DE). Typically a 2 _l sample is placed in a hermetically sealed aluminum pan containing a pinhole lid for interaction of the sample and the reactant gas (dry air). The 2_l sample results in a film thickness of less than 1 mm. This ensures proper oil–air interaction and eliminates gas diffusion limitation. The module is temperature calibrated using indium metal (m.p.156.6 ◦C) and a 10 ◦C/min heating rate. Dry air (Gateway Airgas, St. Louis, MO) is used to pressurize the module at a constant pressure of 1379 kPa (200 psi). A scanning rate of 10◦C/min was used in the temperature ramping experiments. The onset temperature (OT) of oxidation is calculated from the exotherm in each case. The oxidation stability of vegetable oil-based lubricants was also studied in the PDSC using the oxidation induction time (OIT) obtained in isothermal experiments at 200 ◦C in constant pressure mode at 200 psi with air flow rate of 34±3 ml/min.

### 3.2.7 Four Ball wear Test (FBWT):

Transesterification process that converts crude SBO into SBME increases anti-wear property. Also, addition of POME (5%) to SBME increases anti-wear property ,Polar structure and long fatty acid chain in POME make oil to stick between wearing surfaces, thereby increasing wear resistance of SBME. Wear properties of oil samples were tested as per ASTM D 4172 and ASTM D 2783 standard test method using a FBWT apparatus, which includes a motor and adjustable weight assembly supported by upper test ball on lower test balls positioned in a test cup.

**3.9 Four Ball wear Tester**

Lower three balls were immersed in lubricating oil to be tested and upper ball was made to rotate at 600 rpm at various loads (50 kg, 100 kg and so on ) up to welding of balls. Then, scar diameter of ball was found by repeating and stopping experiment before welding of balls. Weld load and scar diameter indicated extreme pressure and wear resistance of lubricating oil respectively. Results from FBWT of oil samples for weld load and scar diameter were found as follows: SBME, 400 kg, 8.07 mm; SBME + 10% castor + 5% POME, 500 kg, 9.17 mm; and 90% SAE 40 + 10% SBME, 500 kg, 10.65 mm. Test results indicated that weld load for soya blend (SBME + Castor + POME) was more than pure ester and also POME blended SBO had less scar diameter at same weld load as compared to mineral oil and ester blend.

### 3.3. Field Tests in Diesel Engines

Field tests were carried out in four stroke four cylinder (water cooling, and electrical loading) diesel engines. Engines were lubed with samples. Engine oil was filled into oil sump through oil filling tube. Thermocouple was fixed to oil sump cap with tip immersed in the oil. Engine was run for 1 h at 1500 rpm. Temperature rise in engine oil was measured at 5 min intervals. After each run, oil sump was drained completely and filled with next oil randomly. It was run for 5 min and drained to remove any residual oil. Then fresh oil was introduced into oil sump. Tests were conducted in close accordance with ASTM standard D-5302. Hence, field tests were carried out o with eight samples at different loads (no load, 5 kg load and 10 kg load) are taken on four stoke four cylinder diesel engine in figure 3.1and.3.2.

## PROPERTIES

### 4.1 Viscosity:

**Viscosity at different temperature at pure lubricating oil**

| Sr. No. | Tempera-ture ($^oC$) | Viscosity of oils | |
|---|---|---|---|
| | | Palm oil | Soybean oil |
| 1 | 80 | 27.87 | 25.01 |
| 2 | 70 | 35.05 | 31,13 |
| 3 | 60 | 42.00 | 37.10 |
| 4 | 50 | 56.20 | 46.08 |
| 5 | 40 | 79.02 | 63.33 |
| 6 | 30 | 116.56 | 83.01 |

**Table 4.1**

**Viscosity at different temperature at lubricating oil blends**

| (PAO+SOBE+ADDITIVE) |
|---|

| Mixing ratio | Viscosity at different temperature | | | | | |
|---|---|---|---|---|---|---|
| | 30 | 40 | 50 | 60 | 70 | 80 |
| 90:10 | 137.09 | 74.10 | 44.10 | 36.22 | 28.01 | 26.02 |
| 80:20 | 113.11 | 66.12 | 43.12 | 36.98 | 29.58 | 28.14 |
| 70:30 | 95.60 | 62.13 | 42.10 | 34.55 | 28.08 | 26.19 |
| 60:40 | 74.58 | 56.98 | 42.58 | 30.12 | 27.04 | 26.14 |

**Table 4.2(a)**

From the given table, and figure, it can be observed that the viscosity decrease with the rise in temperature as usual, Therefore the variation of viscosity with temperature also lubricating oil. From table I and II, shows that the viscosity of the palm oil and their blends with soybean oil was found higher among these four vegetable oils and their blends an increase in temperature enhances the movements of the molecules and reduces intermolecular forces so the layers of the liquid easily pass over one another and thus contribute to the reduction of viscosity. This phenomenon is also verified by other researchers since oil viscosity depends on molecular structure and decreases with the un-saturation of fatty acids. It may be due to the bonds that make the bonding more rigid and rotation between C-C bonds becomes more strenuous. Also, the extended chain makes the flow easier and reduces viscosity.

| (SOBE+PA+ADDITIVE) | | | | | | |
|---|---|---|---|---|---|---|
| Mixing ratio | Viscosity at different temperature | | | | | |
| | 30 | 40 | 50 | 60 | 70 | 80 |
| 90:10 | 72.90 | 52.00 | 38.25 | 30.11 | 26.39 | 25.21 |
| 80:20 | 75.18 | 52.04 | 38.01 | 30.32 | 26.98 | 25.57 |
| 70:30 | 86.08 | 53.02 | 39.48 | 30.01 | 26.04 | 27.01 |
| 60:40 | 78.07 | 56.01 | 42.25 | 31.12 | 28.29 | 27.01 |

**Table 4.2(b)**

It is also probably because of less friction among the acid chains. It was observed that viscosity decreases linearly with the increase in temperature but viscosity of palm oil and their blends with soybean oil is higher in maximum temperature as well as minimum temperature. This might due to presence of fat crystal that coalesce together and need more time for destruction while they increases the friction between the layers and this result in a sharp increases in viscosity.

### 4.2 Acid Values:

**Acid value of pure lubricating oil**

| Sr. No | Lubricating Oil | Temperature | Acid Value |
|---|---|---|---|
| 1 | Soybean oil | Room temperature | 1.7 |
| 2 | Palm oil | Room temperature | 1.0 |
| 3 | Mineral oil | Room temperature | |

**Table 4.3**

**Acid value of different blend lubricating oil.**

| PAO+SOBE+ADD | | | |
|---|---|---|---|
| Sr. No. | Mixture Ratio | Temperature | Acid Value |
| 1 | 90:10 | Room Temperature | 2.01 |
| 2 | 80:20 | Room Temperature | 1.3 |
| 3 | 70:30 | Room Temperature | 1.3 |
| 4 | 60:40 | Room Temperature | 0.7 |

**Table 4.3**

| SOBE+PAO+ADD | | | |
|---|---|---|---|
| Sr. No. | Mixture Ratio | Temperature | Acid Value |
| 1 | 90:10 | Room Temperature | 2.5 |
| 2 | 80:20 | Room Temperature | 1.8 |
| 3 | 70:30 | Room Temperature | 1.0 |
| 4 | 60:40 | Room Temperature | 2.9 |

**Table 4.3**

From the above table it is clear that the acid value of palm oil and their blends with soybean oil is mark ably low which indicates good lubricating properties as compare to other vegetable oils. Due to low acid value a prevent corrosion hazards, gum and sludge formation. With reference to acid value it acts as a best lubricant vegetable oil blends than other above cited oils.

### 4.3 Pour Points:

**Pour Point Temperature of Blends Lubricants Oil (PAO+SOBE+ADD)**

| Sr.No | Mixture Ratio | Temperature ( $^0$C) |
|---|---|---|
| 1 | 90:10 | 13.01 |
| 2 | 80:20 | 10.22 |
| 3 | 70:30 | 4.02 |

| | | |
|---|---|---|
| 4 | 60:40 | -2.33 |

**Pour Point Temperature of Blends Lubricants Oil (SOBE+PAO+ADD)**

| Sr.No | Mixture Ratio | Temperature ( $^0$C) |
|---|---|---|
| 1 | 90:10 | 1.0 |
| 2 | 80:20 | 0.9 |
| 3 | 70:30 | -2.0 |
| 4 | 60:40 | - 3.56 |

**4.4 Flash Point:**

**Flash Point Temperature of Blends Lubricants Oil (PAO+SOBE+ADD)**

| Sr.No | Mixture Ratio | Temperature ( $^0$C) |
|---|---|---|
| 1 | 90:10 | 178 |
| 2 | 80:20 | 177 |
| 3 | 70:30 | 225 |
| 4 | 60:40 | 245 |

**Flash Point Temperature of Blends Lubricants Oil (SOBE+PAO+ADD)**

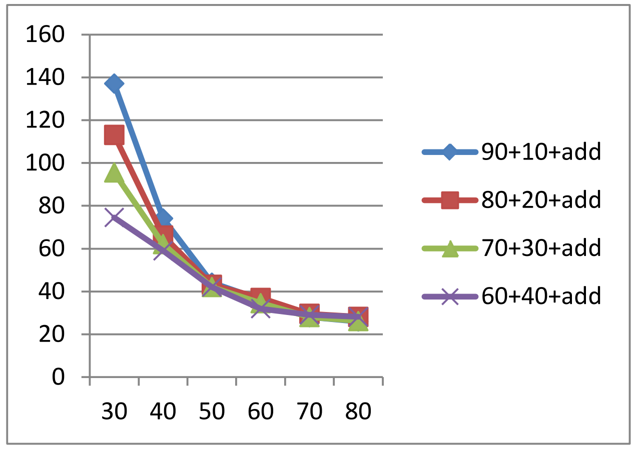
| Sr.No | Mixture Ratio | Temperature ( $^0$C) |
|---|---|---|
| 1 | 90:10 | 278 |
| 2 | 80:20 | 260 |
| 3 | 70:30 | 245 |
| 4 | 60:40 | 21 |

## 05RESULTS

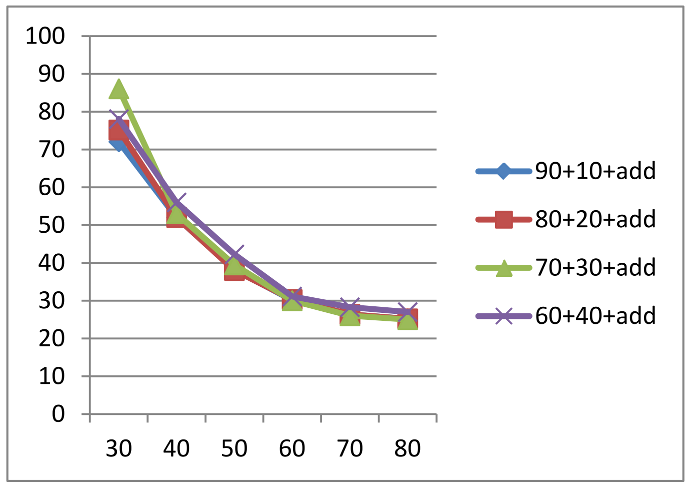
**5.1 Result Analysis:**

The main objective of the study was to lubricant the C.I engine with bio-lubricants of blend soybean oil and palm oil with additives. Using this blends bio-lubricant in CI engine and to investigate the parameter of its properties during working.

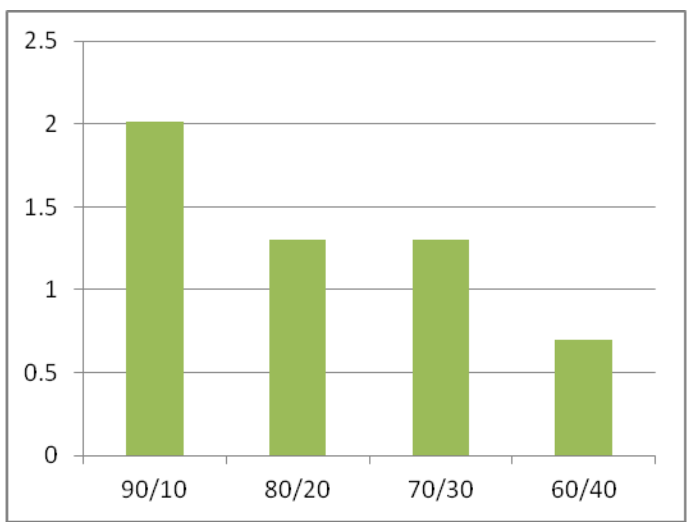
**Viscosity of lubricating oil blends at different temperature (PAO+SOBE+ADD)**



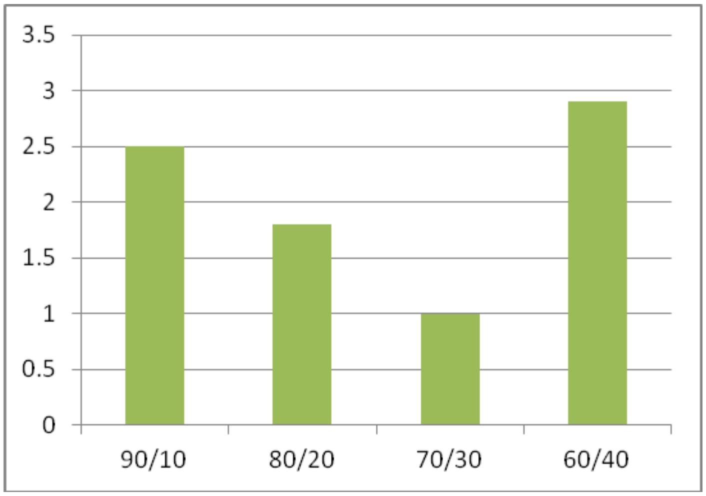

**Viscosity of lubricating oil blends at different temperature (SOBE+PAO+ADD)**



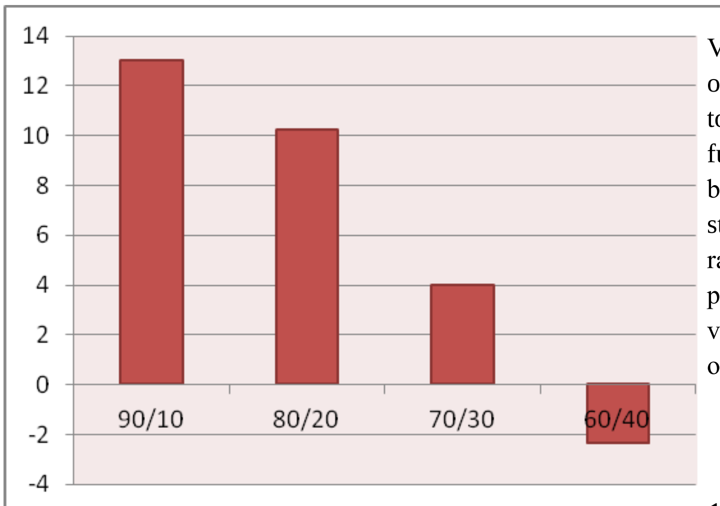

**Acid value of blends lubricant oil at room temperature (PAO+SOBE+ADD)**



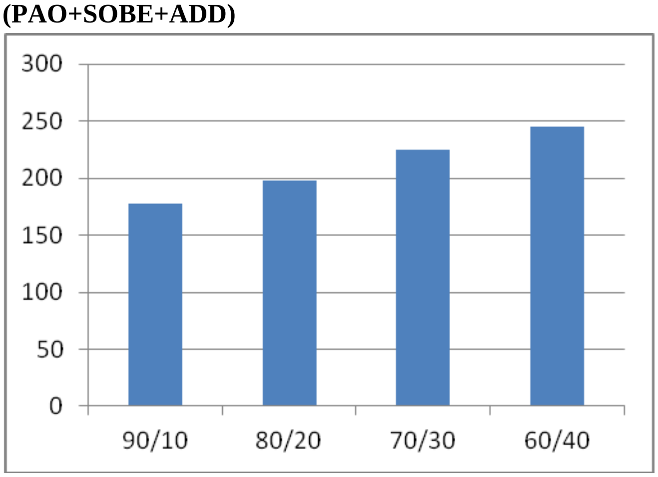

**Acid value of blends lubricant oil at room temperature (SOBE+PAO+ADD)**



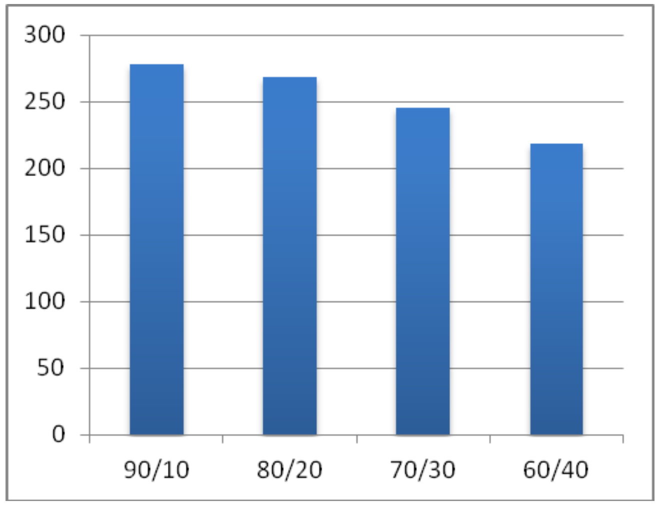

**Pour point of different blends lubricants oil (PAO+SOB+ADD)**




**Flash point of different blends lubricants oil (PAO+SOBE+ADD)**




**Flash point of different blends lubricants oil (PAO+SOBE+ADD)**




## 05 CONCLUSION

Vegetable oils naturally suitable to be used as lubricant base oils. With the cooperative of chemical modification methods to enhance its physical properties the vegetable oils are functioning as good as the mineral and synthetics oils or better. Selective addition of additives is crucial to increase its stability and provide the vegetable oils to work under wider range of temperature and pressure. With the outstanding performance, non toxic, and biodegradability advantages vegetable oil will be a better choice to be use yet it is still offer space for improvement and usefulness.

## 06. FUTURE SCOPES

1. Blends vegetable oils lubricants are produced domestically which help to reduce costly petroleum imports.
2. Development of the bio-diesel industry would strengthen the domestic, and particularly the rural, agricultural economy of agricultural based countries like India.
3. It is biodegradable and non-toxic.
4. Enhanced lubricity, thereby no major modification is required in the engine.
5. Personal safety is improved (flash point is 250 $^0$C equal than that of base oils.
6. Feed stock homogeneity, consistency and reliability are questionable and storage and handling is easy.
7. Flash point in blends is unreliable and cold weather operation of the engine is not easy with vegetable oils and acceptances by engine manufacturers are another major

difficulty.

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