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MODIFICATION AND TRIBIOLOGICAL EVALUTION OF VEGETABLE OIL AS TWO STROKE ENGINE LUBRICANT

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ABSTRACT

The invention of IC engine and subsequent development led to wide spread use of conventional lubricant along with fuel, which are being depleted at a rapid rate and leads to environmental pollution. But vegetable oil was restricted due to low thermo-oxidative stability and poor cold flow behaviour which was improved by chemical modification via esterification process. The aim of this paper was to formulate green lubricant which gives clean and better performance under working condition. From literature, it was suggested that bio-lubricant can be used as an alternative to synthetic lubricants after overcoming poor cold flow properties and oxidative stability. The objective of this research work was to overcome the above said problem. The green lubricant was formulated and compared with synthetic lubricants for their properties. Performance and emission tests of the same were performed using Kirloskar make two stroke petrol engine at constant speed of 3000rpm. Experimental results showed that brake thermal efficiency and mechanical efficiency of green engine oil were improved by 13% and 27% respectively for green engine oil. Also, volumetric efficiency of green engine oil is nearly same as that of MAK 2T engine oil. Emission of CO, CO_2 and HC were reduced to around 62%, 54% and 44% respectively in case of green engine oil compared to synthetic MAK 2T engine oil. Based on this study, green engine oil can be used as a substitute for synthetic MAK 2T engine oil. This work was tested for only two wheeler petrol engine along with fuel it can be extended for four stroke engine without mixing with petrol

INDEX TERMS— Esterification, Methyl Ester of palm oil(ME of palm oil), Methyl Ester of soyabin oil(ME of soyabin oil), Methyl Ester of sunflower oil(ME of sunflower oil), Transterification.

INTRODUCTION

The two stroke engine oil is ultimately burned along with the fuel as a total loss oiling system. Because of this pollution are increases as exhaust emission also increases. Two stroke engine oil must lower in ash content so that deposit that formed in combustion chamber should be minimum. In order to serve this purpose green lubrication is a best option. The synonyms for green lubrication are biodegability, biobased, eco friendly, renewable and non toxic. Green lubricants are those that degrade quickly and naturally with time. The lubricant must be formulated with renewable/vegetable oil in majority, readily biodegradable and free from heavy metals and other toxic ingradient.

The main objective is to form two stroke engine oil which gives clean and better performance under operating condition. To satisfy this objective, blending of different vegetable oil is carried out using Taguchi's experimental techniques.But vegetable oils has low oxidative stability and poor cold flow properties.

OBJECTIVE:-

- To improve properties of vegetable oil by chemical modification.
- To form best combination of two stroke engine oil in order to provide clean and better performance.
- To form less expensive engine oil.

SELECTION OF VEGETABLE OILS

The choice of vegetable oils to be used in two-stroke petrol engines is predominately driven by local availability of the oils. Sources of vegetable oil in Ghana include Palm fruit, Palm kernel, Coconut, Jojoba, Shea nut and Nim seeds. In the Caribbean, research has focused on Coconut oil while in the United States of America, Soybean and Rape seed oil have dominated research. To replace the mineral oils and synthetic lubricant, the soybean oil is recently become one of the most actively studied oils due to its eco-friendly organic property and lower cost. In this work, sunflower oil, soybean oil, palm oil and castor oil have been selected not just because of their availability alone but also because other researchers worked on this vegetable oil for preparing the bio lubricant. Table 2.1 shows the properties of four different vegetable oil.

Table 2.1: Comparision between four different vegetable oils

	Sunflower oil	Soyabin oil	Palm oil	Castor oil
Density (gm/cc)	0.9180	0.9160	0.8850	0.9650
Kin. viscosity at 40° c (cSt)	34	32	41	5.9(at 100°c)
Flash point(°c)	316	324	310	235
Pour point(°c)	-17	-16	5	-10

Sunflower oil can be used as base oil for formation of green lubricant because of its better chemical and physical property [2]. Limitation of soyabin oil is their highest percentage of unsaturation present in the oil [2]. From Table 1, palm oil has a poor cold flow property and thermal decomposition or burning of castor oil may release oxides of carbon, acid smokes, irritating fumes which are oxides of sulphur and acrolein and also other hazardous gases[1,2]. Perhaps its limitation, castor oil is used in small amount in formation of green lubricant because of its better lubricating property.

CHEMICAL MODIFICATION

Vegetable products as well as modified vegetable oil esters can be used as a base stock for preparation of environment friendly, rapidly biodegradable lubricants. The production of environment friendly, rapidly biodegradable fluids for lubricant was based on petrochemicals such as, polyalphaolefins, polyglycols, polyalkylene glycols and synthetic esters. The inherent problem of vegetable oil are poor oxidation and low temperature properties which can be improved by attaching functional group at the sites of unsaturation through chemical modification [2].

Transesterification is the general term used to describe the important class of organic reactions where an ester is transformed into another through interchange of the alkoxy moiety. Fig.3.1 shows the chemical modification of vegetable oil via transesterification process. When the original ester is reacted with an alcohol, the transesterification process is called alcoholysis. For transesterification process, generally catalysts used are base like NaOH and KOH. Bio lubricant can be produced from a great variety of feedstock. This feedstock includes most common vegetable oils (e.g., soybean, cottonseed, palm, peanut, rapeseed/canola, sunflower, safflower, coconut) and animal fats as well as waste oils. The choice of feedstock depends largely on geography. Depending on the origin and quality of the feedstock, changes to the production process may be necessary. Chemical modifications of vegetable oils for them to be used as lubricant base oils without sacrificing favourable viscosity–temperature characteristics and lubricity can be classified into two groups:-Reactions on the hydrocarbon chain and reaction on the carboxyl group[3].

[Triacylglycerols] + [Alcohol] ⟹ **[Alkyl Ester]+[Glycerol] (Vegetable oil)**

Fig. 3.1 Transesterification of vegetable oil

EXPERIMENTAL WORKS

Procedure for esterification of vegetable oil

1) 1000ml of vegetable oil is taken in a round bottom flask.
2) Prepare a solution of potassium methoxide and to the round bottom flask containing vegetable oil. 0.1N sodium hydroxide is taken in a burette. The solution of 0.1N sodium hydroxide is prepared by adding one gram of sodium hydroxide to 250 ml of distilled water. Before preparing the solution of sodium methoxide free fatty acid (FF_A) is calculated by titration.

Procedure for carrying out titration is given be below:-

In a conical flask, 50 ml of isopropyl alcohol is taken and it is neutralized by adding 2-3 drops of 0.1N sodium hydroxide. After neutralizing isopropyl alcohol added 10 gram of sunflower oil which is heated up to 60°C followed by cooling in tap water. Finally, 2-3 drops of phenolphthalein indicator are added and titrated with 0.1N sodium hydroxide. Note down the initial and final reading of burette. Fig.4.1 Final reading is one in which colorless solution changes to dark pink.

Fig. 4.1 Titration of solution

FF_A=(28.2 X 0.1 X Burette reading) / (total wt. of oil)

Burette Reading = Final Reading ─ Initial Reading

If the FF_A is greater than four percent, perform the double stage process by adding concentrated sulphuric acid to bring the FF_A below four percent. Table 4.1 shows the quantity of sodium hydroxide for preparing sodium methoxide solution.

Table 4.1 Quantity of sodium hydroxide for sodium methoxide solution

FF_A of oil	**NaOH in gram**
0	3.5
1	4.5
2	5.5
3	6.5
4	7.5

Sodium methoxide solution is prepared by adding 3.5 gram of sodium hydroxide to the 300ml of methanol. Fig. 4.2 shows the prepared sodium methoxide solution

Fig. 4.2 Sodium Methoxide solutions for Transesterification process

3) Transesterification of vegetable oil is carried out in batch type glass reactor consisting of a four-necked round bottom flask. Fig. 4.3 shows experimental set up for carrying out the transesterification of vegetable oil. A motor driven speed regulated magnetic stirrer is inserted in the reactor through the central neck while the other neck was used for inserting thermometer. A water cooled reflux condenser was fitted to the reactor through the third neck and fourth neck is used for dropping the raw material into the reactor via dropping funnel. The reactor was heated by an electric heating mantle having an arrangement for accurate control of temperature within ± 1°C of the desired temperature. Prior to transesterification process, 1000ml of vegetable oil is heated up to 60°C and stirred by magnetic stirrer to 800- 900 rpm. Sodium methoxide solution is added to 1000ml of vegetable oil which is present in batch reactor for one and half hours for maintaining constant temperature of 60 ±1°C by means of magnetic stirrer.

Transesterification of vegetable oil is carried out in batch type glass reactor consisting of a four-necked round bottom flask. Fig. 4.3 shows experimental set up for carrying out the transesterification of vegetable oil. A motor driven speed regulated magnetic stirrer is inserted in the reactor through the central neck while the other neck was used for inserting thermometer. A water cooled reflux condenser was fitted to the reactor through the third neck and fourth neck is used for dropping the raw material into the reactor via dropping funnel. The reactor was heated by an electric heating mantle having an arrangement for accurate control of temperature within ± 1°C of the desired temperature. Prior to transesterification process, 1000ml of vegetable oil is heated up to 60°C and stirred by magnetic stirrer to 800- 900 rpm. Sodium methoxide solution is added to 1000ml of vegetable oil which is present in batch reactor for one and half hours for maintaining constant temperature of 60 ±1°C by means of magnetic stirrer.

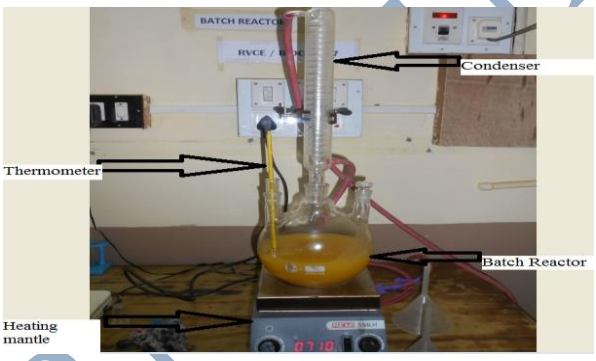

Fig. 4.3 Experimental set up for transesterification process

4) Small amount of methanol is present in the methyl ester (ME) of vegetable oil, which increases the flash point of oil. Therefore, ME of vegetable oil is heated for some time and it is washed by tap water in a washing unit. Fig. 4.4 shows washing unit of ME of vegetable oil.

Fig. 4.4 Washing the ME vegetable oil

5) Finally, after completing the transesterification process 1200ml ME of vegetable oil and 150ml of glycerin are obtained. Fig. 4.5 shows top layer which is separated is a methyl ester of vegetable oil and bottom layer is glycerine which can be used in manufacturing of detergent

Fig.4.5 Seperation of methyl ester and glycerine of vegetable oil.

APPARATUS USED

Apparatus used for finding the chemical and physical property of vegetables oils.

5.1 REDWOOD VISCOMETER

Figure 5.1 shows the Redwood Viscometer which is used to determine the kinematic viscosity and absolute viscosity of the given lubricating oil at different temperatures.

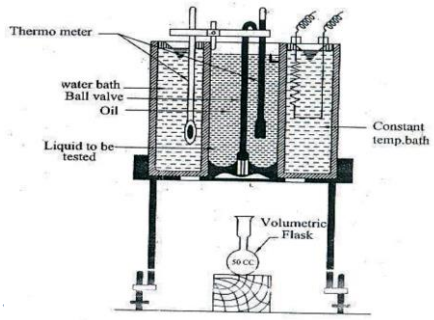

Fig.5.1 Redwood viscometer

REQUIREMENT:-

Thermometer 0-100°c (2 Nos)
Stop watch
50 ml standard narrow necked flask
Given Sample of oil.

The redwood viscometer consists of vertical cylindrical oil cup with an orifice in the centre of its base. The orifice can be closed by a ball. A hook pointing upward serves as a guide mark for filling the oil. The cylindrical cup is surrounded by the water bath. The water bath maintains the temperature of the oil to be tested at constant temperature. The oil is heated by heating the water bath by means of an immersed electric heater in the water bath, The provision is made for stirring the water, to maintain the uniform temperature in the water bath and to place the thermometer ti record the temperature of oil and water bath. This viscometer is used to determine the kinematic viscosity of the oil. From the kinematic viscosity the dynamic viscosity is determined.

Filled oil volume of flask= 50 cc

Kinematic viscosity = 0.026 T – 179/T

Where T = Time taken in sec for collecting 50 cc of given oil at particular temp.

Density = (w2 – w1)/50 (gm/cc)

Where w2 = weight of flask + oil (gm)

w1 = weight of flask (gm)

Absolute or dynamic viscosity in centipoise =
Density × kinematic viscosity
(gm/cc) (cSt)

5.2 CLOUD AND POUR POINT APPARATUS

Devices indicate the lowest temperature of utility for petroleum products. Fig.5.2 shows the cloud and pour point chamber immerses four copper test jackets in suitable freezing mixtures, providing inlet and outlet connections for circulating refrigerated coolant from an external source.

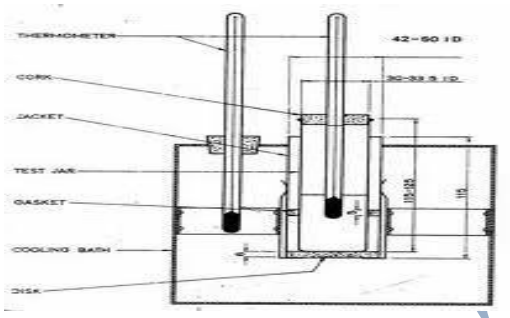

Fig.5.2 Cloud and Pour point apparatus

5.3 PENSKY MARTIN FLASH AND FIRE POINT APPARATUS

Fig.5.3 shows Pensky Martin flash and fire point apparatus where Pensky–Martens closed cup is sealed with a lid through which the ignition source can be introduced periodically. The vapour above the liquid is assumed to be in reasonable equilibrium with the liquid. Closed cup testers give lower values for the flashpoint (typically 5–10 K) and are a better approximation to the temperature at which the vapour pressure reaches the "lower flammable limit" (LFL).

Fig.5.3. Pensky Martin flash point apparatus

5.4 CARBON RESIDUE APPARATUS

Fig.5.4 shows Carbon residue apparatus which will give the percentage of carbon present in the oil. This value gives an approximate indication of combustability and deposit forming tendency of the fuel. Procedure for calculating the carbon residue

1) Calculate the weight of empty crucible.
2) Calculate the weight of crucible and 10 gm of oil.
3) After burning the oil, calculate the weight of crucible and substract it from original weight.

Fig.5.4 Carbon Residue apparatus

5.5 PH INDICATOR

Fig.5.5 shows the PH indicator which is used to measure PH by matching it with the standard chart. It measure PH accurate to the nearest whole number

Fig.5.5 PH indicator

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FORMATION OF HYBRID GREEN LUBRICANT

For the formation of hybrid green lubricant Tagu chi's experimental techniques are very useful.

6.1 TAGUCHI'S ORTHOGONAL ARRAY

Blending of methyl esters and vegetable oil is made by using L27 orthogonal array. Twenty seven experimental runs based on an orthogonal array of Taguchi method were performed. The process parameters were ME of sunflower oil, ME of soyabin oil, ME of palm oil and castor oil each at three level and responses were the kinematic viscosity and flash point.

The controllable input parameters are

ME of sunflower oil: 55%, 60% and 65%
ME of soyabin oil: 15%, 20% and 25%
ME of palm oil: 5%, 10% and 15%
Castor oil: 5%, 10% and 15%

The response variables are kinematic viscosity in cSt and flash point in degree Celsius.

Table 6.1 shows Taguchi's L27 orthogonal array which has twenty seven experimental runs. It has four factors each at three levels.

Table 6.1Taguchi's L27 Orthogonal Array

Sr. No.	Experimental Run	Kinematic viscosity in cSt @ 40 deg.	Flash Point in deg.
1	55 15 5 5	7.01	160
2	55 15 5 5	7.80	162
3	55 15 5 5	7.5	165
4	55 20 10 10	28.6	175
5	55 20 10 10	27.3	170
6	55 20 10 10	27.8	174
7	55 25 15 15	10.07	180
8	55 25 15 15	11.10	185
9	55 25 15 15	10.50	183
10	60 15 10 15	11.67	175
11	60 15 10 15	11.90	172
12	60 15 10 15	11.30	170
13	60 20 15 5	13.84	170
14	60 20 15 5	13.80	165
15	60 20 15 5	13.60	168
16	60 25 5 10	13.84	175
17	60 25 5 10	13.80	172
18	60 25 5 10	13.64	175
19	65 15 15 10	9.75	190
20	65 15 15 10	9.83	185
21	65 15 15 10	9.45	187
22	60 20 5 15	15.64	185
23	60 20 5 15	15.90	189
24	60 20 5 15	15.65	180
25	65 25 10 5	8.41	180
26	65 25 10 5	8.49	178
27	65 25 10 5	8.80	175

PERFORMANCE CALCULATIONS

The performance calculation for single cylinder two stroke engine is

7.1 BRAKE POWER

$$BP = (V \times I)/(1000 \times \eta_{gen}) \quad Kw$$

Where V = dc voltage in volts
I = dc current in amps
η_{gen}= Generator efficiency = 80%

7.2 MASS OF FUEL CONSUMED

$$Mfc = (X \times 0.72 \times 3600)/(1000 \times t) \quad Kg/hr$$

Where X = burette reading in cc
0.72 = density of petrol in gm/cc
t = time taken in seconds

7.3SPECIFIC FUEL CONSUMPTION

$$Sfc = (Mfc/BP) \quad Kg/Kw\ hr$$

7.4 ACTUAL VOLUME OF AIR SUCKED INTO THE CYLINDER

$$Va = Cd \times A \times \sqrt{(2Gh)} \times 3600 \quad in\ m^3/hr$$

Where, $H = (h \times \delta w)/(1000 \times \delta a)$ meter of water
A = area of orifice $= (\prod d^2)/4$
h = manometer reading in mm
δw = density of water = 1000 kg/m^3
δa= density of air = 1.193 kg/m^3
Cd = coefficient of discharge=0.62

7.5 SWEPT VOLUME

$$Vs = (\prod d^2/4) \times L \times N \times 60$$

Where d= diameter of bore= 56.7 mm
L = length of bore = 56.7 mm
N = speed of engine= 3000rpm

7.6 VOLUMETRIC EFFICIENCY

$$\eta_v = (Va \times Vs) \times 100 \quad \%$$

7.7 BRAKE THERMAL EFFICIENCY

$$\eta_{thermal} = (BP \times 3600 \times 100)/(Mfc \times Cv)$$

Where Cv= calorific value of petrol=43500KJ/kg
BP = brake power in kw

7.8 MECHANICAL EFFICIENCY

$$\eta_{mech} = (BP/IP) \times 100$$

Where BP= brake power in KW
IP = indicated power inKW
FP = friction power in KW

$$IP = FP + BP$$

Friction power is obtained by graph using Willan's line

PERFORMANCE TESTING SET UP

Bajaj single cylinder two stroke engine specification

NUMBER OF STROKE 2
DIAMETER OF BORE 56.7mm
LENGTH OF BORE 56.7mm
GENERATOR EFFICIENCY 80%
RATED POWER 2.5HP@3000RPM

Table 8.1: Performance testing of Green engine oil

Sr. No.	Load in KW	Volts	Current in Amp	Time for 10 cc fuel cons. (sec)	Manometer reading in mm	Brake Power in KW
1.	Nil	200	0	31.82	6	0
2.	500	200	2.03	27.69	9	0.5075
3.	1000	200	4.05	27.57	12	1.0125
4.	1500	200	6	24.69	15	1.49
5.	2000	200	7.85	21.97	19	1.9625
6.	2500	200	9.45	19.82	21	2.3625

Table 8.2: Performance charactisics of Green engine oil

Sr. No.	BP in KW	Fuel cons. in kg/hr	Specific fuel cons. in Kg/KWhr	Actual Volume in m^3/hr	Vol. Effi in %	Thermal Eff.	Mech. Eff.
1.	0	0.8125	-	1.7413	6.7	0	0
2.	0.5025	0.9360	1.8443	2.1327	8.2	4.487	16
3.	1.0125	0.9401	0.9284	2.4626	9	8.9	28
4.	1.49	1.0498	0.7045	2.7533	10	11.74	37
5.	1.9625	1.1797	0.6011	3.0987	12	13.76	43
6.	2.3625	1.3077	0.5535	3.2577	12	14.95	48

Table 8.3: performance testing of MAK 2T engine oil

Sr. No.	Load in KW	Volts	Current in Amp	Time for 10 cc fuel cons. (sec)	Manometer reading in mm	Brake Power in KW
1.	Nil	200	0	35.34	6	0
2.	500	200	2.10	30.75	7	0.5250
3.	1000	200	4.14	27.56	8	1.0350
4.	1500	200	5.95	26.84	10	1.4875
5.	2000	200	7.95	23.78	15	1.9875
6.	2500	200	9.80	18.04	25	2.3275

Table 8.4: Performance Charactristics of MAK 2T Engine oil

Sr. No.	BP in KW	Fuel cons. in kg/hr	Specific fuel cons. in Kg/KWhr	Actual Volume in m^3/hr	Vol. Effi in %	Thermal Eff.	Mech. Eff.
1.	0	0.7334	-	1.7413	6	-	0
2.	0.5250	0.8429	1.6055	1.8800	7	5.15	10
3.	1.0350	0.9404	0.9085	2.0107	7	9.10	19
4.	1.4875	0.9657	0.6492	2.2480	8	12.74	25
5.	1.9875	1.0899	0.5483	2.7533	10	15.09	31
6.	2.3275	1.4368	0.6173	3.5544	13	13.40	35

RESULTS AND DISCUSSION

The performance evaluation of MAK 2T engine oil and Green engine oil is done in the MATLAB.

9.1 PERFORMANCE EVALUATION

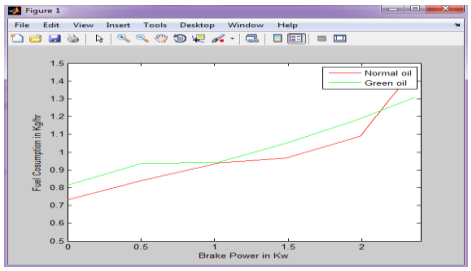

Fig. 9.1 FUEL CONSUMPION Vs BRAKE POWER

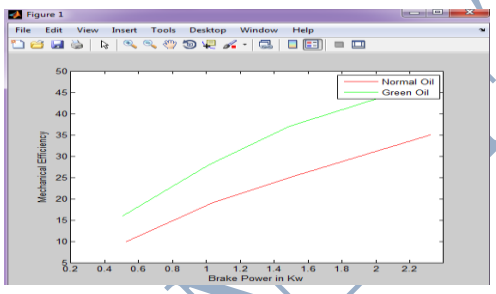

Fig. 9.2 MECHANICAL EFFICIENCY Vs BRAKE POWER

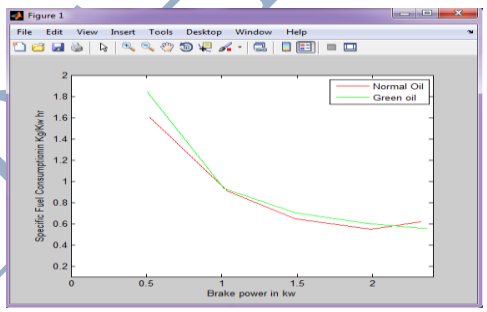

Fig.9.3 SPECIFIC FUEL CONSUMPTION Vs BRAKE POWER

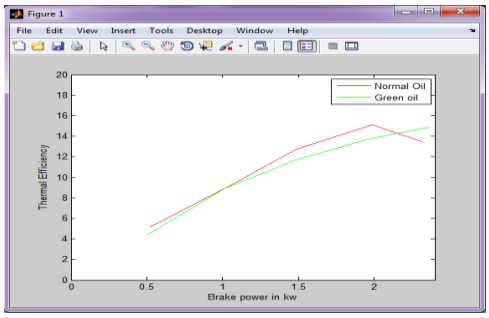

Fig. 9.4 THERMAL EFFICIENCY Vs BRAKE POWER

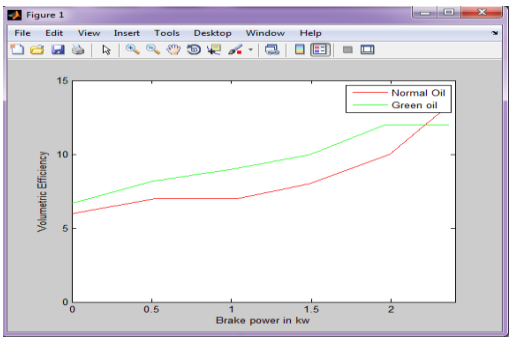

Fig.9.5 VOLUMETRIC EFFICIENCY Vs BRAKE POWER

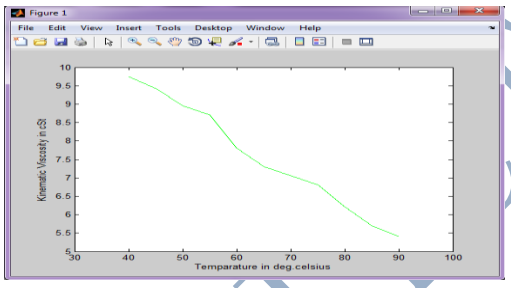

Fig.9.6 KINEMATIC VISCOSITY Vs TEMP. FOR GREEN OIL

9.2 EMISSION CHARACTRISTICS

This characteristic shows the comparision between green engine oil and normal MAK 2T Engine oil.

9.2.1 MAK 2T ENGINE OIL

Fig. 9.7. Emission charactristics of MAK 2T Engine oil

Carbon monoxide (CO) = 2.479%
Carbon dioxide (CO_2) = 2.11 %
Hydrocarbon (HC) = 1828 ppm

9.2.2 GREEN ENGINE OIL

Fig 9.8 Emission charactristics of Green Engine oil

Carbon monoxide (CO) = 0.936%
Carbon dioxide (CO_2) = 0.97 %
Hydrocarbon (HC) = 1013 ppm

9.3 COMPARISION BETWEEN GREEN ENGINE OIL AND MAK 2T ENGINE OIL

Table 9.1: Comparision between Green engine oil and MAK 2T oil

	MAK 2T ENGINE OIL	GREEN ENGINE OIL
Density (gm/cc)	0.8797	0.8557
Kinematic Viscosity (cSt)	8.4	9.75
Flash Point(°C)	94	190
Pour Point(°C)	-7	-3
CarbonResidue (%)	0.01	0.01
PH	7	7
Price per lit.	Rs. 244	Rs.87

CONCLUSIONS

The approach of using chemically synthesized vegetable oil improved the thermo oxidative stability and cold flow properties of bio based lubricant to some extent. This study concentrated on the application of Taguchi's method coupled with Grey Relational Analysis for solving multi criteria optimization problem in the field of formation of hybrid Green lubricant. Table 6.1 shows number of experiment conducted and Grey Relational grade from which best parameter combination was selected. Table 8.1to table 8.4 shows mechanical and thermal efficiency of green engine oil 48% and 15% respectively greater than the MAK 2T engine oil which is 35% and 13% resp. Fig. 9.1 to 9.8 shows the performance and emission characteristics of green engine oil is better than MAK 2T engine oil. Finally table 9.1 shows comparative study between MAK 2T engine oil and Green engine oil. Table 9.1 shows Green engine oil has greater advantages than MAK 2T engine oil.

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