Performance Test on IC engine using Pongamia Oil

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Abstract - An ever increasing demand of fuels has been a challenge for today's scientific workers. The fossil fuel resources are dwindling day by day. Biodiesel seem to be a solution for future. It is an environmental viable fuel. Several researchers have made systematic efforts to use plant oil and their esters (biodiesel) as a fuel in compression ignition (CI) engines .There is various types of raw material like Jatropha curcus L, Pongamia Pinnata (Karanja), Moha, Undi, Castor, Saemuruba, Cotton seed etc. An non- edible oil seeds and Various vegetable oils including palm oil, soybean oil, sunflower oil, rapeseed oil and canola oil have been used to produce biodiesel fuel and lubricants. Out of these Pongamia pinnata can be a definite source of raw material due to its easy availability in wild. Pongamia pinnata is drought resistant, semi-deciduous, nitrogen fixing leguminous tree. It grows about 15-20 meters in height with a large canopy which spreads equally wide. After tranesterification of crude oil shows excellent properties like calorific value, iodine number, cetane number and acid value etc. Detail study intends to identify all advantages and disadvantages of pongamia pinnata as a sustainable feedstock for the production of Biodiesel equivalent to fossil fuel as per ASTM 6751-9B.

Keywords: Biodiesel, esterification reaction, trans-esterification reaction, pongamia pinnata oil, American standards for testing and materials (ASTM), deoiled cake (DOC)

I. INTRODUCTION

The rising prices and dwindling reserves of conventional fuels have led to intensive studies on the use of an alternative fuels, especially renewable once like vegetable oils and alcohols. The use of vegetable oil as diesel engine fuel is not a new concept. In fact early engines were demonstrative with vegetable oils. In a developing country such as INDIA were mass transportation plays a key role, the suitability of an alternative fuels for a diesel fuel engine application has to be thoroughly investigated. Vegetable oils have some important properties like cetane number and calorific value similar to the diesel. They have heat contents approximately 80-90 % of diesel fuel.

Vegetable oils present a very promising substitute to diesel oil, since they are renewable and are produced easily in rural areas. Vegetable oils, usage have been advocated ever since the advent of IC engine. The inventor of diesel engine, Rudolph Diesel confidently predicted that plant oils would be widely used to operate his engine. Rudolph Diesel used peanut oil as fuel in one of his engine at the Paris exposition of 1900. But due to its high price compare readily available petroleum products; the use of vegetable oil based fuels was not explored. But the fuel crisis of 1970's and 1980's focused the attention on the desirability to develop alternate fuels and thereby reduce dependency on diesel fuels. However it is only in the recent years that systematic efforts have been made to utilize vegetable oils as fuels in engine

II. PONGAMIA OIL AS AN ALTERNATIVE FUEL

In this century, it is believed that crude oil and petroleum products will become very scarce and costly to find and produce. Alternative fuel technology, availability, and use must and will become more common in coming decades. Because of the high cost of petroleum products, some developing countries are trying to use alternate fuels for their vehicles. Another reason for motivating the development of alternate fuels for the I.C.engine is concern over the emission problems of gasoline engines. The third reason being the fact that a large percentage of crude oil must be imported from other countries which control the large oil fields.

India ranks sixth in the world in terms of energy demand accounting for 3.5% of world commercial energy demand, and is expected to grow up to 4.8% in the near future. A large part of India's population, mostly in rural areas, does not have access to it, hence a program for development of energy from the raw material, which grows in the rural areas will benefit in providing energy security to rural people. Vegetable oils extracted from soybean, cotton seed, rape seed, peanut, coconut, linseed, palm, olive, con-castor, Pongamia and Jatropha are found to be promising alternatives to conventional fossil fuels. Pongamia and Cotton Seed oil are economical and sustainable compared to other vegetable oils.

"Oh there is nothing much here", a villager was saying. "No river, no wells, no electricity; just thousands of kanuga trees and tones of seeds. Not much use now. Our grandparents used the uneatable oil for lamps".

Kanuga oil is internationally known as "Pongamia oil" .It is concerned to Pongamia pinnate (Linn) piperre family. Pongamia pinnata is a botanical name for 'kanuga' in Telugu, 'honge' in Kannnada and 'karanj' in Hindi. Pongamia pinnata is a native of India and grows all over the country from the coast line to the hill slopes [9]. The oil trees are hardy trees that require minimum water and they grow in all soils. These trees need very little care, cattle do not browse it and their rich leathery ever green foliage provides wonderful manure. With the raising of these plantations, farmers can develop and utilize wastelands, which improves their economy also provides employment opportunities for rural people. These trees yield an average of 160 kg of seeds per year per tree. They normally start yielding in 3 to 4 years and continue up to their lifetime of 100 yrs [10]. Generally,10 trees can yield 400 liters of oil, 1200 kg of fertilizer (oil cake), and 2500 kg. of biomass as green manure per year. Pongamia pinnata will fetch same income as that of coconut. The grower may get around Rs.40,000 per hectare; it is almost equal to income generated by the coconut trees owner. So it also becomes as an agricultural crop for the villagers in our country.

The oil can be produced from dry seeds of the pongamia tree. The kernel of the seed contains 27-39% of oil and is extracted in a process similar to the extraction of sunflower oil. During extraction, for each 4 kgs of seeds we get 1 kg of oil and 3 kgs of cake. The cetane number of pongamia oil is in the range of 35-40, which is slightly lower than that of diesel [11]. They can be mixed easily with diesel to form stable blends, enabling them to be used in engines either directly or in the blended form. The oil also has great medicinal value, which can cure various skin diseases and rheumatism which are recurrent in character. The villagers can use the oil for lighting lamps too. It also results in reduction in emission of green house gases, thereby improving energy security.

Kanuga oil is non-edible oil. It possesses a disagreeable odour and bitter taste. The Pongamia crude oil includes toxic phenolic compounds. The Specific gravity of Pongamia oil is 0.925 to 0.940 at 30ºC. The Gross Calorific Value of Kanuga oil is 39,057 kJ/kg. Kanuga oil is used as a lubricant in heavy duty lathes, bearings. It is used as raw- material in soap and candle industries. It is also used for medicinal purposes. Economics-wise also, the fuel compares well with high speed diesel oil.

Properties of Pongamia oil

I. PARAMETERS	*A. Pongamia oil*	*Diesel*
Density(g/cm^3)	0.9408	0.85
Viscosity(CST)	39	8.6
Flash Point (ºC)	>100	55-60
Saponification Value	179.55	-nil-
Iodine Value	82.78	38.3
Acid Value	16.08	0.062
Moisture and volatile matter (%)	0.25	24.66

Cloud point (^{0} C)	3	13
Pour point (^{0} C)	-2	1

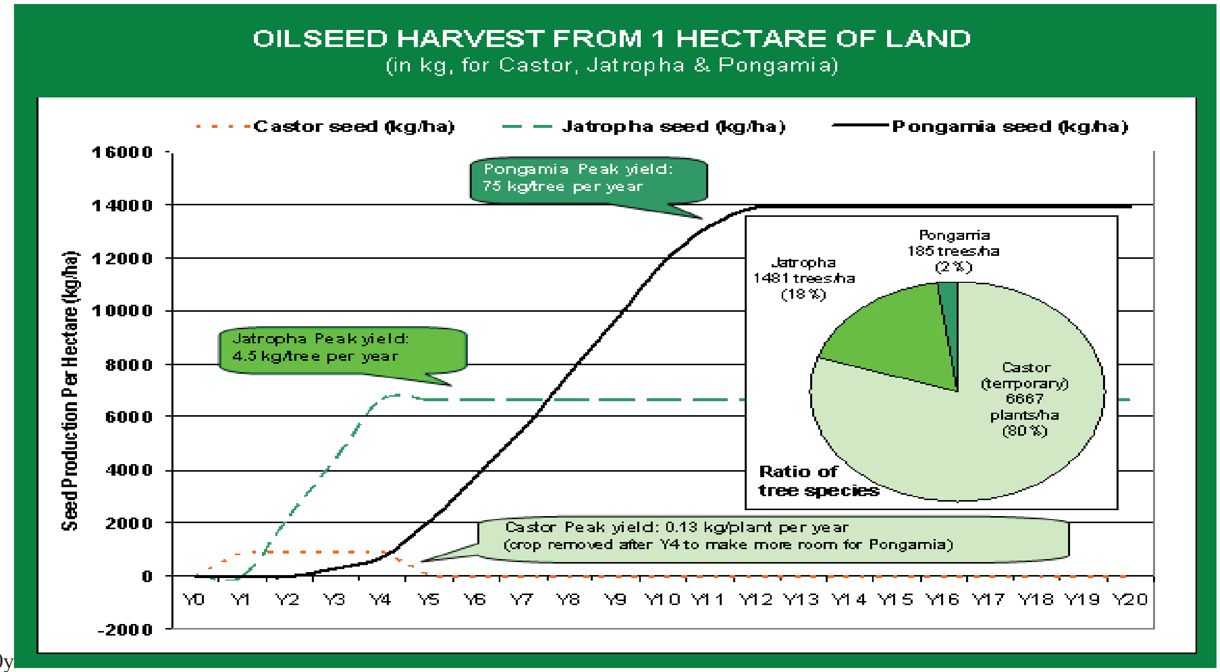
Pongamia Seed [17]

- Pod contains usually one seed but rarely two.
- Resembles kidney shape
- eddish brown in color
- Size of the seed Pongamia

Length (in cm)	1.7 to 2.0
Breadth / Diameter (in cm)	1.2 to 1.8
Weight (in gm)	1.0 to 1.2

Fig.2 Pongamia Seed

Fig.3 Pongamia Oil and Cake1.8 Short gestation 3y & 7y-Long productive life 50y &



100y

Added Advantages of the Pongamia oil:

- The high Cetane number of fuel compared to petroleum diesel indicates potential for greater engine performance.
- The superior lubricating properties of fuel increases functional engine efficiency.
- Higher flash point makes it safer to store.
- The fuel molecules are simple hydrocarbon chains containing no sulphur, or aromatic substances associated with fossil fuels.
- They contain higher amount of oxygen (up to 10%) that ensures more complete combustion of hydrocarbons.

III. COTTON SEED OIL AS AN ALTERNATIVE FUEL

India is the fifth largest cotton producing country in the world today, the first-four being the U.S, china, Russia and Brazil. Our country produces about 8% of the world cotton. Cotton is a tropical plant.

Fig.4 Cotton Seeds

Fig.5 Cotton Seed Oil

It is a vegetable oil extracted from the seeds of the cotton, after the cotton lint has been removed. After being freed from the linters, the seeds are shelled and then crushed and pressed or treated with solvents to obtain the crude cotton seed oil. Cotton seed oil is one of the most widely used oils and it is relatively inexpensive and also readily available. Cottonseed oil, extracted from cotton seeds, is used in some margarine and in commercially made salad dressing. The ancient Chinese used the oil as a medicine and a lamp oil. Cotton seed oil (CSO) is internationally known as "gossypium". This is belongs to mallow family. Blending CSO with diesel oil lowers the cetane number and raises cloud and pour points significantly. The gross calorific value of CSO is 38141 kJ/kg. [2]

IV. PROPERTIES OF CSO

In some respects the properties of CSO are very close to those of diesel oil but in other they are quite different.

1. The densities of the cotton seed oils are slightly higher compared to diesel.
2. The calorific value is slightly lower on mass basis.
3. Viscosities at room temperature are much higher compared to diesel oil.
4. The cetane number is slightly lower than the diesel oil.
5. The flash point is very high.
6. Volatility is quite low.
7. Carbon residue is very high.

Physical properties of vegetable oils are such that they are incompatible with spark-ignition engines. Property comparisons indicate vegetable oil viscosities to be much higher and eating values to be somewhat lower for these oils than for diesel fuels. The difficulties in using vegetable oils directly in diesel engines can be overcome by modifying these oils.

The modifying methods are:

1. Heating the oil.
2. Thermal cracking of the oil.
3. Transesterification

The Trasesterification is a chemical reaction that aims at substituting the glycerol of the glycerides by mono-alcohols like methanol and ethanol. The vital merit of these oils over mineral oil is that vegetable oil contains no sulphur hence the environmental damages caused by sulphuric acid vegetation as well as building structures is very low.

The Table: 1 gives comparison of some of the properties of Cotton seed oil with other vegetable oils [13].

Table 1: Comparison of properties

Oil	Kinematic Viscosity at 20^{o}C ($10^{-6}m^2s^{-1}$)	Kinematic Viscosity at 40^{o}C ($10^{-6}m^2s^{-1}$)	Kinematic viscosity at 70^{o}C ($10^{-6}m^2s^{-1}$)	Density (kgm^{-3})	Acid value (mg KOH/g)	Glycerol (wt %)	Miscible
Castor	961	268	61.9	993	0.022	4.12	Between 70% and 100% oil
Cotton seed	85.0	43.7	23.2	951	7.073	18.40	0-100% oil
Groundnut	91.8	41.4	27.6	942	3.185	5.43	0-100% oil
Moringa oil	53.7	39.1	21.7	919	22.754	11.47	Insufficient oil
Rubber seed	44.0	39.9	33.0	920	10.814	4.00	Insufficient oil
Soya bean	74.1	35.8	30.7	950	0.669	5.50	0-100% oil
Sunflower	78.9	45.6	24.7	953	2.124	7.64	0-100% oil
Diesel	22.8	12.3	8.53	879	4.17×10^{-4}	0.70	-
ASTM Standard	-	1.9-6.0	-	-	0.8 max	0.02 max	-

V. LITERATURE SURVEY

Pryde et al. [1] reviewed the reported successes and shortcomings for alternative fuel research. However, longterm engine test results showed that durability problems were encountered with vegetable oils because of deposit formation, carbon buildup and lubricating oil contamination. Thus, it was concluded that vegetable oils must either be chemically altered or blended with diesel fuel to prevent premature engine failure.

Mazel, M.A et al. [2] in this paper reviewed that an alternative technological methods that could be used to produce cotton seed oil. Biodiesel from cotton seed oil was produced by transesterification process. Performance of IC engine using cotton seed oil biodiesel blending with diesel and with various blending ratios has been evaluated.

Canakei, M. and Van Gerpen, J [3] reviewed the transesterification is achieved with monohydric alcohols like methanol and ethanol in the presence of an alkali catalyst. Biodiesel and its blends with petroleum-based diesel fuel can be used in diesel engines without any significant modifications to the engines. The advantages of biodiesel are that it displaces petroleum thereby reducing global warming gas emissions, tail pipe particulate matter, hydrocarbons, carbon monoxide, and other air toxics. Biodiesel improves lubricity and reduces premature wearing of fuel pumps.

Vivek and A K Gupta [4] investigated the potential of Karanja oil as a source of biodiesel. Biodiesel ia an alternative fuel made from renewable biological resources such as, vegitable oil and animal fat. It is completely biodegradable and non-toxic. Main objective of the study are feasibility of Karanja oil for the production of biodiesel, optimization of different parameters for high yield/conversion of Karanja oil to biodiesel. Optimum condition were found to be: Pressure 1 atoms, Temperature 68-70 C, Reactant ratio 8-10 (Moles of MeOH of oil), Reaction time 30-40 min, Catalyst (KOH) 1.5 per cent w/w. Test were also conducted to compared to the biodiesel with diesel fuel in tearms of engine performance and emissions.

R.Karthikeyan et al. [5] there very important aim in this paper is to present the production technique of bio diesel in rural areas. The Indian oil seed survey says that there are 100 oil seeds available in India in which there are less than 20 oil seeds have been tapped so far. Remainings are still being as unexplored oil seeds. Among the 80 oil seeds any one of oil seeds may available abundantly in your local area .In such case biodesel production may be started with the help of this paper.

The paper discusses very simply and elaborately on the production technique of Biodiesel using locally available goods. A simple biodiesel processor is also suggested and its working principle is explained. Over and above an elaborate discussion is given over precautionary measures to be taken before the chemicals are handled.

With the help of this paper everyone can produce biodiesel for their need and indirectly help the development of the nation. Also it eliminates the unemployment problem prevails among the young scholars to a large extent by producing the biodiesel on their own in their local area.

EXPERIMENTATION

The main objective of this work is to evaluate the performance and emissions of the four stroke C.I engine using Pongamia Oil and Cotton Seed Oil as an alternate fuel.

VI. RESULTS AND DISCUSSION

Experiments have been conducted and performance curves and heat balance sheets are obtained.

Table 1 Results of Performance Test

(Fuel: Pongamia Oil -100% by Volume)

II. DETAILS	LOAD			
a)	**¼th Load**	**½ Load**	**¾th Load**	**Full Load**
Indicated Power (IP), kW	3.0	3.7	3.8	4.4
Brake Power (BP), kW	1.3	2.1	2.8	3.1
Specific Fuel Consumption (SFC)	0.589	0.344	0.321	0.310
Efficiency (Mechanical) %	43.33	56.75	72.68	70.45
Efficiency (Indicated thermal) %	45.34	54.67	76.66	61.34
Efficiency (Brake thermal)%	38.45	45.67	68.95	56.99
Efficiency (Volumetric) %	51.12	58.35	63.07	77.43

Table 2 Results of Performance Test (Fuel: Diesel Oil-100% by Volume)

III. DETAILS	LOAD			
a)	**¼ th Load**	**½ Load**	**¾ th Load**	**Full Load**
Indicated Power (IP), KW	3.90	4.10	4.90	4.70
Brake Power (BP), KW	1.80	2.70	4.20	3.80
Sp. Fuel Consumption (SFC)	0.532	0.287	0.338	0.379
Efficiency (Mechanical) %	46.15	65.85	85.71	80.85
Efficiency (Indicated ther) %	48.42	59.07	79.82	73.83
Efficiency (Brake thermal)%	41.80	49.28	73.27	59.82
Efficiency (Volumetric) %	52.17	58.08	65.03	78.07

Table 3 Heat Balance Sheet (Fuel: Pongamia Oil -100% by Volume)

Sl No.	Details	Heat in kW	% Heat
1	Heat input	81.48	100
2	Heat equivalent of BP	29.03	35.63
3	Heat equivalent of FP	10.55	12.94
4	Heat lost to cooling water	15.70	19.26
	Heat lost to exhaust gas		
5	Heat unaccounted for	13.76	16.88
6		12.43	15.25

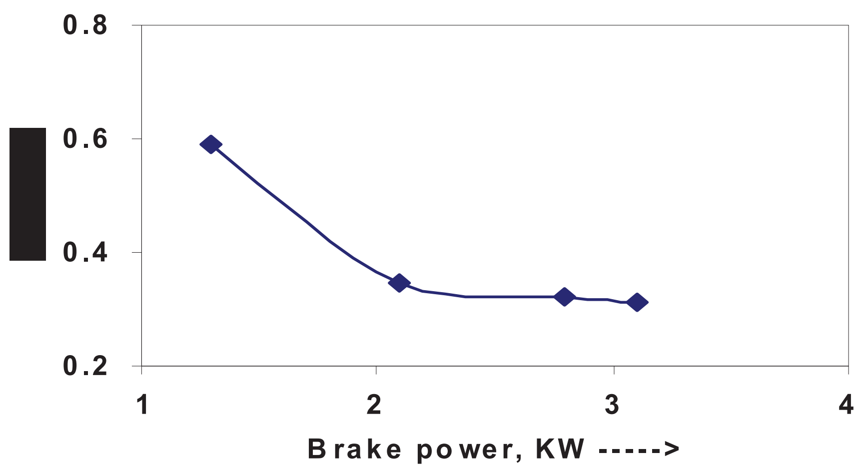


Fig 3. SFC Vs Brake power (BP)

The most important parameters which are of interest are Indicated Power (IP) developed and maximum mechanical stresses to be faced by the engine parts. The other parameter is mechanical efficiency which is an indicator of frictional losses in the engine. The other two parameters are Specific Fuel Consumption (SFC) and Brake Thermal Efficiency which are responsible for economical running of the engine. The lost factor is volumetric efficiency which is important to indicate the amount of air taken by the engine and is responsible for proper combustion of fuel. All the above said parameters are evaluated in the present research to evaluate the performance of the engine.
The results of the performance tests of the investigation is tabulated as shown in Table-1 when engine was tested with pongamia oil and loaded to ¼, ½, ¾ and at full load conditions. Table 2 shows the results of the performance tests when the same engine was tested with diesel as the fuel. The results of the above performance tests using pongamia oil as fuel are also depicted as shown in Figures 2 and 3. It is observed from the above results of the performance tests that, the test results remain almost the same when the same engine is loaded up to half of its full load. Therefore, to compare the results, the engine is tested both with both fuels viz. diesel and pongamia oil. By comparing the test results, one can infer that, in general the mechanical efficiency of the engine has come down by about 13 % when engine was tested with pongamia oil. This is because the power reduction due to the differences in calorific values of diesel and pongamia oil. Decrease in the efficiencies was observed particularly when the engine was tested (both with pongamia and diesel fuels) at its full load conditions.
Performance test plots when engine is tested with pongamia oil also shows that, mechanical, brake thermal and indicated thermal efficiencies continually increase with increase in brake power and they all reach its peak value (around 68 to 78%) when brake power is 2.8 kW and later, it falls as though the brake power is increased. Hence from the Table 1 it can be confirmed that, the engine running using pongamia oil possesses maximum efficiency when it is loaded to 3/4th of the full load where its break power is maximum at 2.8 kW.
Table 3 shows the heat balance sheet of the above engine when it is tested under 3/4th of full load condition using pongamia oil, indicating the various means the input heat is utilized. It is observed that only 35% of the heat is utilized at the shaft for doing work.

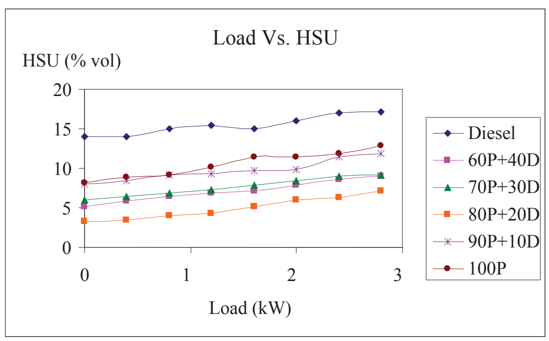


Figure.5Variation of HSU emissions against load

The variation of HSU emissions against load is shown in Figure.4. As the load increases HSU (%) increases for all the fuels. It is found to be highest for diesel and lowest for the blend 80P+20D. This can be attributed to the absence of sulphur in pongamia oil.

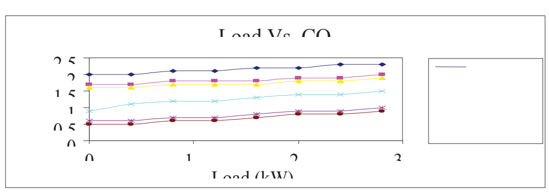
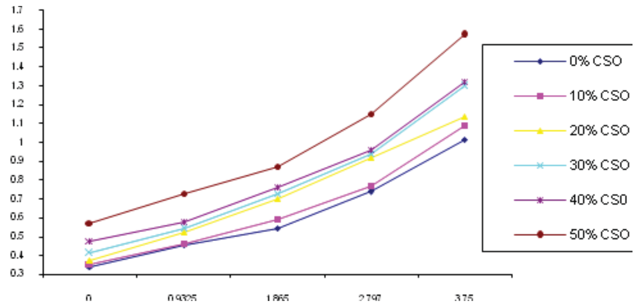


Figure.6 Variation of CO emissions against load

The variation of CO emissions with load is shown in Figure.5. CO emissions are found to be highest for diesel and lowest for pongamia oil. This can be attributed to the presence of O2 in pongamia oil, which enables complete combustion of CO to CO2.



B.P (kW)

Fig. 7 Variation in fuel flow rate with B.P for different CSO/DO blends

Figure.6 shows fuel flow rate with respect to brake power. It is seen that the lower energy content/ unit mass of blend compared to diesel fuel resulted in increased mass flow rate. A possible explanation is that the more viscous fuel blends reduce normal injection pump leakage enough to make a significant change in the volume discharged per stroke. Although the heating value relationship tends to reduce the specific energy input rate as blend fraction increases, the net effect is an increase in fuel heat supplied. Engine performance and emissions were influenced by basic difference between diesel fuel and (CSO+ DO) blends such as heating values, viscosity, density etc.,

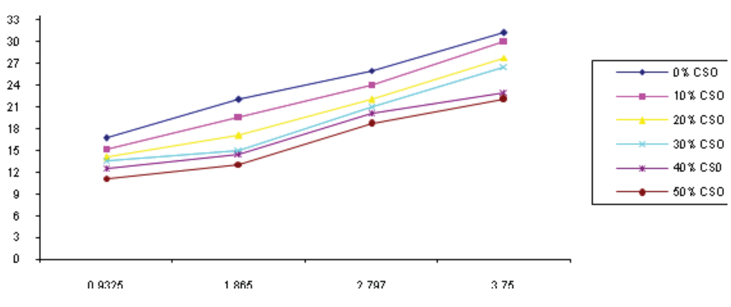
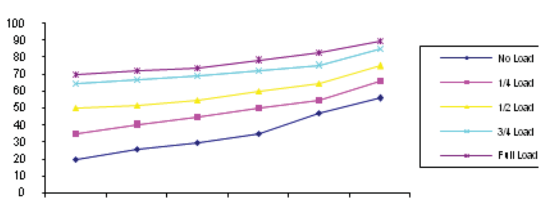


Fig. 8 Variation of B.T.E with B.P for different CSO/DO blends

In Figure.7, at constant speed of 1500 rpm it is observed that brake thermal efficiency decreases with the increase in CSO content in diesel. This decrease in efficiency is less compared to the ability of combustion system to accept the CSO blends as fuel. This may be due to the high viscosity of CSO content in the blends, and this may degrade fuel spray characteristics and lead to improper combustion, which result in minor decrease in efficiency. Brake Thermal Efficiency decreases slightly with respect to B.P at the maximum load; this may be due to lower heat content of CSO, which leads to non-uniform combustion of the fuel.



PERCENT CSO IN DIESEL

Figure.8, shows the increase in soot with increase in CSO content in diesel at different load conditions, which may be due to the incomplete combustion of blends due to low heat values associated with high fuel viscosity, resulting in larger mean fuel droplet size and decrease in air fuel mixing rate. Poor atomization is a result of the viscous nature of the oil. The fuel physical properties such as density, viscosity can have a greater influence on smoke emission than the chemical properties. This can be attributed to higher carbon content in vegetable oils.

- Viscosities of vegetable oils are significantly higher, whereas densities are slightly higher when compared with diesel fuel.
- Heating values of blends reduced by 10%.
- In the general test observations there is very slight deposition on nozzle tip; deposits
- formed were soft and easily removable with cloth.
- For the long-term operation injection nozzle carbon deposits may lead to poor fuel
- Atomization and dilution of crankcase oil. Deposits that are formed on the nozzle tip exterior are believed to originate from the thermal cracking of the fuel that boils from the nozzle sac late in the expansio stroke.
- This problem can be overcome by relocating the position of the injector nozzle in the engine cylinder head.

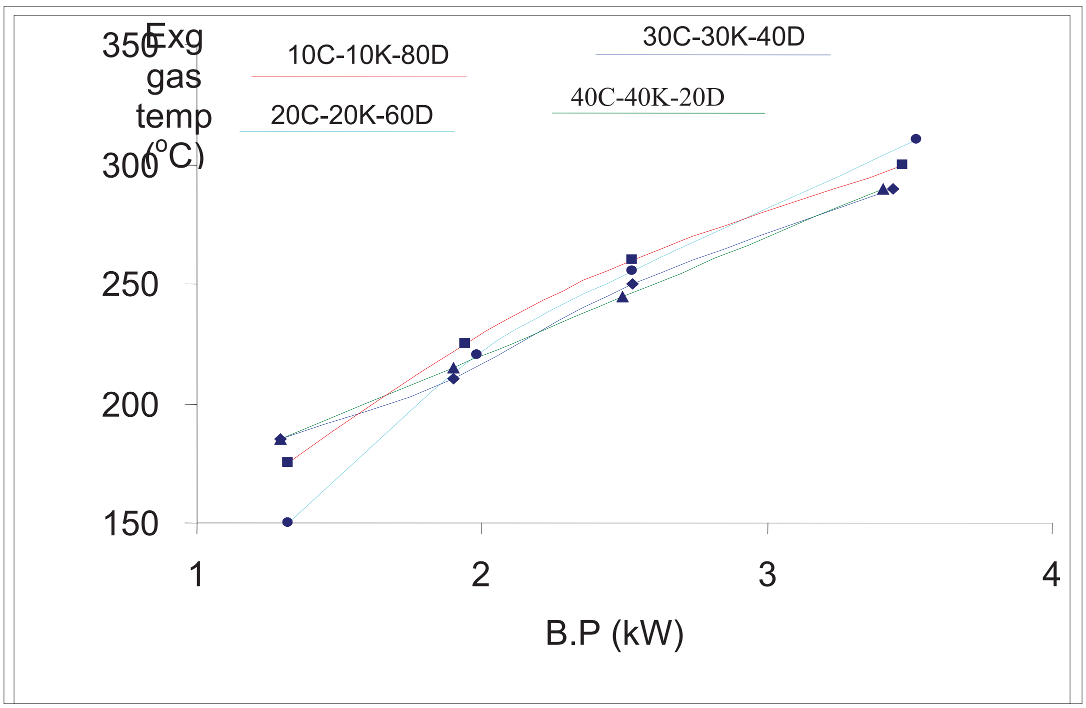


Fig.9 Exhaust gas temperature Vs B.P

The comparison of exhaust gas temperature Vs B.P (Figure.9) shows that all the blends emission gases are higher than the 100% diesel at all points of B.P.

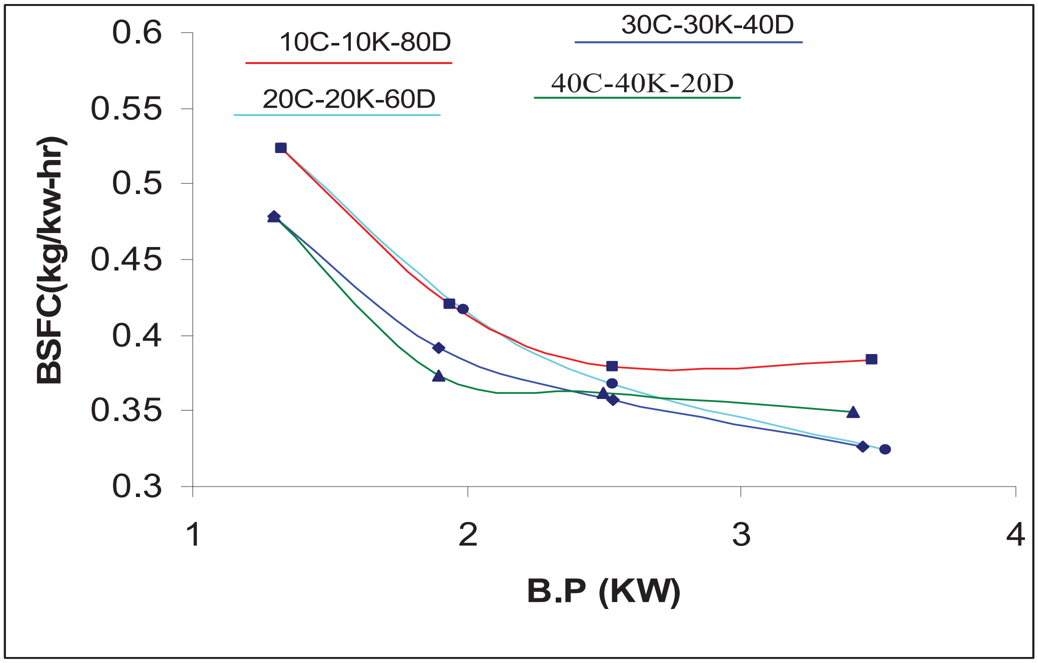


Fig.10 BSFC Vs B.P results of different blends

The Figure.10 shows the comparison of BSFC Vs B.P results of different blends with each other and with 100% diesel. On observation it is seen that for all blends the SFC curves show similar trends. While at lower loads the SFC of the blends show clear higher values than 100% diesel, and the SFC is seen to be higher by 15-20% than the 100% diesel SFC. At higher loads the SFC of the blends show clear higher values than 100% diesel and SFC is seen to be higher by 10-15% than that of the 100% diesel. But at intermediate loads, the blends show similar values as that of the 100% diesel.

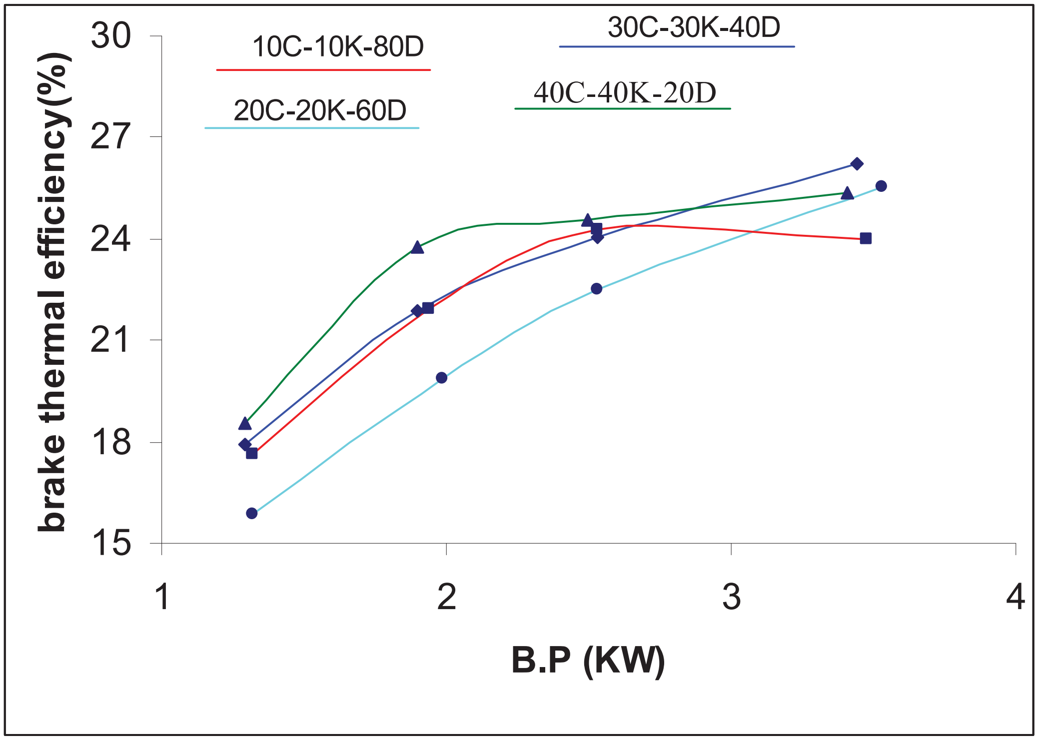


Fig.11 BTE Vs B.P results of different blends

The Figure.11 shows brake thermal efficiency Vs B.P curves for different blends. The plots shows at lower B.P. values & at higher B.P. values, the100% diesel have higher brake thermal efficiency. At intermediate loads, the blends show higher brake thermal efficiency than 100% diesel.

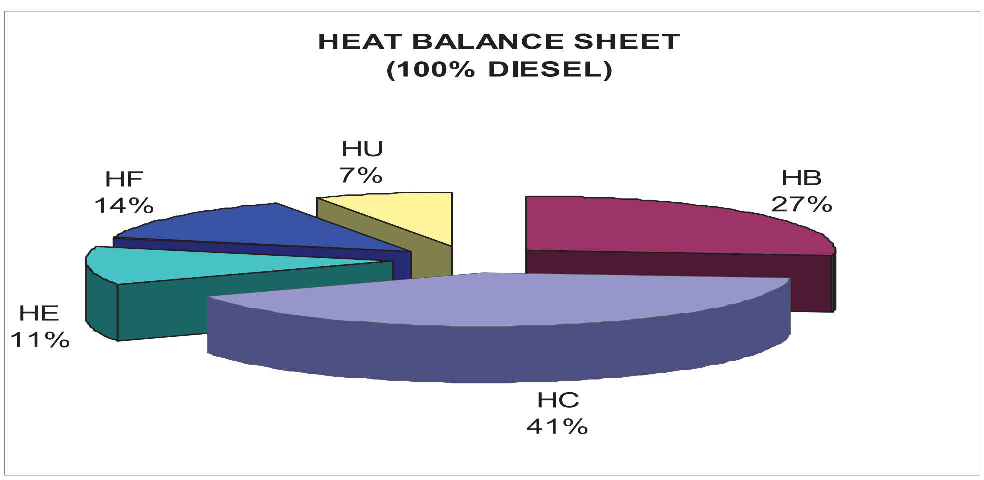


Fig.12 Heat Balance Sheet (100% Diesel)

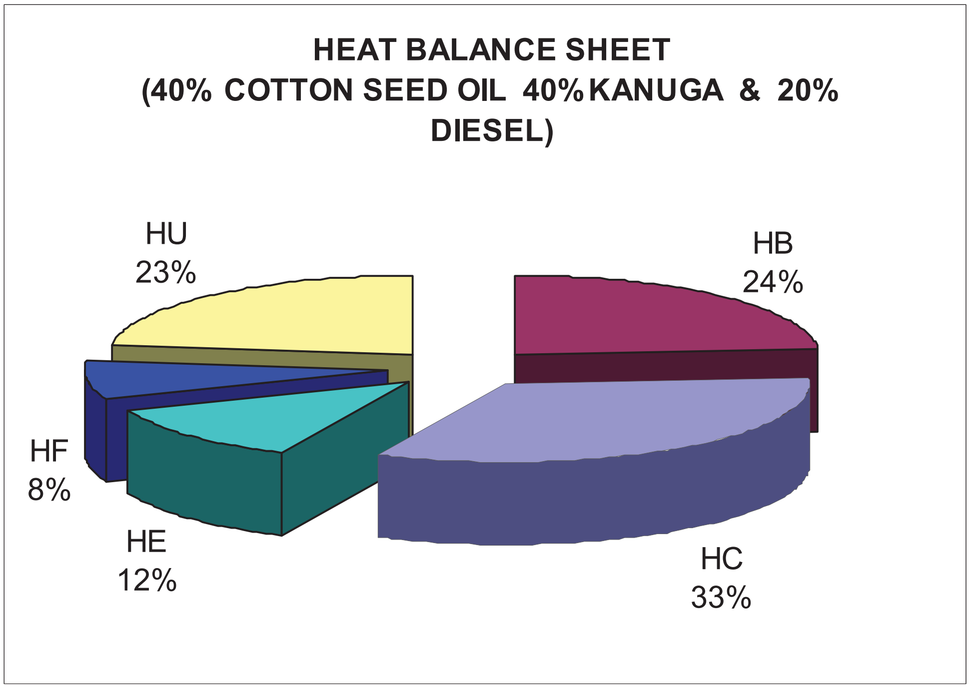


Fig.13 Heat Balance Sheet (40% CSO + 40% Pongamia + 20 Diesel

The heat balance sheets (Figure 12 & 13) show more or less same results. From the observations made, it can be concluded that the cotton seed oil & Kanuga (or Pongamia oil) are the best alternative fuels for C.I. engine. The performance of this cotton seed & kanuga oil are expected to be similar to that of diesel

VII. CONCLUSIONS

Results of the above investigation reveal the following.

1. Mechanical efficiency of the engine was reduced by 13 % when engine was run with Pongamia Oil and this is because the calorific value of Pongamia Oil is slightly lesser compared to diesel.
2. All efficiencies in general were maximum (68 to 78 %) when brake power was 2.8 kW when engine was tested with Pongamia Oil under $3/4^{th}$ of full load.
3. The use of pongamia oil in the present work resulted in increased brake thermal efficiency compared to diesel.
4. Experiments indicate that there is a substantial reduction of unburnt hydrocarbons, CO, and particulate matter compared to that from diesel. In addition to this, the exhaust emissions of sulfur oxides and sulphates are essentially eliminated using pongamia oil.
5. The blend 80P+20D is exhibiting optimum performance characteristics in terms of increased brake thermal efficiency and lowest HSU emissions. Thus Pongamia Oil can be conveniently used as an alternate fuel for diesel.
6. As Pongamia Oil is viscous, it is highly preferred for slow speed engines such as engines coupled to run pumps and generators. Comparison of engine performance for diesel and blends resulted in 5% to 10% lower thermal efficiency.
7. The blends of CSO up to 40-50% can be successfully employed in the rural areas to meet short– term, fuel scarcity, without engine modification.
8. Soot was found to be increasing with increase in the percentage of CSO in the blend due to the poor atomization as a result of viscous nature of the oil. Hence providing an advanced injection timing and higher compression ratio can minimize this.
9. Thus in developing nations CSO is available in ample quantity, if it is processed as per the fuel requirements in mass production then there is a chance for reducing its overall cost. Then it will become a renewable source of energy where diesel fuel is a scarcity.

10. Thus it can be concluded that blended oils can replace diesel within the range of experimentation. The performance is expected to be as good as that with diesel.
11. Therefore, it is concluded that CSO and Pongamia Oil can be best suited for stationary engines where cleaning after a run can be made easily. If it is to be used on automobile engines then diesel has to be used at the starting of the engine and also end of the running to facilitate easy restart, because the engine temperature falls than 70ºC temperature when not in running condition.

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