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Performance of Pre-heated Cottonseed Oil and Diesel Fuel Blends in a Compression Ignition Engine

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Abstract

Viscosity of vegetable oil is considered a constraint for its use as an alternate fuel for Internal Combustion(IC) engines. In this experimental investigation, the viscosity of cottonseed oil (CSO), which is considered a potential alternate fuel, is reduced by blending it in different proportions with diesel, and its viscosity at various temperatures was analyzed and used as a fuel in a compression ignition (CI) engine. Performance, combustion and emission parameters at various loads were calculated using a single cylinder CI engine and compared with neat diesel and cottonseed oil. A remarkable improvement in the performance of the engine is noticed as the viscosity of the oil is reduced. Brake thermal and volumetric efficiencies of the engine increased with a significant reduction in the exhaust gas temperature. Reductions in smoke, CO and HC emissions are also noticed. Results show that a blend containing 60% of cottonseed oil with diesel, which is heated to a temperature of 70°C, can be used as an alternate fuel without any engine modification.

Keywords: Cottonseed oil (CSO); Diesel; viscosity; Temperature; Blend

Abbreviations

IC	Internal Combustion
CSO	Cottonseed oil
CI	compression ignition
HC	Hydrocarbon
CO	Carbon Monoxide
TDC	Top Dead Center
cSt	Centi Stoke
PH	Preheated
BSU	Bosch Smoke Units
PPM	Parts per Million
bTDC	Before Top Dead Center
cc	Cubic Centimeter
Cp	Specific Heat at Constant Pressure
CR	Compression Ratio
SAE	Society of Automotive Engineers

Symbols

°C	Degree centigrade
°CA	Degree crank angle
hr	Hour
K	Kelvin
kJ	Kilo Joules
kW	Kilo Watt
kg	Kilogram
P	Pressure (bar)
rev/min	Revolutions per minute
rpm	Revolutions per minute
T	Temperature (K)
t	Time (s)

1. Introduction

The idea of using vegetable oil began in the year 1893 itself when diesel engines came into existence. In the year 1911, Rudolf Diesel operated his first engine using straight vegetable oil (peanut oil).

The physical and combustion properties of vegetable oils are closer to that of diesel and in this context; vegetable oils can stand as an immediate candidate to substitute for fossil fuels. The greatest advantages of vegetable oils are that they are obtained from seeds of various plants. In view of this, researchers have started showing renewed interest towards vegetable oils because of its advantages as a potential alternate fuel. Vegetable oils are renewable and eco-friendly in nature and at the same time, it can be easily produced in rural areas.

Sustainable development of a country depends on the extent that it is managing and generating its own resources. This also helps in conservation of depletion of non-renewable petro-products. However due to inherent high viscosity and low volatility, vegetable oils would pose problems such as fuel flow and poor atomization and constrain their direct use in engine without any modifications.

Vegetable oils are either edible or non-edible. Some of the edible oils are sunflower oil, palm oil, rice bran oil, and cottonseed oil. The non-edible oils are mahua oil, jatropha oil, rubber seed oil, etc. As rice bran and cottonseed oil (CSO) are not very much in use for cooking purpose, these can be used as substitute for diesel in CI engines. Cottonseed oil has several properties closer to that of

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diesel but certain properties such as high viscosity and low volatility pose problem when used as an alternate fuel for C.I engines.

The potential of using vegetable oil for diesel engines was studied by Recep Altin et al. [1], Yoshomoto .y et al. [2] and Kensuke Nishi et al.[3]. The engine performance was very much similar to that for diesel with little power loss and slight increase in the emission level. Karaosmanoglu.F et al [4] studied long-term utilization of vegetable oil and no significant increase or loss in power was noticed. Nwafor O.M.I et al. [5] carried out combustion studies on both diesel fuel and vegetable oil fuel with standard and advanced injection timings. Advanced injection timing compensates the effects of the longer delay period and slower burning rate that is exhibited by vegetable oils.

The problems related to low volatility and high viscosities are offset by subjecting the oil into the process of transesterification, and the high viscosity can be reduced. Methyl and ethyl esters of vegetable oil (called as bio-diesel) have the physical and chemical properties closer to that of diesel. The performance and emission characteristics of the diesel engine using methyl ester are comparable with that of diesel as per Dilip Kumar Bora et al. [6]. Babu A.k et al. [7] also has reported problems related to high viscosity.

Blending vegetable oil with diesel decreases the viscosity and improves the volatility. This improved properties results in better mixture formation and spray penetration. A number of investigators tried the vegetable oils in varying proportions with diesel. Results obtained from experiments shows that vegetable oil and diesel blends showed improvement in engine performance [8, 9]. Pre heating the vegetable oil reduces the viscosity and improves combustion characteristics (Pramanik. K [10]).

This paper examines the use of preheated cottonseed oil diesel blends on the performance of a single cylinder diesel engine. Preheating the vegetable oil decreases the viscosity and improves the atomization and mixing process, which results in better combustion.

2. Experimental Setup

A single cylinder, water cooled, four stroke direct injection compression ignition engine with a compression ratio of 17.5: 1 and developing 5.2 kW power at 1500 rpm was used for this work. Fuels used were diesel, cottonseed oil and blends of cottonseed oil-diesel pre heated to 70°C. The cylinder pressure and top dead centre (TDC) signals were acquired and stored using a high-speed computer based digital data acquisition system. The stored signals were processed with specially designed software to obtain the performance and combustion parameters. Viscosity of the fuel was measured with a Saybolt viscometer. A CRYPTON exhaust gas analyzer was used to measure carbon monoxide (CO) and hydrocarbon (HC) levels. The analyzer is a fully microprocessor controlled system employing nondestructive infrared techniques. Smoke level was measured using a standard BOSCH smoke measuring system.

3. Experimental Procedure

During all the tests, the rated power and speed of the engine (5.2 kW @ 1500 rpm) were maintained. Load was changed in 5 levels, 20%, 40%, 60%, 80% and 100%. Load, speed, air flow rate, fuel flow rate, exhaust gas temperature, exhaust emissions of HC, CO and smoke were stored in the computer at all load conditions. Cylinder pressure and TDC position signals were also recorded to obtain combustion parameters.

4. Results and Discussion

4.1. Effect of preheating cottonseed oil and blending with diesel:

Table.1 shows the variation of viscosity of diesel, CSO and the blends at 30°C. The high viscosity of CSO drastically falls with the increase in the quantity of diesel in the blend. Even with an addition of 20% diesel, the viscosity of the blend drops from 49.6 cSt to 22.3 cSt, which is 55.04% less than that for CSO. With further increase in the quantity of diesel in the blend the viscosity dropped. The viscosities of 40%, 60% and 80% diesel with CSO are 16.2, 11.6 and 7.2 cSt respectively. The corresponding percentage reduction in viscosity is 67.33%, 76.61% and 85.48%. Therefore, to bring the viscosity close to diesel, 60-80% of diesel has to be added to CSO.

Table 1: Viscosity of diesel, CSO and blends @ 30°C.

Fuel	Diesel	CSO	20% Diesel	40% Diesel	60% Diesel	80% Diesel
Viscosity (cSt)	4.59	49.6	22.3	16.2	11.6	7.2

In order to reduce the viscosity, the blends were heated from 20°C to 90°C in steps of 10°C. Table.2 shows the results obtained. Variation of viscosity of diesel, CSO and blends at various temperatures are shown in Figure.1. From Table.2 the viscosity of 20%, 40% and 60% diesel blends at 70°C are close to that for diesel. Therefore, blends containing 20%, 40% and 60% diesel were tried as a fuel for the CI engine and results for 20% and 40% are presented in this paper keeping in mind the maximum reduction of diesel usage.

Table 2: Viscosity of Diesel, CSO and blends at various temperatures.

Temperature (°C)	Kinematic Viscosity (cSt)					
	Diesel	CSO	20% Diesel	40% Diesel	60% Diesel	80% Diesel
30	4.59	49.6	22.3	16.2	11.6	7.2
40	3.4	32.7	16.2	13.1	10	6.2
50	3.1	23.3	11.7	10.3	8	5.1
60	2.7	16.8	8.3	6.6	5.2	4.2
70	2.2	9.3	6.4	5.3	4.6	3.6
80	2	6.2	5.4	4.9	3.8	2.8
90	1.9	5.3	4.9	4.1	3.4	2.6

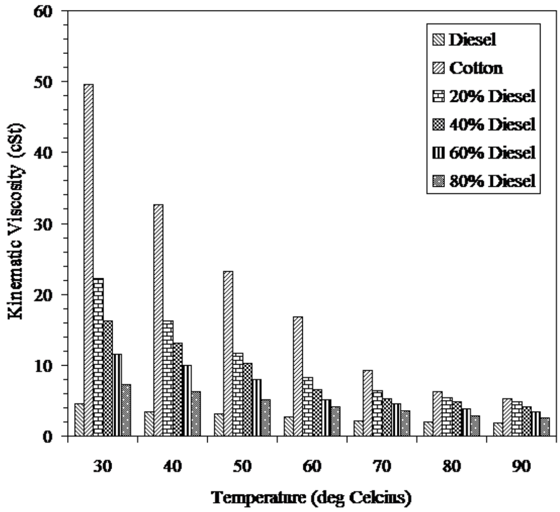

Figure 1: Variation of viscosity of diesel, cottonseed oil and blends with various temperatures.

4.2. Brake thermal efficiency:

The brake thermal efficiency plots in Figure.2 shows an increase of brake thermal efficiency with increase in the engine load, as the fuels are preheated. The brake thermal efficiency of CSO increased from 28% to 28.8%. The blend containing 20%and 40% diesel, preheated to 70°C shows an increase in brake thermal efficiency, which is very close to diesel. The values are 30% and 30.5% as against 32.3% for diesel at 100% load. This is due to the reduction in viscosity, density and improved atomization, fuel-air mixture formation and increase in the heating value as the proportion of diesel in the blend increases.

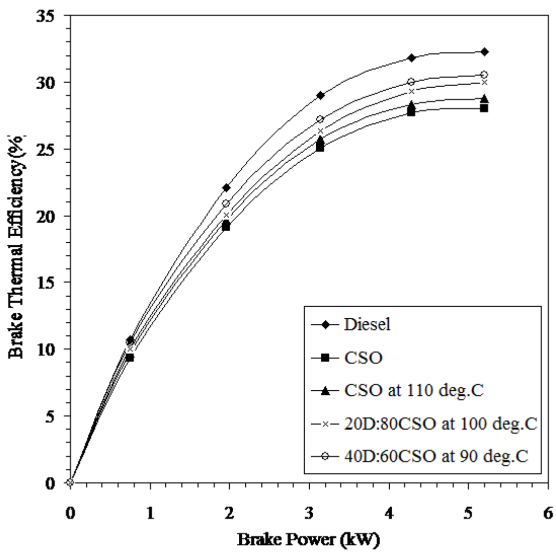

Figure 2: Variation of brake thermal efficiency with brake power.

4.3. Volumetric efficiency:

Figure.3 shows the variation of volumetric efficiency with brake power. There is an improvement of volumetric efficiency with preheat when compared to CSO at room temperature. The volumetric efficiency of preheated oil increased from 82.3% to 83% at the peak load. The trend is the same for the blends also. Volumetric efficiency is 84.6% for diesel and 84.12% for 40% preheated diesel blend. The low volumetric efficiency of neat CSO is due to its high exhaust gas temperature. High exhaust gas retained temperature will lead to heat the incoming fresh air and this will result with in reduction of volumetric efficiency. As seen in Figure. 4, the exhaust gas temperature decreases, when the fuel mixture is heated. Due to that, there is improvement in volumetric efficiency with preheated fuels, but it is still lower compared with diesel value of 84.6%.

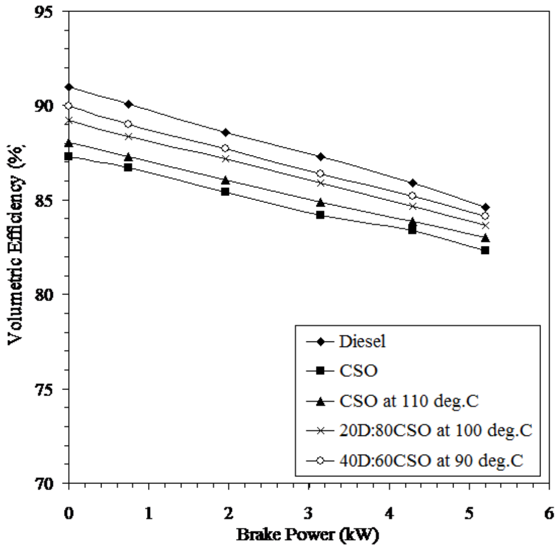

Figure 3: Variation of Volumetric efficiency with brake power.

4.4. Exhaust gas temperature:

The variation of exhaust gas temperature is shown in Figure.4. There is an increase in exhaust gas temperature with neat CSO. It is 445.1ºC for CSO and 407.3ºC for diesel at full load. This is mainly due to higher viscosity of CSO leads to late burning of fuel. There is a slight increase in exhaust gas temperature with preheated neat CSO. The exhaust gas temperature reduces as the proportion of diesel is raised due to the better vaporization of mixture. Exhaust gas temperatures is 423.5ºC for 20% and 416.1ºC for 40% preheated diesel blend at the peak load condition. The reduction in the exhaust gas temperature of the blends indicates that the premixed combustion of the preheated blend has improved. This is mainly due to the reduction in the viscosity of the fuel.

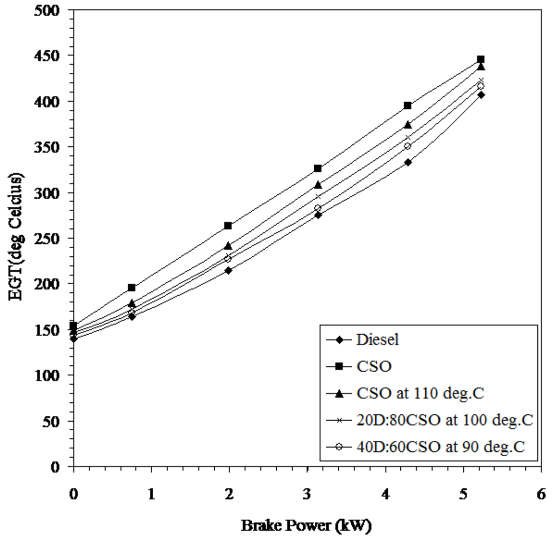

Figure 4: Variation of Exhaust gas temperature with brake power.

4.5. Smoke

Figure.5 shows the variation of Smoke emission with brake power for diesel, CSO and for the preheated blends. The results show that the smoke level increased with the power output of the engine for all the fuels. With preheated CSO, the smoke level is 3.6 BSU that is lower than unheated oil, which is 3.9 BSU. Preheated blends also showed the same trend. The smoke emission is 3.4 BSU with diesel and 3.5 BSU with the preheated 40% diesel blend. When compared to CSO, this value is low which indicates a better combustion. Still the trend at the full load is comparatively high for CSO and the blends.

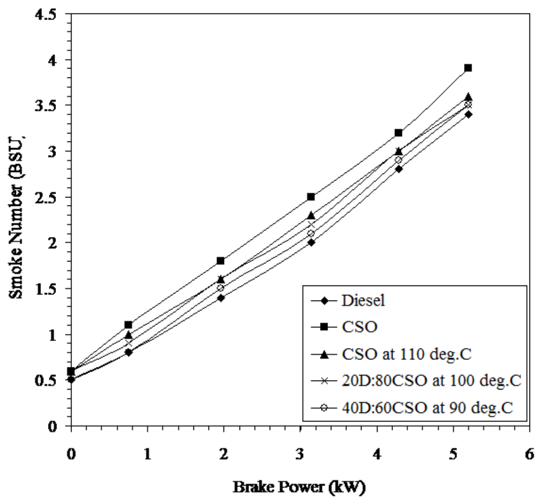

Figure 5: Variation of Smoke with brake power.

4.6. HC and CO emission:

Continuous exhaust gas sampling shows a significant reduction in the hydrocarbon and carbon monoxide emissions with the preheated CSO and the blends as compared to neat CSO. Nevertheless, through out the load range, the HC and CO emissions for CSO, preheated CSO and blends were higher than that for diesel. However, the HC and CO levels are less for preheated CSO when compared to neat CSO. This trend indicates that the combustion efficiency improve with preheat. The improved spray and fuel distribution inside the combustion chamber has resulted in better combustion rate and hence the reduction in the HC and CO emissions with preheat. The variation of HC and CO with brake power for the different fuels is shown Figure.6 and Figure.7. The HC and CO emissions reduce as the viscosity of the fuel decreases. These results indicate that the viscosity of the fuel influences the HC and CO emissions.

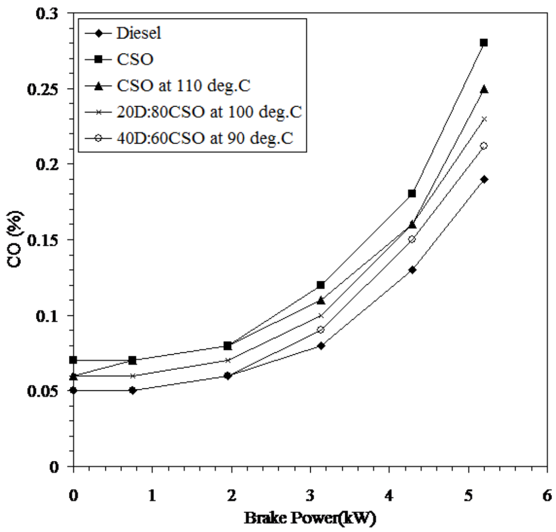

Figure 6: Variation of Carbon Monoxide Emission with brake power.

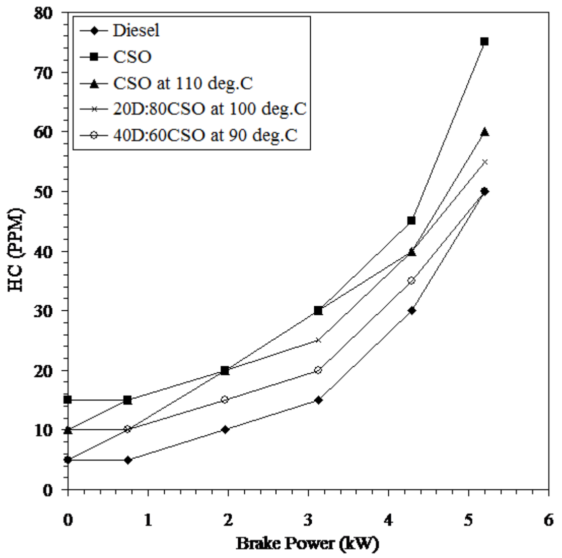

Figure 7: Variation of Hydrocarbon Emission with brake power.

4.7. Peak pressure and maximum rate of pressure rise:

Figure.8 and Figure.9 show the variation of peak pressure and max rate of pressure rise. The values with neat diesel is the highest followed by the preheated blends and cottonseed oil. The peak pressure with diesel is 73.21 bar followed by the 40% diesel blend whose value is 72.84 bar at the peak load. The increase in the pressure is due to the cracking of the double bond of the carbon chain, which might have produced light volatile compounds.

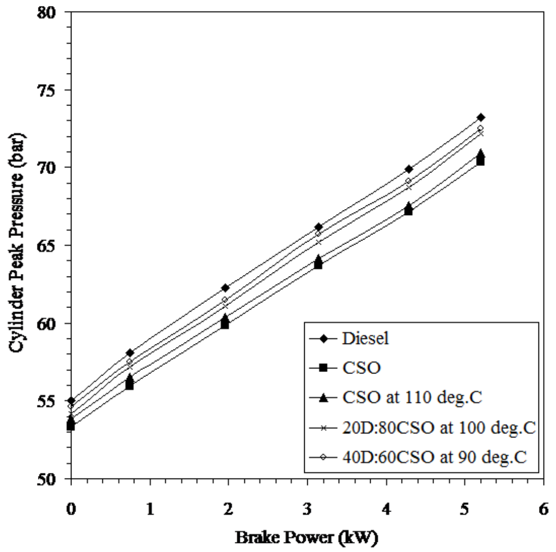

Figure 8: Variation of Cylinder Peak Pressure with brake power.

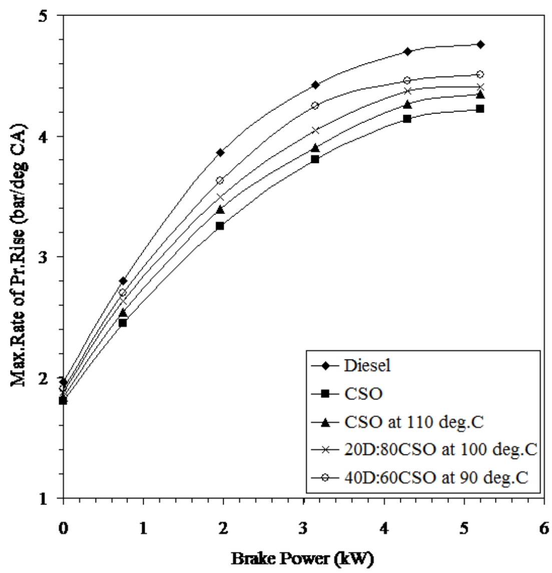

Figure 9: Variation of Maximum rate of pressure rise with brake power.

5. Conclusion

A single cylinder compression ignition engine was operated successfully on preheated and neat cottonseed oil. The following conclusions are drawn based on the experimental results at 5.2 kW load:

- Lower thermal efficiency (28%) is found in neat CSO compared to diesel (32.3%). However, preheating the mixture increases the thermal efficiency.
- The exhaust gas temperature is higher for CSO compared to diesel. This is due to the late burning of CSO. It is further reduced with preheated CSO and diesel mixture.
- Significant reduction in smoke level with preheated CSO and diesel mixture compared to neat CSO is observed. The improvement in volatility of preheated mixture is beneficial in improving the fuel evaporation resulting smoke reduction.
- NO emission for the CSO operation is 703 ppm and 756 ppm with diesel at full load. Marginal increase in NO emission with preheated mixture of CSO and diesel than neat CSO because of increased fuel temperature leads to high combustion temperature is observed.
- The concentration of premixed combustion phase is lower for CSO compared to diesel. However, the rate of heat being released improves with preheated CSO and diesel mixture.
- Combustion duration and ignition delay is longer with CSO as compared with diesel at all loads. There is a reduction in combustion duration and ignition delay with preheated mixture (40% diesel and 60% CSO) at 90°C.

It is concluded that the preheating the fuel mixture (40% diesel and 60% CSO) is the effective method to reduce emission and improving performance of a diesel engine.

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