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Performance, Combustion and Emission Characteristics of Single Cylinder Diesel Engine Using Custard Apple Seed (Annona Squamosa) Oil

Mahalingappa[1], M.C.Navindgi[2], Dr.Omprakash Hebbal[3]

[1] M.Tech Scholar, Department of Mechanical Engineering, PDA College of Engineering, Gulbarga, Karnataka (INDIA)

[2]Associate Professor and [3] Professor Department of Mechanical Engineering, PDA College of Engineering, Gulbarga, Karnataka (INDIA)

Abstract

Environmental degradation and depletion of fossil fuel reserves are matters of great concern around the world. Diesel is one of the main transport fuel used in sector and India depends heavily on oil import. Recent concerns over the environment, increasing fuel prices and shortage of its supply have promoted the interest in development of the alternative sources for petroleum fuels. In present work we have conducting experiment of custard apple seed oil. performance , combustion and emission characteristics of single cylinder diesel engine using custard apple (Annona Squamosa) Seed biodiesel-diesel blends (20%, 40%, 60%, 80%, and 100%).These blends are used on the 5.2 kW diesel engine with constant speed at 1500 rpm and varying load conditions. The results shows that brake thermal efficiency of CA80 is equal to diesel compare to other blends, less exhaust gas temperature, specific fuel consumption is decreases in lower loads and at full load its equal to diesel .Almost overlapping p-θ diagram, heat release rate is same as that of diesel. Exhaust emissions like CO_2, HC and NOx are slightly increases and CO and smoke decreases.

Keywords**:** *Biodiesel, custard apple seed oil, Efficiency.*

1. Introduction

Custard apple, any of various *Annona* species of small trees or shrubs of the Annonaceae family, native to the New World tropics and Florida, or their fruits. The fruit of the common custard apple (*A. reticulata*), also called sugar apple or bullock's-heart in the West Indies, is dark brown in colour and marked with depressions giving it a quilted appearance; its pulp is reddish yellow, sweetish, and very soft (hence the common name); the kernels of the seeds are said to be poisonous. The soursop, or guanabana, is the fruit of *A. muricata,* native to the West Indies. In India Custard apple is cultivated in Maharashtra, Andhra Pradesh, Karnataka, Bihar, Orissa and Tamilnadu. According to an estimate made by Indian Council of Agricultural Research (ICAR), custard apple trees are grown in about 40,000hectares and can yield about 4 lakh tones seeds. This in turn can yields 1.12 lakh tones oil.It had also been known as sweetsop and sugar apple (English), seetaaphala and amritaphala (Kannada), Atoa and shariffa (Hindi).

The present work is focused on the performance, combustion and emission characteristics of custard apple seed oil by using different types blends, to find its suitability as fuel for CI engine.

2. Experimental Methods

2.1. Transesterification:

Procedure: Take 1ltr of custard apple seed oil in a three neck flask with reflux condenser, heat the oil up to 60°C add 300ml of methanol and 10gms of potassium hydroxide catalyst. Run the process for about 90minutes..Transfer that oil into separating funnel, allow it to settle for about 7-8 hours then two layers will be formed. Upper layer is biodiesel and lower layer is glycerin. Separate the glycerin and biodiesel. The Yield after this process was found to be 85-90% of biodiesel. (850-900ml).

3. Experimental Set-Up

The experiments of performance, combustion and emission characteristics were conducted on a stationary single cylinder four-stroke diesel engine and compare it with baseline data of diesel fuel. The engine is coupled with an eddy current dynamometer as shown in fig: 1. the eddy current dynamometer was used for loading the engine. The various components of experimental set up are described below. Shows line diagram & Fig. shows the photograph of the experimental set up. The important components of the system are,

1. The engine
2. Dynamometer

3. Smoke meter
4. Exhaust gas analyzer

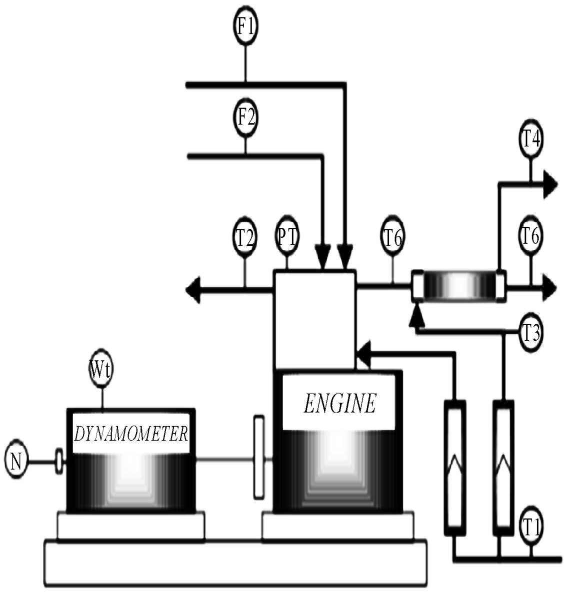

Fig-1. Line diagram of the experimental set up

PT- Pressure Transducer.
T1-Jacket water inlet temperature.
T2-Jacket water outlet temperature.
T3--Calorimeter water inlet temperature.
T4-Calorimeter water outlet temperature.
T5-Exhaust gas to calorimeter Temperature.
T6-Exhaust gas from calorimeter temperature-Rotary encoder,
Wt– Weight, **F1**-Fuel flow,
F2-Air flow,
F3- Jacket water flow
F4-Calorimeter water flow

Technical specifications of the engine.

Manufacturer	Kirloskar Oil Engines Ltd., India
Model	TV–SR II, naturally Aspirated
Engine	Single cylinder, DI, 4 strokes
Bore/stroke	87.5mm/110mm
Compression ratio	17.5:1
Speed	1500 r/min, constant
Rated power	5.2 kW
Injection pressure	240 bar/23° BTDC
Type of sensor	Piezo electric
Response time	4 micro seconds
Crank angle sensor	1-degree crank angle

4. Results and Discussion

The experiments were carried out on a test engine running on CA20, CA40, CA60, CA80, CA100 and D100 fuels in order to investigate the performance, combustion and emission characteristics. All the experiments were conducted at rated engine speed of 1500 rpm under varying load conditions for CA20, CA40, CA60, CA80, CA100 and D100 fuels. After completion of each experiment the engine was run on diesel in order to flush the fuel in the fuel line.

4.1 Properties of Custard Apple Oil

The properties of Custard Apple (CA100) were determined in laboratory .The properties are like kinematic viscosity, density, flash point and calorific value are shown in Table 2.

Table 1: Properties of Custard Apple Oil

Properties	Biodiesel (Custard Apple)	Biodiesel Standard Value (ASTM)	Commercially Available Diesel
Kinematic Viscosity@ 40^0C (cst)	5.6068	1.9-6.0	2.54
Density (kg/m^3)	875	870-900	840
Flash Point(^{0}C)	159	130	54
Calorific Value (KJ/Kg K)	37510	37000-42500	42500

4.2 Performance Characteristics

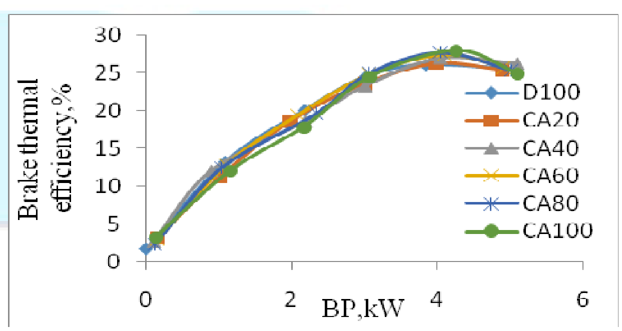

Fig 2. Variation of brake thermal efficiency with brake power.

The variation of brake thermal efficiency with brake power for different blends are shown in figure(2).The graph shows that the brake power increases the brake thermal efficiency increases to an extent and then decreases slightly at the end . the brake thermal efficiency reduces due to heat loss and increase in power developed with increase in brake power. The decrase in brake thermal efficiency for higher blends may be due to the combined effect of its lower heating value and increase in fuel consumption. The curve CA80 is nearer to diesel curve .

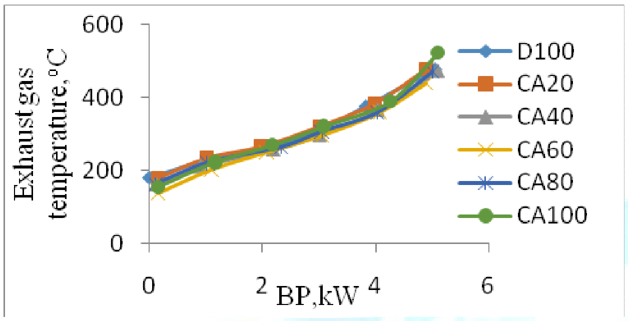

Fig 3. Variation of exhaust gas temperature with brake power

The variation of exhaust gas temperature with brake power for different blends shown in figure(3) .It is evident from the graph that exhaust gas temperature is increased along with the increase in load for all fuels. The increase in exhaust gas temperature with load is obvious from the fact that more fuel is required to take additional load. The exhaust gas temperature was found to increase with increasing concentration of biodiesel in the blends. This could be due to lower heat transfer rate in case of biodiesel which in evident from trends of thermal efficiency.

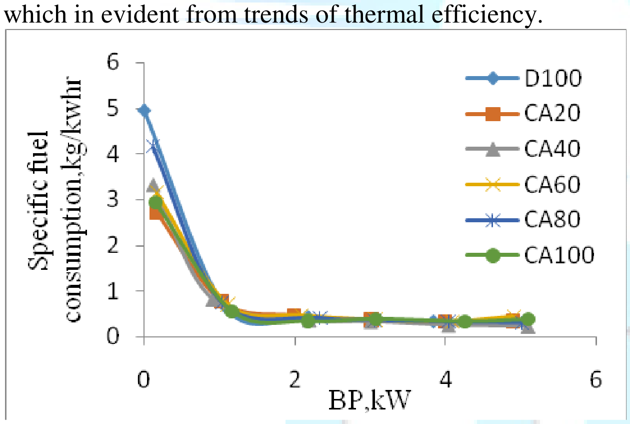

Fig 4 . Variation of specific fuel consumption with brake power

The variation of specific fuel consumption with brake power shown in figure(4). As the power developed increases the specific fuel consumption decreases for all the tested fuels. The specific fuel consumption of blends is more than that of diesel, this is due to lower calorific value of the fuel, and engine consumes more amount of the fuel in order to produce the same out-put power. The CA80 is almost nearer to diesel.

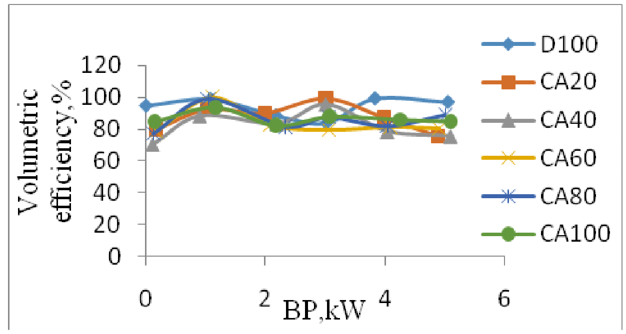

Fig 5.Variation of volumetric efficiency with brake power

The variation of volumetric efficiency with brake power is shown in figure(5).from graph diesel has higher volumetric efficiency compare to blends .the graph for different blends are in zigzag in nature because of breathing ability of engine for the particular combinations .i.e.,raio of the air actually induced at ambient conditions to the swept volume of the engine

4.3 Combustion Characteristics

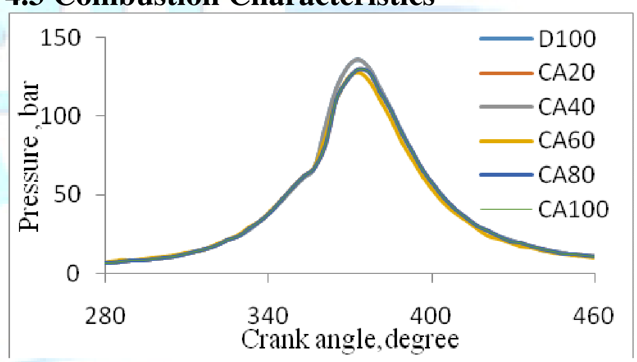

Fig 6. Variation of pressure with crank angle

In a CI engine the cylinder pressure is depends on fuel burning rate during the premixed burning phase, which in turn leads better combustion and heat release. It can be seen from Figure (6) that custard apple biodiesel (CA40) had a higher peak pressure than that of neat diesel.

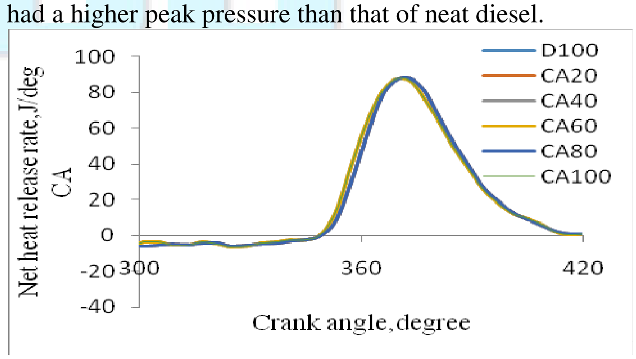

Fig 7.Variation of Net HRR with crank angle

The variation of net HRR with crank angle is shown in figure (7). The heat release rate for all other tested fuel was slightly less than that of diesel this may be attributed to low vaporization, high viscosity and low peak pressure of blends as compared to that of diesel.

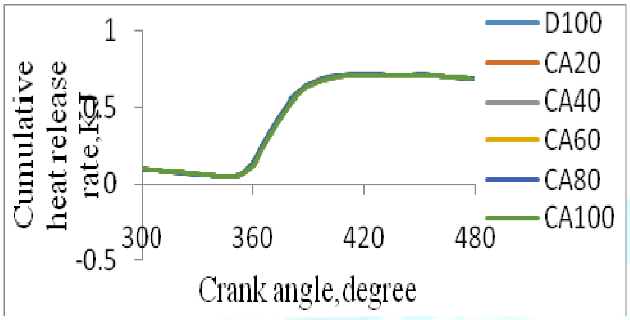

Fig 8. Variation of cumulative heat release rate with crank angle

The variation of cumulative heat release rate with crank angle is shown in figure (8). The diesel and blend values are same in all loads.

4.4 Emission Characteristics

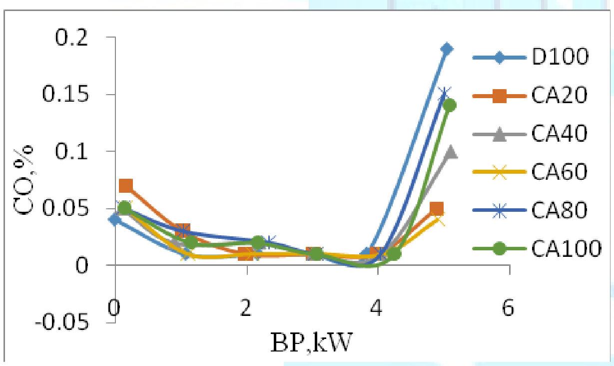

Fig 9. Variation of carbon monoxide with brake power

The plots of carbon monoxide (CO) emissions of custard apple and diesel fuel operation at different load conditions are shown in figure(9). The plots show reducing CO emissions at higher loads. The decrease in carbon monoxide emission for biodiesel is due to more oxygen molecule present in the fuel and more atomization of fuel as compared to that of diesel. The decrease in CO emission may be due to better vaporization biodiesel fuel and more oxygen present in the biodiesel, resulting in complete combustion.

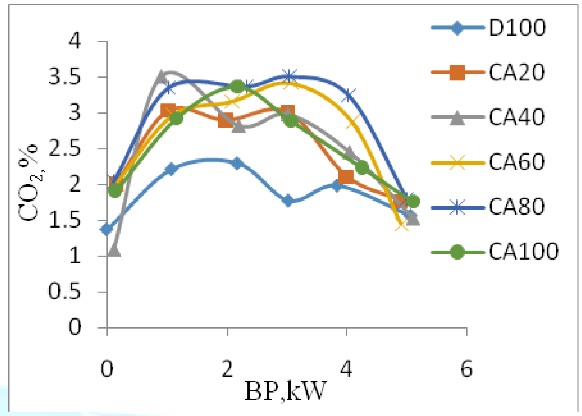

Fig 10. Variation of carbon dioxide with brake power

The variation of CO_2 produced at different engine brake power is shown in figure (10). For different blends of custard apple increases initially and then it decreases .this may be due to complete combustion of the fuel.

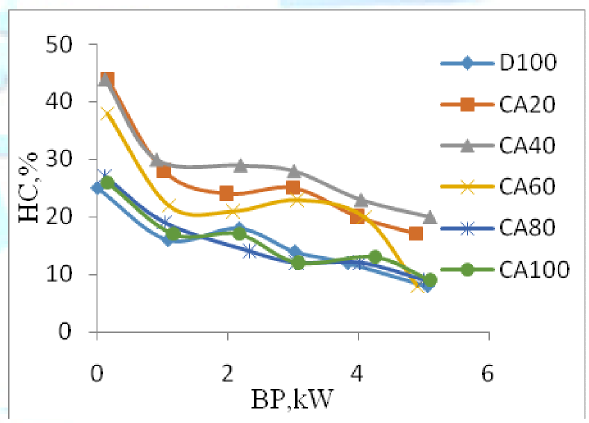

Fig 11. Variation of hydrocarbon with brake power

The variations of HC emission for diesel and biodiesel are shown in the figure (11) it has been observed that HC emissions are nominal for CA80, CA100, and more at CA20, CA40 and CA60. The reason for this may be incomplete combustion. The higher cetane number of biodiesel results decrease in HC emission due to shorter ignition delay. Lower HC emissions in the exhaust gas of the engine may be attributed to the efficient combustion of custard apple biodiesel and blends due to the presence of fuel bound oxygen and warmed-up conditions at higher loads. This is due to the reason that at lower loads the lower cylinder pressure and temperatures were experienced that was caused by lower rate of burning. This feature results in higher HC emissions.

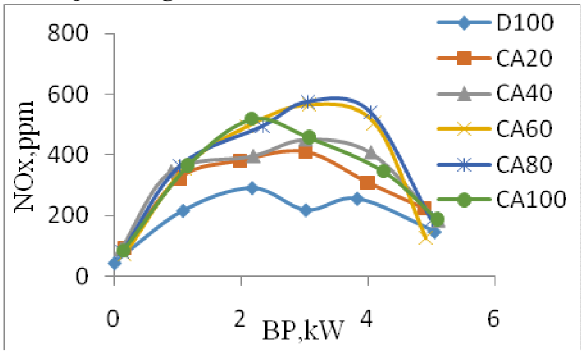

Fig 12. Variation of NOx with brake power

The variation of NOx with brake power is shown in figure (12). The NOx values as parts per million for different blends of diesel and biodiesel in exhaust emission are plotted as function of BP. At low and full load emissions are nearer to diesel. In other loads increase NOx emission compared with that of diesel. These could be attributed to increase exhaust gas temperature due to lower heat transfer and the fact that biodiesel has some oxygen content in it which facilitates NOx formation.

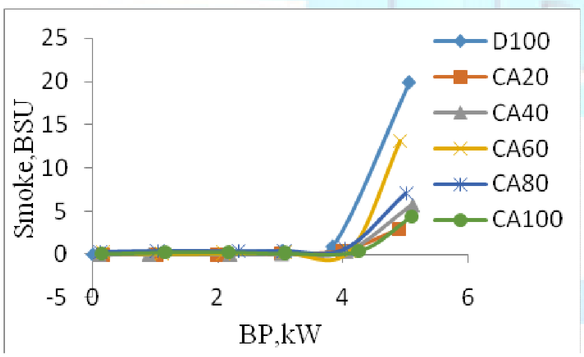

Fig 13 Variation of smoke with brake power

The variation of smoke with brake power is shown in figure (13). It is observed from graph that the smoke increases slowly and at the full load increases exponentially. At all loads, smoke emissions for the blend decreased significantly than those of standard diesel may be due to presence of oxygenated fuel leads o an improvement in diffusive combustion. Smoke levels low for some blends because more complete combustion due to air fuel mixing and presence of oxygen.

5. CONCLUSION

Following are the conclusions based on the experimental results obtained while operating single cylinder diesel engine fuelled with biodiesel from custard apple oils and their diesel blends.

- Custard apple oil satisfies the important properties as per ASTM standards.
- Custard apple (biodiesel) can be directly used in diesel engines without any engine modifications.
- Engine works smoothly on custard apple oil with Performance comparable to diesel operation.
- Brake thermal efficiency of CA80 blend is equal to diesel compared to other blends
- The exhaust gas temperature is decreased with the custard apple oil.
- Specific fuel consumption is decreased at lower loads and equal in full load.
- Combustion characteristics are all blends of custard apple oil is almost same as that of diesel.
- The emission characteristics like CO_2, HC and NOx are increases and CO and smoke levels are decreases.
- By observing all results of biodiesel from custard apple seed oil can be used as a biodiesel feedstock.

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