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Performance and Emission Analysis of Diesel Engine using Biodiesel and Preheated Jatropha Oil

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KEYWORDS

Jatropha oil and preheating

A B S T R A C T

Today in this fast developing World the need of various transportation system is increasing day by day, in the result of this Number of vehicles and engine are increasing, but the conventional fuel used in the vehicles (like diesel and petrol) are limited and decreasing gradually with time. So there is a requirement of various means to drive these vehicles without a heavy modification in the engine of these vehicles. This situation leads to requirement of alternative fuels for engines. Bio-diesel is the best substitute of the Diesel in the Diesel Engine(1). Vegetables oil is the best alternative fuel. The main advantage of vegetable oil over the conventional fuel(as diesel in the diesel engine) is of reducing the cost and able to reduce net CO2 and CO emissions to atmosphere due to their agricultural origin(2). In this paper we investigate the prospective of Jatropha oil to use as a Bio-fuel in the conventional diesel engine. Jatropha oil is derived from Jatropha curcas plant which has been considered as a sustainable alternate fuel for diesel engine and also Jatropha curcas plant is renewable and non edible(3). However several durable and operational problems of using straight vegetable oils in the diesel engine are reported in literature, due to their higher viscosity and low volatility as compare to mineral diesel fuel(4). Hence vegetable oil does not give the better performance without proper modification. In this experimental work, performance of diesel engine operating on preheated Jatropha oil was evaluated and compared with diesel operation. The performance parameter considered for comparing is brake specific fuel consumption, thermal efficiency. This study target on investigating the effect of engine operating parameter viz. Fuel injection pressure and injection timing on performance of diesel engine with preheated jatropha oil and diesel.

Introduction

With the Modernization and industrial growth in the world, the consumption of the petroleum resources is increasing day by day but these resources are limited, it is widely acceptable that these natural petroleum resources are likely to be depleted in 100 years from now (5). Thus in the favour of this experimental data there is a requirement of alternative sources to replace these petroleum resources without a wider change in the conventional engines and which are renewable and easily achievable in the nature and Also should be available at low cost.

Biodiesel will be the best alternative over the diesel because it is renewable, environment friendly and easily produced in rural area (6). It can produce same power as the conventional diesel fuel in the conventional diesel engine. It is non toxic and produced less CO2 and CO on the combustion. Biodiesel is derived from the vegetables like Sunflower, Neem, Jatropha curcas, corn and canola etc. In recent years many efforts have been taken by the several researchers in making the Biodiesel suitable to use in the conventional diesel engine (7). There is Number of Countries which are working on different aspect of producing Biodiesel, for example in Philippines research on coconut oil, USA research on the soyabean oil, Thailand research on the palm oil. Europeans country research on sunflower oil etc. Some of the non-edible oils such as Mahua, Castor, Jatropha curcas, Neem, Linseed, Karanja (Pongamiapinnata), Rice bran can be used in diesel engines after some chemical treatment.

In the all non-edible Tree Bearing Oil (TBO) seeds, jatropha is considered as most favourable plant for the production of biodiesel, because it can be harvest in the non agricultural land and also in the area of low rain fall (~27 cm) as well as heavy rain fall. It can be used directly after the extraction (without refining) in the conventional diesel engine. Jatropha curcas can grow in the variety of agro-climatic conditions (8). Thus it ensures the reasonable production at the low input. Jatropha Biodiesel can be used or mixed in any ratio with the diesel. But preferred ratio is between 5 to 20%. But in the straightway directly use of jatropha oil in the diesel engine encountered a problem due to its high viscosity in comparison of diesel fuel, this problem can be sort out by pereheating Jatropha oil before using in the engine for the purpose of decreasing its viscosity.

Experimental Setup

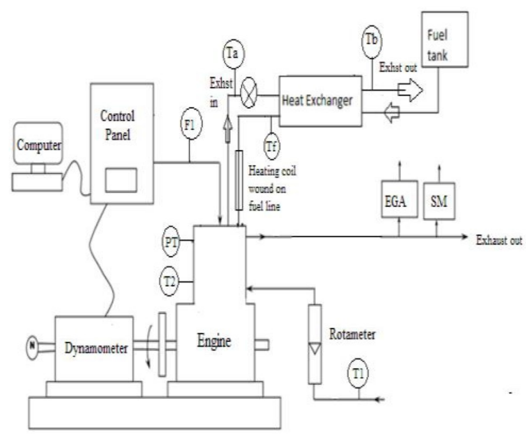


Fig.1 Schematic diagram of experimental test rig

N- RPM Decoder
T1- Inlet engine water temperature
PT - Pressure transducer
T2 - Outlet engine jacket water temperature
Ta, Tb - In and out temperature of Exhaust gas in H.E
Tf - Fuel temperature at outlet of H.E
EGA - Exhaust Gas Analyzer
F1- Fuel Flow (Differential Pressure unit)
SM – Smoke Meter

There are some main components of the experimental setup which are as follows- two fuel tanks (Diesel and Jatropha oil), fuel conditioning system, heat exchanger, exhaust gas line, by-pass line, and performance and emissions measurement equipment. To ensure the continues supply of the jatropha fuel, Two fuel filters are provided next to the Jatropha oil tank so that when one filter gets clogged, supply of fuel can be switched over to another filter while the clogged filter can be clean/replace without stopping the engine operation.

Specifications of VCR Engine

Product VCR	Engine test setup 1 cylinder, 4 stroke, Diesel (Computerized)
Engine Make	Kirloskar
Type	1 cylinder, 4 strokes Diesel, water cooled,
Power	3.5 kW at 1500 rpm,
Stroke	110 mm,
Bore	87.5 mm. 661 cc,
CR	17.5, Modified to VCR engine CR range 12 to 18
Dynamometer Type	Eddy current, water cooled, with loading unit
Propeller shaft	With universal joints
Air box	M S fabricated with orifice meter and manometer
Fuel tank	Capacity 15 lit with glass fuel metering column
Calorimeter Type	Pipe in pipe
Piezo sensor	Range 5000 PSI, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition device	NI USB6210, 16 -bit, 250kS/s
Digital mili voltmeter Range	0-200mV, panel mounted
Temperature sensor Type	RTD, PT100 and Thermocouple, Type K Temp transmitter

Initially the engine is started with diesel and once the engine warms up, it is switched over to Jatropha oil. After concluding the tests with Jatropha oil, the engine is again switched back to diesel before stopping the engine until the Jatropha oil is purged from the fuel line, injection pump and injector in order to prevent deposits and cold starting problems. This purging typically takes about 15 min at idling. A shell and tube type heat exchanger is designed to preheat the vegetable oil using waste heat of the exhaust gases. A thermocouple was provided in the exhaust line to measure the temperature of the exhaust gases. Voltmeter and ammeter were used to measure the voltage and current consumed by the load in the load bank. Exhaust gas opacity was measured using smoke opacitymeter. The exhaust gas composition was measured using exhaust gas analyzer. It measures CO2, O, HC, and O2 concentrations in the exhaust gas. The basic principle for measurement of CO2, CO, and HC emissions is non-diffractive infrared radiation (NDIR) and electrochemical method for oxygen measurement.

Result Analysis

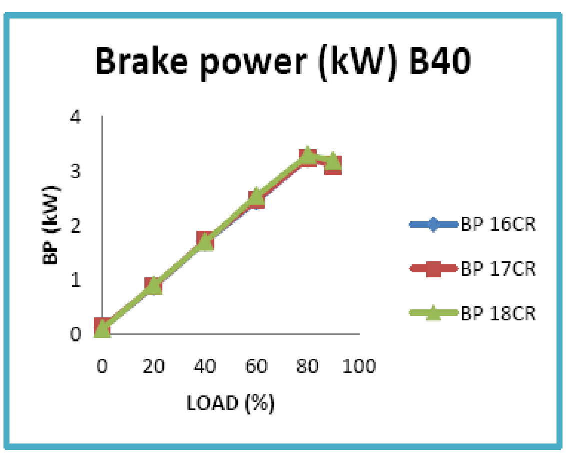
Performance Analysis

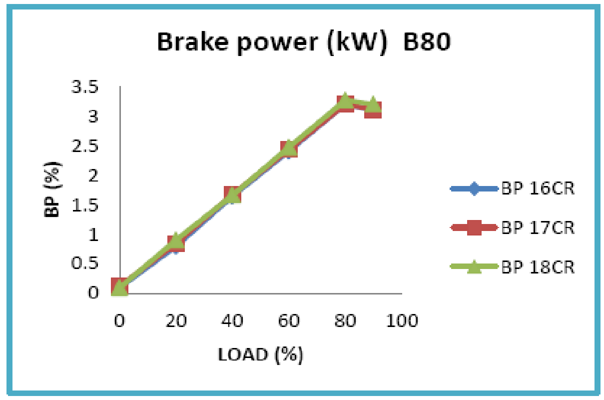
Engine tests are conducted for performance and emissions using unheated Jatropha oil and preheated Jatropha oil. The baseline data were generated using mineral diesel. In this paper we considered the comparison between the B40 and B80 biodiesel and preheated biodiesel on the base line of mineral diesel.

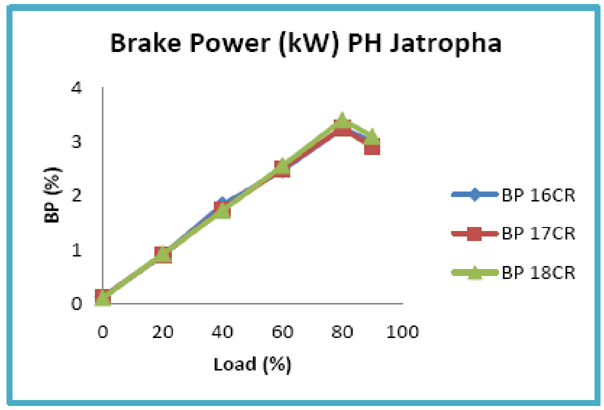
Comparison on the basis of Brake Power

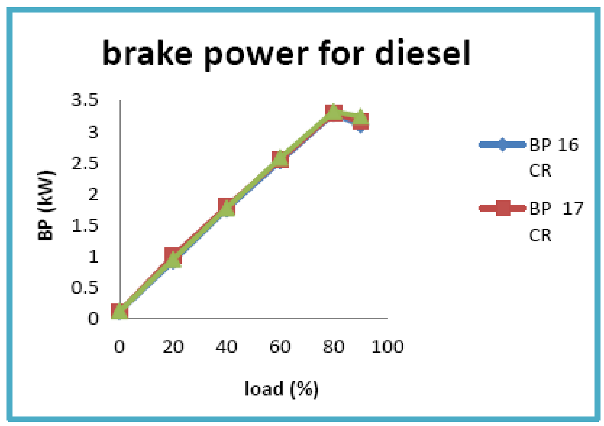
Brake power for diesel and all biodiesel blends are calculated and compared with diesel. For all fuel tested, the power increased with increased in the load. As we shown in the graphs that Brake power for the diesel is highest in the comparison of the Jatropha Biodiesel, this is due to that Calorific value of the Diesel is higher than Jatropha biodiesel. The engine power decreased with the utilisation of biodiesel. But it is also reported some power recovery and it is attributed to the higher density, higher bulk modulus and higher viscosity of biodiesel. High density results in injection of increased mass of fuel, while high viscosity reduces the leakage. However, the higher mass fuel flow for the methyl ester is not sufficient to compensate for the approximately 12.8% lower heating value in comparison of diesel. It was also reported that there was no significant difference in engine power between biodiesel and diesel.

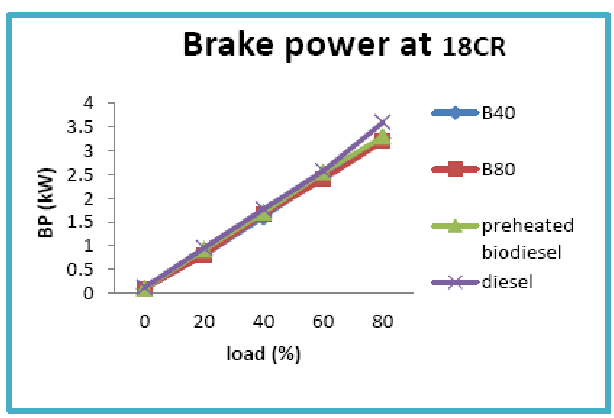
The explanation is that engine delivers fuel on volumetric basis and biodiesel density is higher than that of diesel, which supplies more biodiesel to compensate the lower heating value. Higher viscosity of biodiesel leads to larger spray droplet which enhances fuel spray penetration due to higher momentum, thus improving air–fuel mixing. In addition, in-built oxygen of biodiesel also benefits the combustion process. Therefore, the higher BSFC of biodiesel and improved combustion are the reasons for increase in the engine power. As shown in the graph that maximum power at the 80% load and 18CR thus we will compare all biodiesel blends with the D Diesel at the 80% load and the 18CR.











Comparison on the Basis of BSFC

The variation of brake specific fuel consumption with load for different biodiesel blends, preheated biodiesel and diesel is presented in the graphs as shown in below. It is observed that for all tested fuels, with the increasing load from 0 to 80%, BSFC decrease with the load. Different trend of Jatropha biodiesel is maintained at the similar trend to that of diesel. The reason behind that friction power remains constant while indicated power increases.

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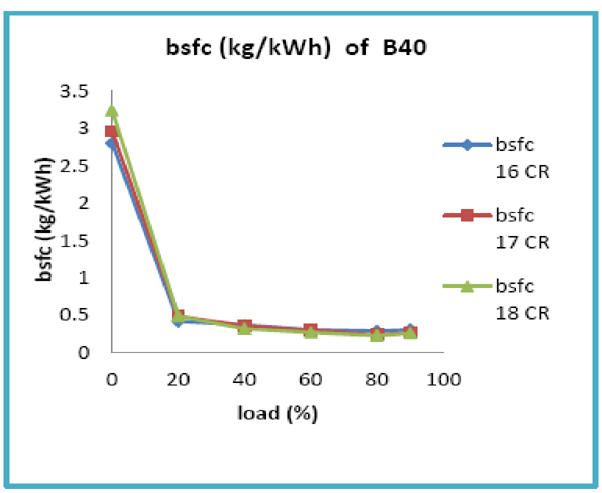
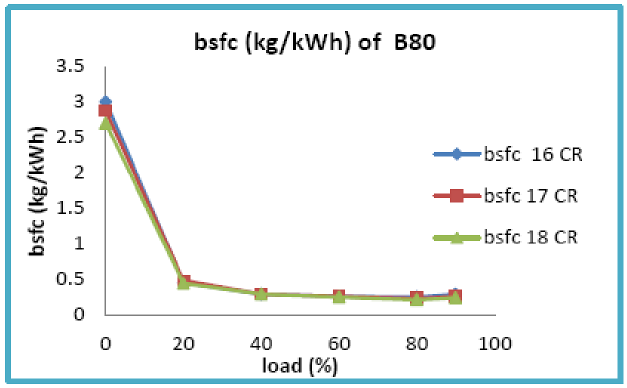
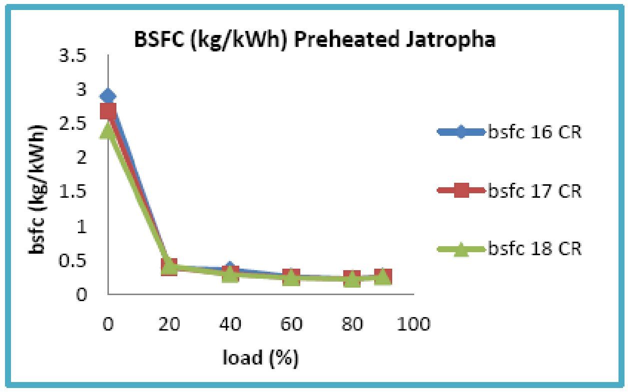
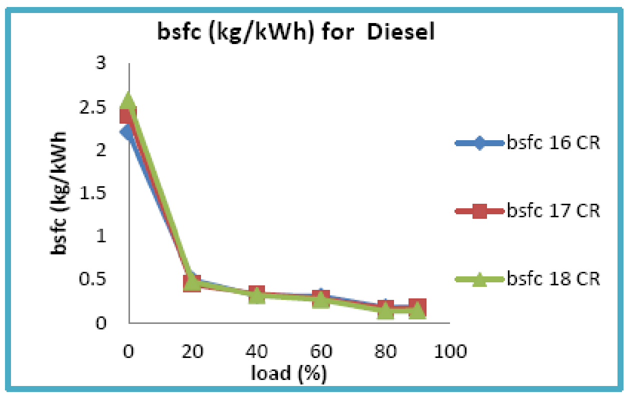
The brake power increase gradually thus brake specific fuel consumption decrease rapidly. It is clear from the from the graphs that BSFC for blends of the biodiesel is something higher than that of Diesel the reason behind this is that engine delivers fuel on volumetric basis and biodiesel density is higher than that of diesel, which supplies more biodiesel to compensate the lower heating value.

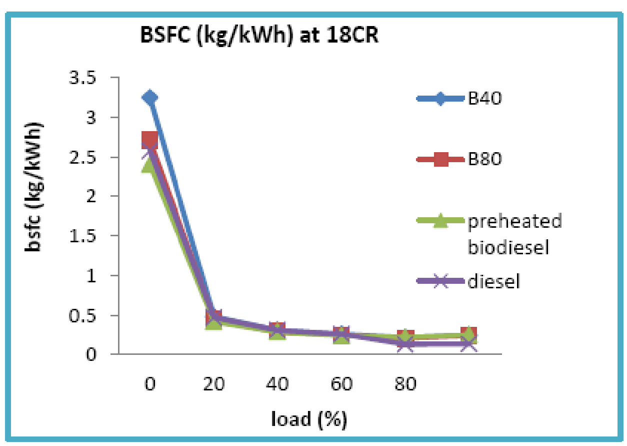
Thus the loss of heating value of the biodiesel is can be compensated with higher fuel consumption. This explains the phenomenon of increasing the BSFC with increasing concentration of the Blends of biodiesel.











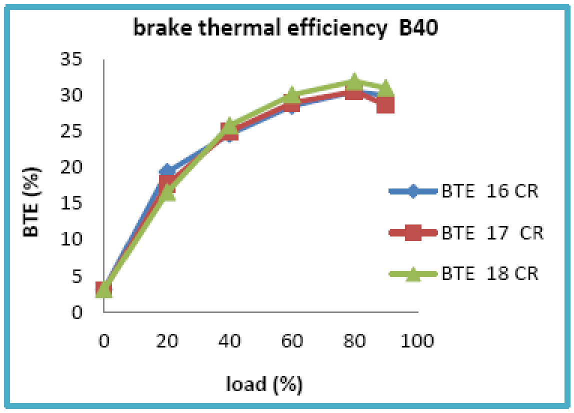
Comparison on the basis of Brake thermal efficiency

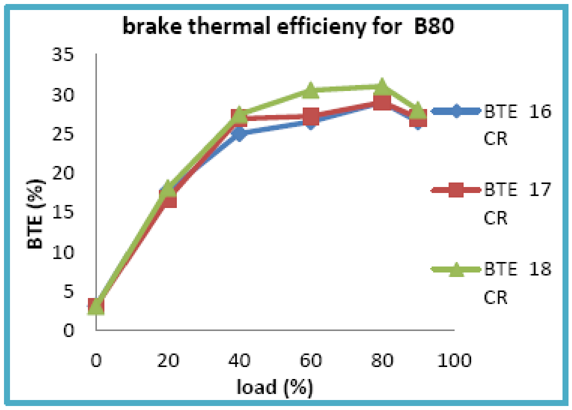
The brake thermal efficiency of the different blends of Jatropha biodiesel and diesel are calculated. The variation of brake thermal efficiency with respect to load for different fuels at CR 16, CR17 CR18 is considered in the present analysis is presented in graphs.

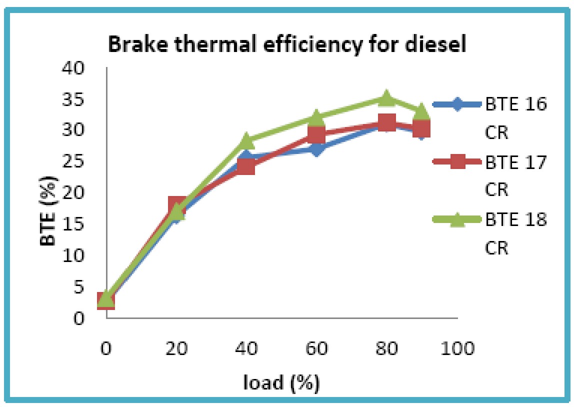
It is found that in all the cases, brake thermal efficiency increase with increase in the load. This increment is due to reduction in the heat loss and increases in the power develop with increase in the load. For the lower concentration of the biodiesel in the blend, thermal efficiency of the engine of the engine improved compared to the condition when engine runs on the biodiesel.

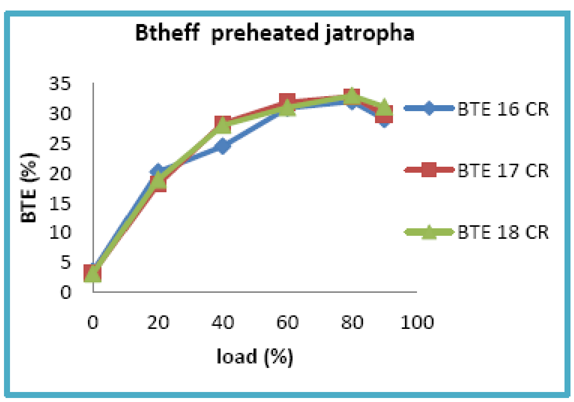
Additional lubricity provide by the biodiesel may be the possible reason behind this also additional inbuilt oxygen in to the biodiesel improve BTE by providing the extra oxygen for the complete combustion of the fuel. If the concentration of the biodiesel increase BTE opposite the initial condition, starting decreasing. This is due to higher viscosity and poor volatility of vegetable oils lead to their poor atomization and combustion characteristics.

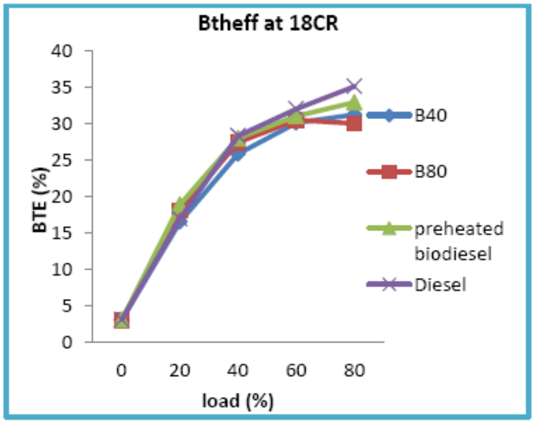
Therefore, thermal efficiency is found to be lower for higher blends concentrations compared to that of mineral diesel. But for the preheated Jatropha biodiesel it thermal efficiency is higher than the blends of biodiesel due to the it low viscosity but lower than the diesel due to it lower calorific value.











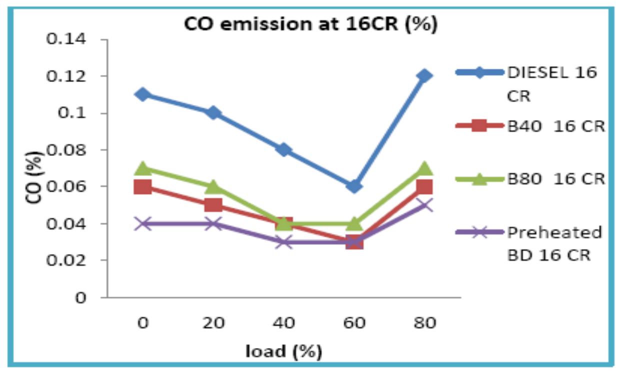
Emission Analysis

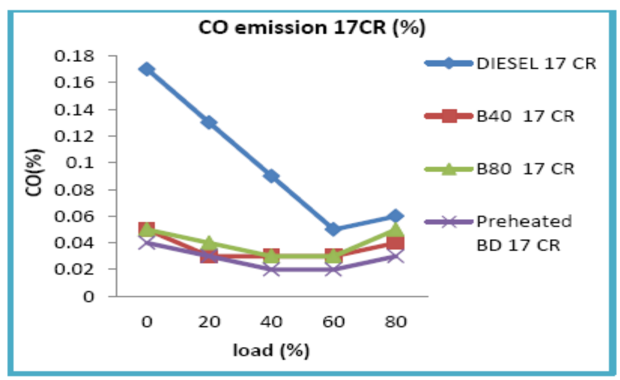
Engine emission was measured with AVL gas analyzer (for CO, CO2, HC, and O2) and smoke meter. The measured emission has been shown graphically.

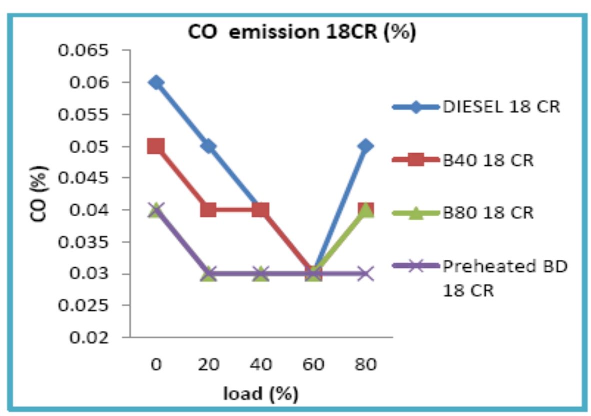
Co Emission

As shown in graphs that CO emissions for the Diesel is higher than that of the blends of Jatropha biodiesel. The increase of CO emission as load decrease was an indication of improve combustion efficiency was in correlation to the change in brake thermal efficiency BTE under change in load. But at the 80% load CO emission rapidly increase it is due to that at higher load fuel consumption is high and combustion process also high this increase incomplete combustion, resulting in rapid increase in the CO emission. The emissions of CO increase with increasing load (Fig. 7). Higher the load, richer fuel–air mixture is burned, and thus more CO is produced due to lack of oxygen.

As we discussed above that co emission in the blends of the biodiesel is lower than that of the diesel due to the less carbon content in to the biodiesel blends, but as in graph that CO emission for the B80 is slightly higher than that of the B40. Its reason may be the improper atomization and high viscosity of the Biodiesel blend, which leads to the improper combustion and lead to increase emission of CO. In the this is case of preheated jatropha oil the CO emission is less in comparison to all blends this is due to the pure biodiesel which have less carbon content and also due to preheating of the biodiesel, leads to decrease it viscosity and improve atomization and proper combustion and resulting in the less CO emission.





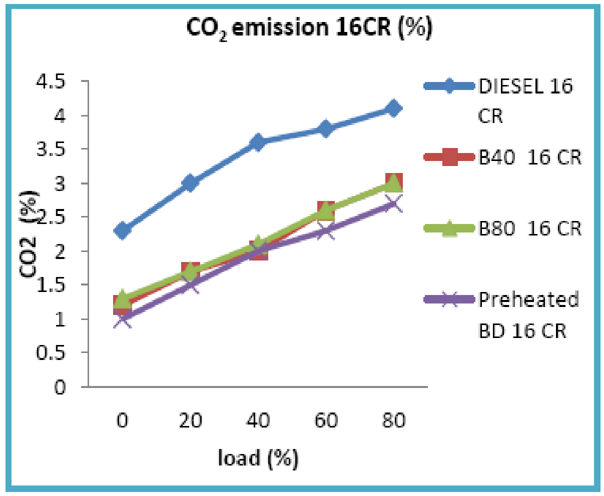


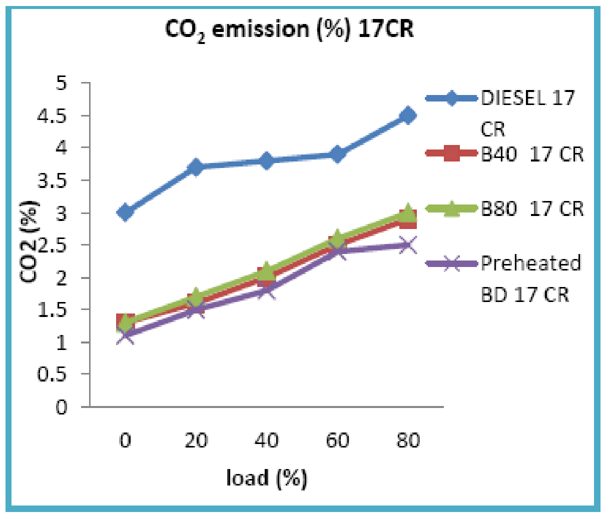
CO_2 EMISSION

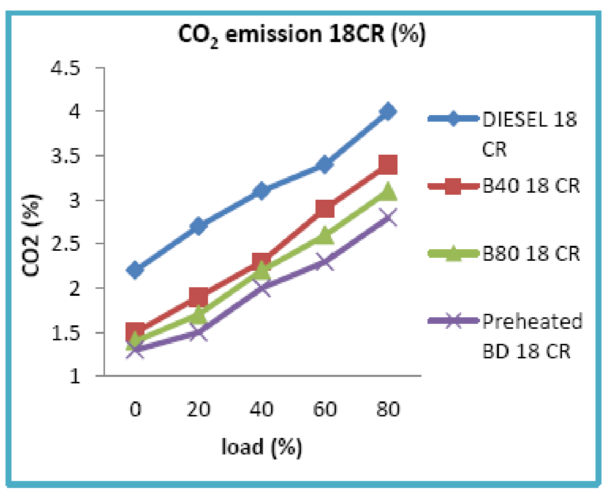
The carbon dioxide emission from the diesel engine with different blends is shown in graphs. The CO2 increased with increase in load conditions for diesel and for biodiesel blended fuels. The carbon dioxide emission from the diesel engine with different blends is shown in graph. The CO2 increased with increase in load conditions for diesel and for biodiesel blended fuels. The Jatropha biodiesel followed the same trend of CO2 emission, which was higher than in case of diesel.

Since biodiesel is produced from plant oils or animal fats, it has been promoted as means for reducing emissions of carbon dioxide that would otherwise be produced from the combustion of petroleum-based fuels. Carbon dioxide is considered by many to be an important component in global warming, though other pollutants can also play a role. The total impact that biodiesel could have on global warming would be a function not just of its combustion products, but also of the emissions associated with the full biodiesel production and consumption lifecycle.

We perform the experiment for the B40 and B80 blends of the biodiesel and compare it with Diesel in the diesel engine. Thus we can see in the graphs that CO2 emission for the diesel is higher than that of the any blends of the biodiesel this is due to that diesel contain carbon content in high quantity in comparison of biodiesel. And also emission of CO2 for the blends is nearly same, but that for preheated biodiesel is lower than the blends, this may be because pure biodiesel with any mixing of the Diesel very low carbon content.





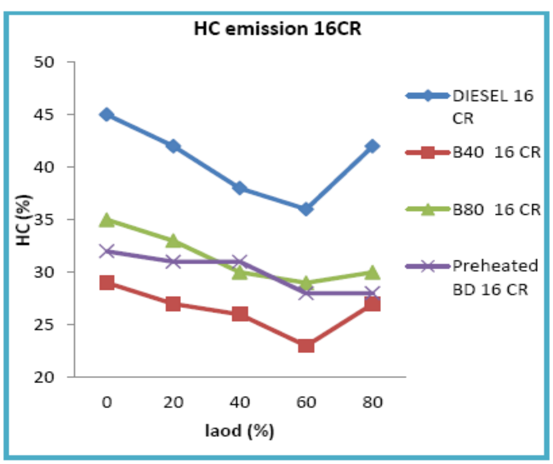


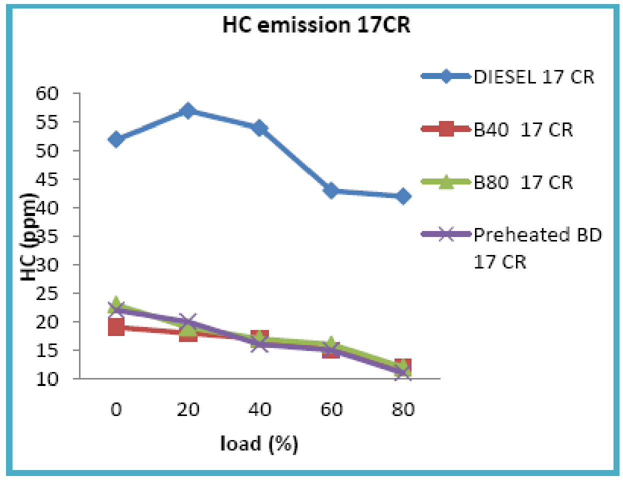
HC EMISSION

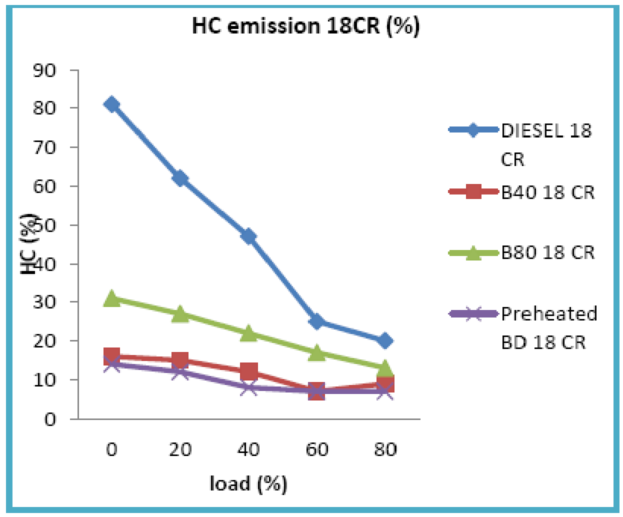
HC exhaust emissions are shown in the graphs. For all of blends, the HC emissions were less than that of the diesel fuel. Biodiesel contains oxygen in its structure. When biodiesel is added to diesel fuel, the oxygen content of fuel blend is increased and thus less oxygen is needed for combustion. However oxygen content of fuel is main reason for better combustion and reduction in to the HC emission.

On the other hand, the reduction of HC is due to the oxygenated fuel of biodiesel, it leads to a more complete combustion. The higher cetane number of biodiesel fuel reduces delay period leading to lower HC emissions. Thus, the higher oxygen content and cetane number of biodiesel-diesel fuel blends tend to reduce HC emissions when compared to conventional diesel.

Diesel engine performance showed that the biodiesel blend offered lower engine power output, higher specific fuel consumption, and lower mechanical efficiency. Consequently, the biodiesel producing cleaner emission with the significant drop in CO, and HC emissions compares to the conventional diesel.

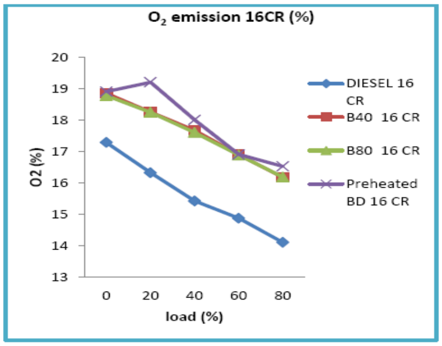


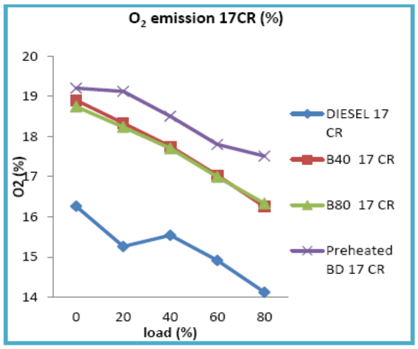


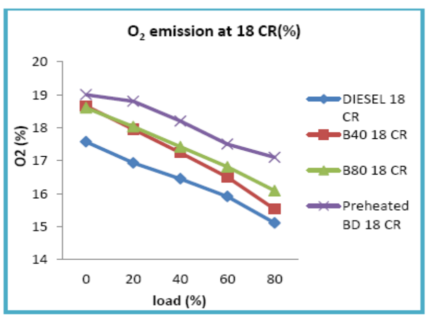


O2 EMISSION

As we seen in the graphs that O2 emission for the blends of biodiesel is higher than that of the Diesel. This is due to because Biodiesel is an oxygenated fuel and it contains oxygen of about 11% by weight. High oxygen content leading to complete combustion. The presence of oxygen in biodiesel fuel results in higher heat release during the premixed phase combustion. As we seen in the graphs that O2 emission is maximum for the preheated biodiesel is maximum and then for the biodiesel's blends and lowest for the mixture the emission of the O2 will be increase.



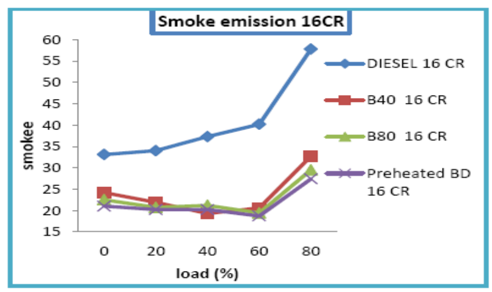


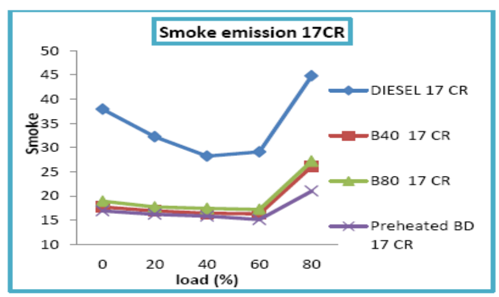


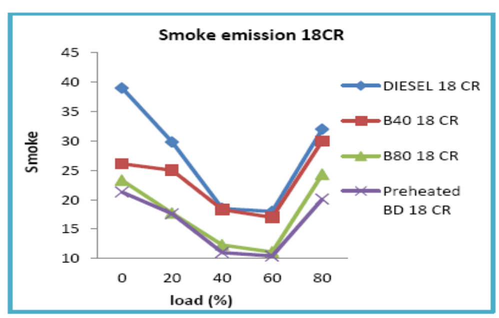
Emission of the O2 decrease with the increase in the load. And it is minimum at 80% load, because at this load the brake power is maximum thus mean increase in the combustion rate and consumption of the oxygen of the fuel for the combustion process.

Smoke Emission

The graph was plotted between smoke emission and varying load (%). The smoke emission found to increase continuously with the increase in load. It is clear from the graph that smoke emission for the diesel is maximum and minimum for the preheated Jatropha oil, Blends of Jatropha biodiesel shows intermediate performance for the smoke emission, the lies between the Diesel and Preheated Jatropha oil in the smoke emission characteristics. At the zero load smoke emission is high but as the load increase it value decrease till 60% load, but at 80% load it value suddenly increase. Smoke emission for the diesel is minimum at the 60% load approximate 20 % 18CR, and for the B40 and B80 blends also minimum at 60% load, this also continue in the case of preheated biodiesel. Thus from the this experimental data it is clear that Diesel, all blends of Jatropha Biodiesel and preheated Jatropha oil shows good smoke emission characteristics for the 60% load and 18 compression ratio.







Conclusion

The Experimental work carried out in this study was analyzed and the results were discussed as above and the major findings are listed in this.' The main objective of the experiment is to analyse the performance and emissions characteristics of Jatropha oil in the variable compression ratio engine. The Jatropha oil has viscosity higher than that of the diesel so viscosity is reduced by blending the Jatropha biodiesel with the diesel or preheating the Jatropha oil, Viscosity of the Jatropha blends up to the B40 is found close to that of thediesel. The results shows that engine performance when fuelled with the biodiesel are comparable to that when fuelled with petroleum diesel.

- The fuel consumption when fuelled with the biodiesel are higher than when that when fuelled with petroleum diesel, since a little more biodiesel must be supplied to the engine to produce an equivalent amount of work, as evidence by the lower calorific value stated earlier. All blends having Jatropha biodiesel shows brake specific fuel consumption close to diesel.
- The lower concentration of the blends found to improve thermal efficiency. Jatropha biodiesel blends gives a good improvement in thermal efficiency due to the additional lubricity and oxygen content is the possible reason for it.
- Brake power is comparable for the all the fuel tested. The variation in the power is very less for all the tested fuels. However, at lower percentage of biodiesel in the blend small increase in brake power is observed.
- For various blends and preheated biodiesel BSFC and exhaust gas temperature are found higher compared to Diesel at lower compression ratio.
- It is found that the performance of the diesel engine at the 80% load is efficient.
- CO, CO2 and HC emission for the biodiesel blends and preheated biodiesel is lower than that of the diesel fuel, this is due to that biodiesel is a green fuel and contain less carbon molecules.
- O2 emission for the blends of the biodiesel is higher than that of diesel, this shows that Biodiesel is an oxygenated fuel and it contains oxygen of about 11% by weight.

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