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Investigation of Variable Compression Ratio Engine fueled with Jatropha oil

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Abstract: The increasing amount of Green-House Gases (GHG) causing global warming and climate change, as well as the declining reserve of fossil fuels, and more importantly, the high fuel prices have strongly increased the interest in the use of bio-oils and biodiesel for land, transport and power generation. Bio-fuel should be economically attractive and performance competent in order to replace the fossil fuel. The conventional petroleum fuels for internal combustion engines will be available for few years only, due to tremendous increase in the vehicular population. Moreover, these fuels cause serious environmental problems by emitting harmful gases into the atmosphere at higher rates. Generally, pollutants released by engines are CO, unburned hydrocarbons (UBHC), nitrogen oxides (NOx), smoke and limited amount of particulate matter. Biodiesel has emerged as a clean fuel and offers a very promising alternative to diesel fuel since they are renewable and have similar properties. The objective of this research work is to investigate the performance characteristics (brake thermal efficiency) and emission (UBHC and NOx) of a variable compression ratio engine using jatrobha oil as an alternate fuel at different loads with different blends and variable compression ratios.
Key words: internal combustion engines, compression ratio, emission, Jatropha, efficiency.

Introduction

The increase in the emission of pollutants into the environment coming from road transport, depletion of natural resources, and economic considerations are the main reasons for the development of alternative fuels to power internal combustion engines [1]. The present energy scenario now is heavily biased towards the conventional energy sources such as petroleum products, coal, atomic energy etc, which are finite in nature besides causing environmental pollution. Of the available energy, the present energy utilization pattern is heavily biased for meeting the high energy requirement in urban and metropolitan cities [2].

Depletion of fossil fuel resources and increased environmental awareness are driving the researchers and the fuel industry to develop alternative fuels that are environmentally more acceptable and renewable in nature [3].Transesterified vegetable oil derivatives called 'biodiesel' appear to be the most convenient way of utilizing bio-origin vegetable oils as substitute fuels in diesel engines. The idea of using vegetable oils as fuel for diesel engine is not new. When Rudolf Diesel first invented the diesel engine, he demonstrated it with peanut oil as fuel. Vegetable oils can be used in diesel engines either in raw form, or can be converted into biodiesel. The raw vegetable oils require engine modifications, whereas the biodiesel (methyl esters of vegeta-ble oils) do not require significant modification of existing engine hardware.

There are different types of bio-diesels are available such as sunflower, soya bean, cottonseed, linseed, Mahua, jatropha, pongamia, etc. The vegetable oils can be used in diesel engines by various techniques such as fuel modifications by transesterification and diesel vegetable oil blends. Biodiesel is an alternative fuel for diesel engine. The esters of vegetable oils and animal fats are known collectively as biodiesel. It is a domestic, renewable fuel for diesel engine derived from natural oil like jatropha oil. Biodiesel has an energy content of about 12% less than petroleum-based diesel fuel on a mass basis. It has a higher molecular weight, viscosity, density, and flash point than diesel fuel. The use of biodiesel is an effective way of substituting diesel fuel in the long run. One important conclusion that can be drawn from the work done earlier is that the vegetables oils can't be used directly in the diesel engine. Several problems crop up if unmodified fuel is used and viscosity is the major factor. It has been found that transesterification is the most effective way to reduce the viscosity of vegetable oils and to make them fit for their use in the present diesel engines without any modification [4].

Jatropha curcas is unusual among tree crops which is a renewable non-edible plant. From jatropha seeds jatropha oil can be extracted which have similar properties as diesel but some properties such as kinematic viscosity, solidifying point, flash point and ignition point is very high in jatropha oil. By some chemical reactions, jatropha oil can be converted into biodiesel. Jatropha oil can also be used directly by blending with diesel. Some benefits of jatropha oil are high saponification value, burns without emitting smoke, being an alternative fuel and renewable and produces decreased amount of carbon dioxide (CO_2), oxides of nitrogen (NOx) and particulate matter [4].

The objective of this research work is to investigate the performance and emission characteristics of a variable compression ratio engine using jatrobha oil as an alternate fuel. The experiments were conducted at constant speed and different load condition. The blends of 80% Diesel, 20% Biodiesel and 85% Diesel15% Biodiesel at three different compression ratios of 19:1, 20:1 and 21:1 were conducted.

Experimental Set up

The layout of experimental setup and photograph of laboratory test conditions are shown in Figure 1 and Figure 2. It consists of a twin cylinder variable compression ratio engine with dynamometer. AVL Gas analyser was used to measure the emission at the exhaust. The specifications of the tested engine, dynamometer and gas analyser are given in Table 1, Table 2 and Table 3 respectively. The engine was initially tested using diesel and the two blends of 80% diesel and 20 bio-diesels and 85% diesel and 15% bio-diesel. The entire test was conducted at the constant speed of 1500 rpm and variable load conditions at three different compression ratios of 19:1, 20:1 and 21:1.The emission characteristics are studied using AVL five gas analyzer in all tested conditions.

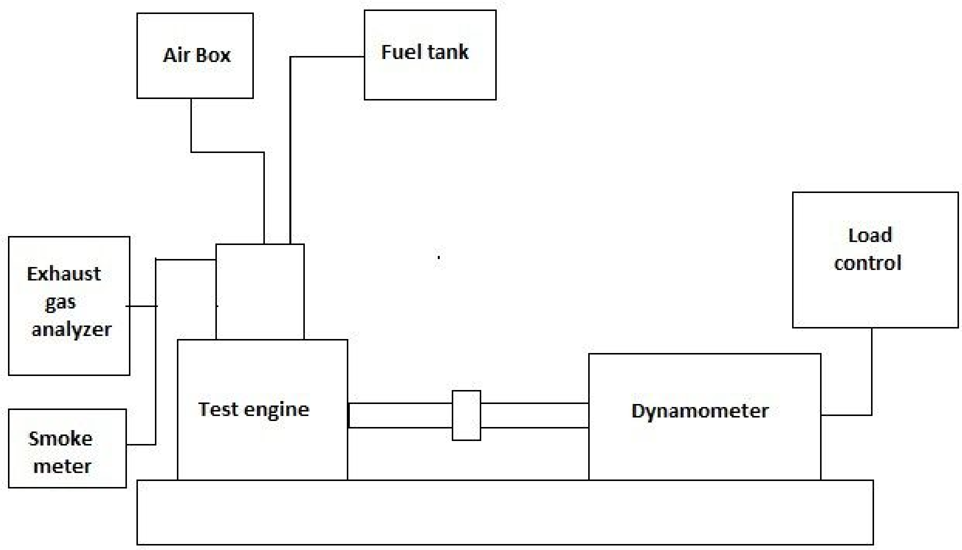

Figure 1 Layout of experimental setup

Figure 2 Photograph of experimental set up

Table 1 Specification of engine

Sl.No.	Description	Specifications
1	Make	KIRLOSKAR
2	Single cylinder variable compression ratio engine	5 – 11 for SI mode 12 – 20 for CI mode 12 – 22 for alternate fuel mode
3	Max. Power	5 HP @ 1,800 rpm

Table 2 Specification of dynamometer

Sl.No.	Description	Specifications
1	Make	ATEE
2	Model	E-SSPL
3	Control	L1 ,TC Series
4	Torque	Load Cell (range 0- 160 Nm)
5	Max. Power	25 HP @ 4200/10,000 rpm
6	Dynamometer water	1 bar pressure,54lpm

Table 3 Specification of AVL Five Gas Analyzer

Sl.No.	Description	Specifications
1	Type	Digas 444
2	Power supply	11 to 22 V DC /100 - 300 V AC
3	Power max	25 W max
4	Operating temperature	5 – 45°C
5	Storage Temperature	0 - 50°C
6	Inclination	0 - 90°
7	Normal Gas Flow	1801/h
8	Max. Over pressure	450hpa
9	Oxygen sensor type	Electro chemical ,O_2SENS 1
10	Carbon monoxide	10% vol
11	Hydrocarbon	20,000ppm vol
12	Carbon dioxide	20% vol

Results and Discussions

Biodiesel has similar combustion characteristics as diesel. Biodiesel engines offer acceptable engine performance compared to conventional diesel fueled engines. The main advantage in biodiesel usage is attributed to lesser exhaust emissions in terms of carbon monoxide, hydrocarbons and particulate matter. Biodiesel is said to be carbon neutral as more carbon dioxide is absorbed by the biodiesel yielding plants than what is added to the atmosphere when [burnt] used as fuel. Even though biodiesel engines emits more NOx, these emissions can be controlled by adopting certain strategies such as the addition of cetane improvers, retardation of injection timing, exhaust gas recirculation, etc. The objectives of acceptable thermal efficiency, fuel economy and reduced emissions using biodiesel in CI engines are attainable, but more investigations under proper operating constraints with improved engine design are required to explore the full potential of biodiesel engines [5].

The performance and emission characteristics of the engine with compression ratios of 19:1, 20:1 and 21:1 were tested using diesel and different biodiesel blends. The variation of brake thermal efficiency and hydrocarbon emissions at compression ratios of 19:1, 20:1 and 21.1 are shown in Figure 3, Figure 4 and Figure 5 respectively.

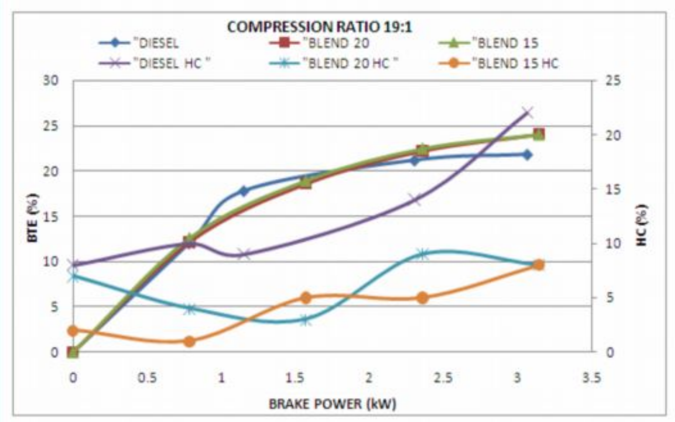

Figure 3 Variation of Brake thermal efficiency and HC emission at the compression ratio of 19:1

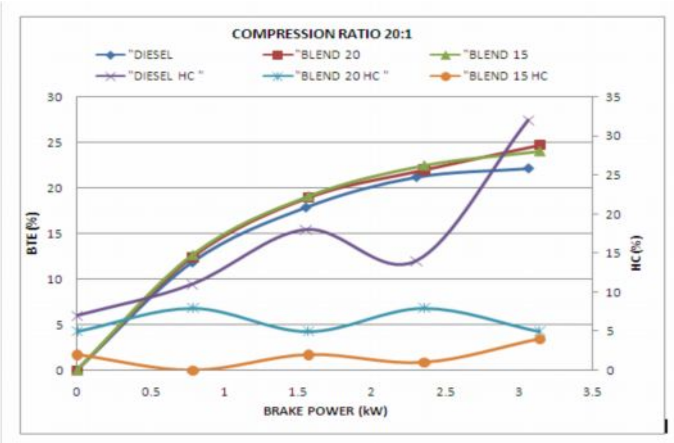

Figure 4 Variation of Brake thermal efficiency and HC emission at the compression ratio of 20:1

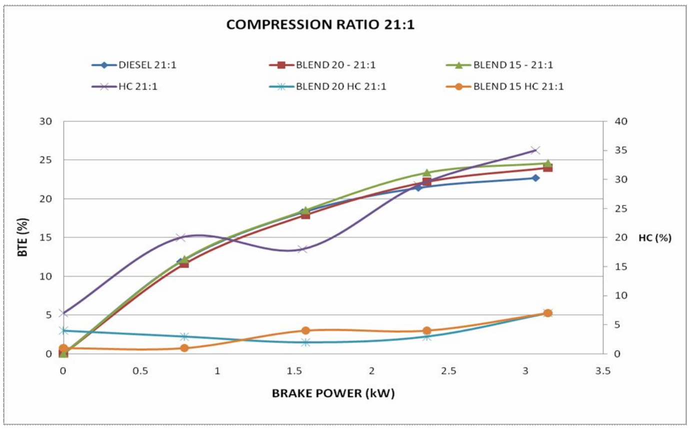

Figure 5 Variation of Brake thermal efficiency and HC emission at the compression ratio of 21:1

Effect of blending on brake thermal efficiency

The brake thermal efficiency of engine was low at part load as compared to the engine running at higher load. This is due to relatively less portion of the power being lost with increasing load. The variation in brake thermal efficiency between various blends of fuel at higher load was less than that at part load and is in accordance with the trend observed for brake specific fuel consumption. Because of increased temperature inside the cylinder due to more amount of fuel burning at higher load, resulting in proper atomization and ease of vaporization, which in turn forms a better oil-air mixture in the combustion chamber and yields better combustion. As the load on the engine increased, brake thermal efficiency increased due to the fact that brake thermal efficiency is the function of brake power. At part load conditions, the brake thermal efficiency was more than diesel because mass of diesel-biodiesel blend supplied was less than that of diesel and calorific value of diesel-biodiesel was also less than that of diesel. Brake thermal efficiency of diesel-biodiesel blends are almost same at part loads and were lesser than diesel. At full load conditions, brake thermal efficiency of diesel-biodiesel was almost same but was lesser than that of diesel [7].

The variation of Nitrogen oxides (NOx) emissions at compression ratios of 19:1, 20:1 and 21.1 are shown in Figure 6, Figure 7 and Figure 8 respectively.

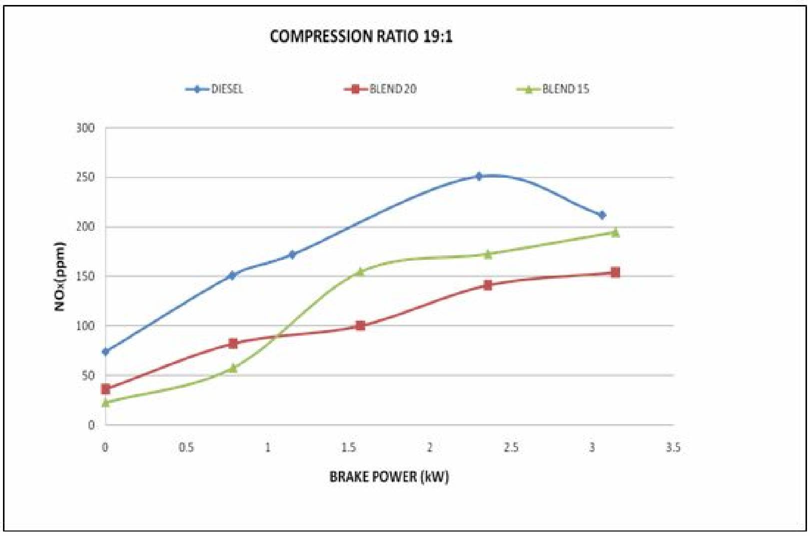

Figure 6 Variation of Nitrogen oxides (NOx) at the compression ratio of 19:1

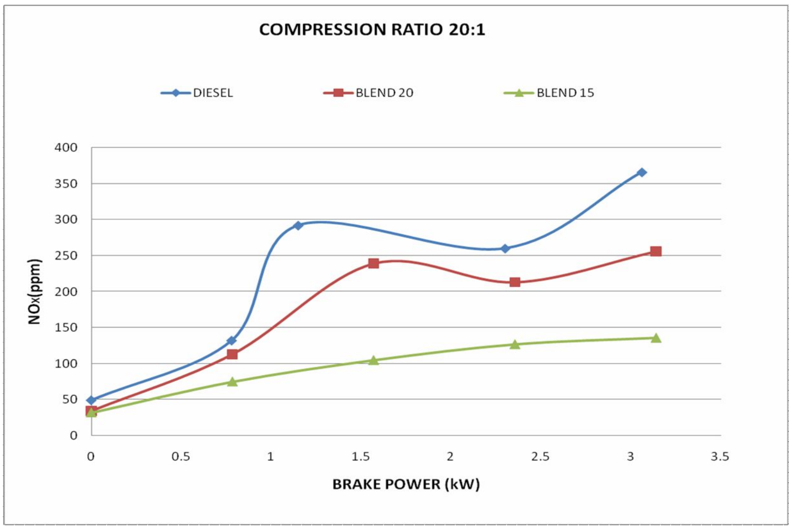

Figure 6 Variation of Nitrogen oxides (NOx) at the compression ratio of 20 :1

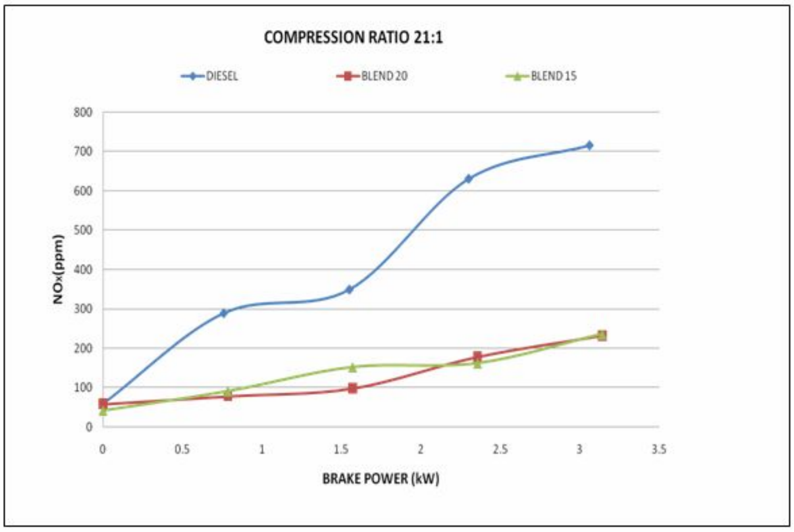

Figure 6 Variation of Nitrogen oxides (NOx) at the compression ratio of 21:1

Effect of biodiesel on emissions

Unburned hydro carbon (UBHC)

Biodiesel mainly emits unburned hydrocarbons, carbon monoxide, oxides of nitrogen, sulphur oxides and particulates. A brief review has made of these pollutants emitted from biodiesel-fuelled engines. Since biodiesel is an oxygenated fuel, it promotes combustion and results in the reduction of UBHC emissions [5].

At no load conditions, diesel and bio-diesel blends emitted same amount of unburned hydrocarbons. At part and full loads, bio-diesel blends resulted in maximum unburned hydrocarbons. Poor atomization and lower volatility of biodiesels compared to diesel oil is responsible for this trend. Since unburned hydrocarbons are the products of incomplete combustion, the lower cetane number of blend fuels results in lower tendency to form ignitable mixture, and thus, higher unburned hydrocarbons. Higher viscosity of the biodiesel also plays a key role in increasing the unburned hydrocarbons in the exhaust emissions. Due to the higher viscosity, atomization of the biodiesel does not take place properly i.e. all of the hydrocarbons present in the biodiesel do not get completely combusted, so come out in the engine exhaust in the form of carbon particles [7].

Nitrogen oxides (NOx)

NOx is formed by chain reactions involving Nitrogen and Oxygen in the air. These reactions are highly temperature dependent. Since diesel engines always operate with excess air, NOx emissions are mainly a function of gas temperature and residence time. Most of the earlier investigations show that NOx emissions from biodiesel engines are generally higher than that in conventional diesel fueled engines. Also earlier investigations revealed that NOx emissions increase with an increase in the biodiesel content of diesel[5]. The diffusion burning technique can be used as the controlling factor for the production of NOx. However, biodiesel's lower sulfur content allows the use of NOx control technologies that cannot be otherwise used with conventional diesel. Hence, biodiesel's fuel NOx emissions can be effectively managed and eliminated by engine optimization (adjustment of injection timing and introducing to exhaust gas recirculation) [8].

Conclusion

The use of diesel with Jatropha curcas methyl ester reduces the global warming potential and the nonrenewable energy demand as compared to fossil fuels.On the other hand,the environmental impacts on acidification, ecotoxicity, eutrophication and water depletion showed increases.Neverthless,the environmental impacts of the assessed jatropha curcas value chain show large variations, which are mainly caused by the difference in crop cultivation practices and are strongly dependent on the resource efficiency during crop cultivation [6].

When the engine was tested with diesel, the maximum brake thermal efficiency is attained at the compression ratio of 20:1 with lower emissions of both HC and NO_x. When the engine was tested with the blends of bio-diesel, the maximum brake thermal efficiency is attained at the compression ratio of 20:1 with the blend of 85% diesel and 15 % of biodiesel. The emission level of unburned hydro carbon and Nitrogen oxides (NOx) are lower than that of the other compression ratios. Therefore, bio-diesel can be used as an alternative fuel instead of fossil fuel in a variable compression ratio engine.

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