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Eucalyptus Biodiesel; an Environmental friendly fuel for Compression Ignition Engines

N. S Senthur[1], T. S Ravikumar[2], Cijil. B. John[3]
[1,2,3](Hindustan Institute of Technology & Science, Chennai, Tamil Nadu, India)

Abstract: - Fossil fuels have always been the most important source of energy for the world. But in view of the energy crisis faced by the world today due to fossil fuel depletion, it is time for us to shift our attention to other renewable sources which could be used as fuel alternatives. This paper examines the suitability of Eucalyptus oil as a source of biodiesel, for use in Compression Ignition Engines. Biodiesel was produced from pure Eucalyptus oil by the process of Transesterification and the fuel properties were studied. In the next phase, a single cylinder direct injection diesel engine was used to test the blends of eucalyptus biodiesel with neat diesel fuel in various ratios (10%, 20% and 30% by volume). The various performance and emission characteristics of the engine for each of the fuel blends were analyzed for all operating conditions of the engine. Results showed that the use of biodiesel blends resulted in a significant reduction in the HC and CO emissions with a performance almost equivalent to diesel fuel at almost all loads. However, an increase in the NOx emissions was noticed while raising the biodiesel content in the fuel blend, which could be reduced by suitable engine optimisation techniques.

Keywords: *- Alternate fuels - biodiesel –eucalyptus oil - performance and emission –transesterification.*

I. INTRODUCTION

Depletion of fossil fuels, environmental concerns caused by increased emissions and the steep hike in the price of petroleum products have become one of the most serious problems faced by the world today. Fossil fuels have always been the main source of energy for the power production and transportation sectors of the world. The fact that the fossil fuel reserves are getting depleted day by day is leaving the world at stake. It is time for us to pay serious attention to finding other renewable fuel sources which could be used as alternative fuels to the conventional fuels – petrol and diesel.

An alternative fuel to petrol or diesel must be technically feasible, economically competitive, environmental friendly and abundantly available [1]. There are many sources of alternative fuels like Ethanol, Natural Gas, Hydrogen, HHO etc., but the most suitable alternative to conventional fuels – mainly diesel – is Biodiesel. Biodiesel refers to a vegetable oil or animal fat based diesel fuel consisting of long chain alkyl (methyl, ethyl, or propyl) esters [2]. Biodiesels are produced from vegetable oils by a process known as transesterification. Transesterification involves the reaction of the vegetable oil with an alcohol, in the presence of a catalyst, to form Esters and glycerol. These esters are referred to as biodiesels and they can be used in Compression Ignition engines either as a sole fuel (neat biodiesel) or by blending with petro-diesel in various proportions [3,4].

Numerous biodiesels, which are extracted from different vegetable oil sources, have been tried as alternative to diesel fuel for several years. Previous researches in this field showed that the use of biodiesels resulted in a performance comparable to diesel fuel with added benefit of lower emissions. Biodiesels are also expected to reduce the engine wear in diesel engines as they are found to have better lubrication properties than petro-diesel [5]. In the present work, Eucalyptus oil was selected as the source of biodiesel and the various characteristics wereanalyzed. The eucalyptus tree is a non-edible species capable of growing in all climatic conditions. Eucalyptus oil was derived mainly from the leaves and barks of the tree and is available throughout the year [6].

Once the pure eucalyptus oil has been extracted, it was converted into biodiesel by the process of transesterification. The physico-chemical properties of the biodiesel thus obtained were analyzed and compared with those of petro-diesel to find its suitability for use in diesel engines. Eucalyptus biodiesel was then blended with petro-diesel mainly in three blend ratios E10, E20 E30 (10%, 20% and 30% by vol.). The engine tests were carried out on a single cylinder direct injection diesel engine at loads varying from zero (no load) to full load. The results of engine performance and emission characteristics were thus determined and discussed.

II. PREPARATION OF BIODIESEL AND ITS CHARACTERIZATION

Transesterification of vegetable oils is, so far, the best known and the most widely accepted method for the production of biodiesel. It is the chemical reaction between a triglyceride and an alcohol in the presence of a catalyst [7]. Even though several other techniques are available for biodiesel preparation, transesterification is the best method as the physical characteristics of the (m)ethyl esters produced closely resemble those of petro-diesel and the production process is relatively simple[8].

In the preparation of Eucalyptus biodiesel, ethyl transesterification was adopted. Ethanol was used as the alcohol in the preparation of eucalyptus biodiesel. Pure eucalyptus oil was taken in a reaction flask. The proportions were 500 ml pure eucalyptus oil, 100 ml ethanol and 5g NaOH pellets as the catalyst. The pellets of NaOH were dissolved in ethanol solution taken in a beaker. Once all the NaOH pellets were completely dissolved, the solution could be called Sodium Ethoxide solution. The solution thus obtained was then added to the pure eucalyptus oil in the beaker and it was heated and stirred thoroughly for about an hour at 55^o-65^o. The stirring process was characterized by a change in the color of the mixture from clear yellow to reddish yellow. The solution obtained was then poured in an inverted flask and allowed to settle down for nearly 24 hours. Then glycerol would be settle at the bottom of the flask as a dark brown colored liquid and ethyl esters (coarse biodiesel) would be formed at the top. The glycerol was removed and the coarse biodiesel was heated above 100^0C to remove any untreated ethanol. The NaOH impurities were removed by washing with water. The cleaned biodiesel thus obtained was the ethyl ester of Eucalyptus oil, simply known as Eucalyptus biodiesel.

The various physico-chemical properties of the obtained biodiesel were studied so as to find its suitability for use in diesel engines. The closeness in properties of the proposed biodiesel with petro-diesel shows that it could be used as an alternative with reasonable performance. Table 1 shows the various properties of the tested fuels.

Table 1. Properties of fuels

Property	Petro-diesel	Eucalyptus biodiesel
Calorific Value	43.2 MJ/Kg	42.5 MJ/Kg
Density (15^0 C)	0.845	0.908
Viscosity (40^0 C) cSt	1.57	1.85
Flash point (^{0}C)	56	32
Fire point (^{0}C)	65	42
Cetane Index	50	48

It is quite obvious from the table that eucalyptus biodiesel shows similarities in properties to petro-diesel and is hence evaluated to be a fuel alternative to diesel.

III. EXPERIMENTAL SETUP AND PROCEDURES

The performance and emission tests were performed on a constant speed, single cylinder, directinjection diesel engine. The detailed specifications of the engine used for the test are given below. All the performance and emission tests were conducted at a constant speed of 1500 rpm.

Table 2. Test engine specifications

Engine	Kirloskar TV1
Type	Single cylinder, Direct Injection, 4S
Bore * Stroke	87.5mm*110mm
Cubic Capacity	0.661 cc
Compression Ratio	17.5 :1
Rated power	3.5 kW @ 1500rpm
Injection Timing	23^o BTDC
Type of cooling	Water cooled

Figure 1 shows the experimental setup. The engine was coupled to a rheostat load bank with electrical loading. A DC generator with electrical load bank was used for loading purposes. The rheostat connected in series to the circuit controls the load on the engine by controlling the voltage. Carbon monoxide, Unburned Hydrocarbons and Nitrogen oxide emissions in the engine exhaust were measured by using a Crypton Five gas analyzer and the smoke density was measured using the AVL smoke meter.

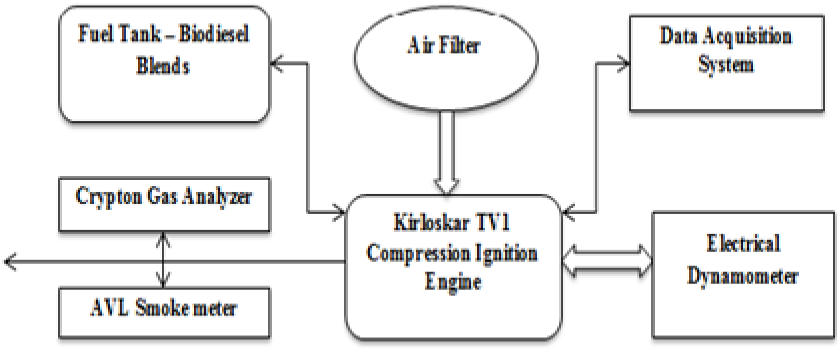

Figure 1. Experimental setup

The engine was started with neat diesel as fuel and was allowed to warm up for a few minutes. The performance and emission characteristics of the engine were noted using diesel as the reference fuel. The fuel was then switched to E10 [10% biodiesel + 90% diesel] and the characteristics were noted. The same procedure was repeated for the other blends [E20, E30] also. Once the tests were completed and all the required readings were taken, the engine was again switched to pure diesel fuel so as to avoid any future startup problems. The various performance and emission characteristics were obtained in this procedure.

IV. RESULTS AND DISCUSSIONS

The experiments were conducted at an injection pressure of 200 bar, compression ratio 17.5:1 and a standard injection timing 23^o BTDC.

Performance Characteristics

Brake thermal Efficiency (BTE) indicates the efficiency of the engine to convert the chemical energy of the fuel into useful output power. The variation in BTE with respect to power output at various loads for diesel and

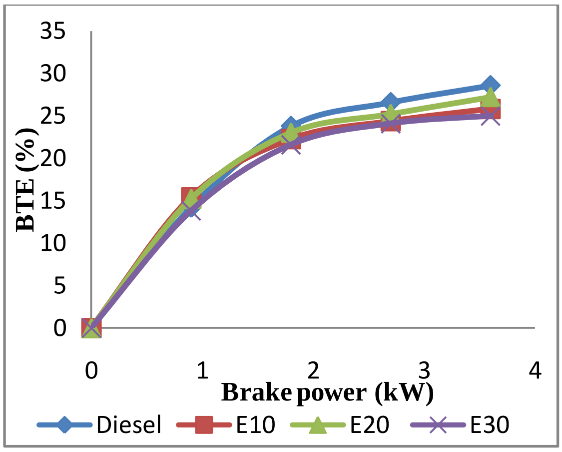

Figure 2. Variation of BTE with power output

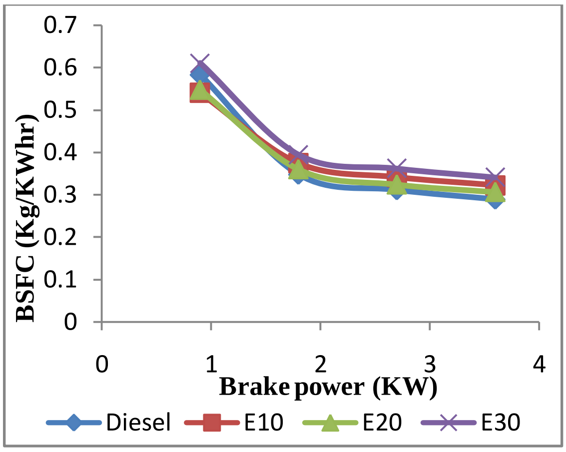

Figure 3. Variation of BSFC with power output

biodiesel blends is shown in the figure 2. It can be seen that the BTE increases with an increase in the load on the engine, as a result of the increase in the brake power. The highest BTE was recorded for petrodiesel (28.5%) at the rated power output. E20 fuel blend resulted in a reduction in the maximum BTE by a marginal 4.8%. It can be seen that the BTE of biodiesel blends is lower than that of diesel. Also, as the biodiesel content in the blend increases, the BTE decreases. This may be due to the lower heating values leading to a slower burning process when compared to diesel.

The fuel consumption characteristics of the engine are represented by the term Brake Specific Fuel Consumption (BSFC). BSFC is defined as the ratio of the total fuel consumption of the engine to the brake power produced by the engine. Figure 2 represents the variation of BSFC for diesel and the various biodiesel blends at different power outputs and loads on the engine. Similar to BTE, BSFC also depends mainly on the calorific value and viscosity of the fuel blend. BSFC of the engine is also inversely proportional to the BTE. Since the BTE is highest for diesel fuel, the lowest BSFC is also recorded by diesel fuel when compared to biodiesel blends. The reason for the increase in fuel consumption of biodiesel blends is that when the biodiesel content in the blend increases, the overall heating value of the blend reduces. Therefore, increased fuel consumption is required to maintain the same speed and power output of the engine. BSFC decreases as the power output of the engine increases.

EMISSION CHARACTERISTICS

Carbon monoxide (CO) is an important emission occurring in an engine. CO emissions take place due to the incomplete combustion of the fuel, mainly due to lack of oxygen atoms for effective combustion to occur. Another reason for CO emissions is the lack of time for effective combustion to occur. The variation in CO emission for diesel, neat biodiesel and the various blends at various loads of the engine are shown in figure 4. It can be seen that there is a significant reduction in the CO emissions while using biodiesel blends when compared to petrodiesel. The reason for the reduced CO emissions is the more effective and complete combustion taking place due to the increased number of oxygen atoms in the biodiesel. The availability of sufficient oxygen atoms causes most of the CO to be oxidized and converted to CO_2 but the complete conversion of CO to CO_2 is never possible.

Hydrocarbons (HC) are another prominent parameter in the emission characteristics of a diesel engine. Similar to CO emissions, HC emission also occurs when the fuel molecules fail to burn completely inside the engine. The variations in HC emission for diesel fuel, neat biodiesel, and the various blends at varying loads on the engine are shown in figure 5. The figure shows that the HC emissions of biodiesel blends are much lower than those of diesel fuel. It can also be seen that the lowest HC emissions were recorded by E30 blend. As the biodiesel content in the fuel blend increases, the HC emissions decrease. The reduction in HC emissions while using biodiesel as the fuel can be attributed to the efficient and more complete combustion taking place due to the presence of greater number of oxygen atoms in the biodiesel fuel blends. It was found from the investigation that the use of E30 fuel blend resulted in a reduction of HC emission by about 32.5% while the use of E20 blend resulted in a reduction of nearly 25% when compared to petroleum diesel.

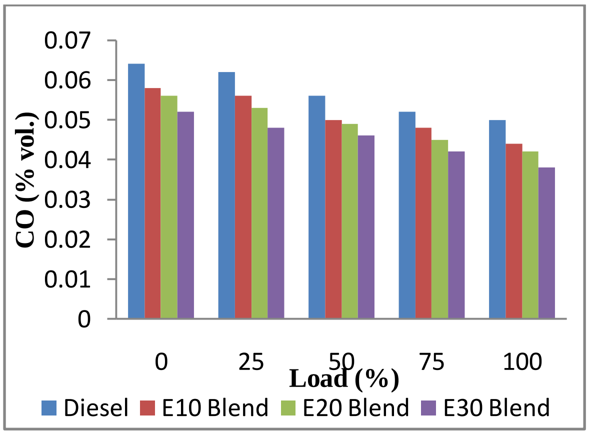

Figure 4. CO emissions at various engine loads

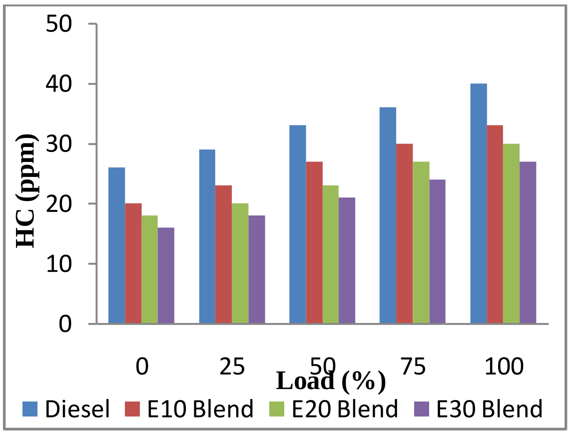

Figure 5. HC emissions at various engine loads

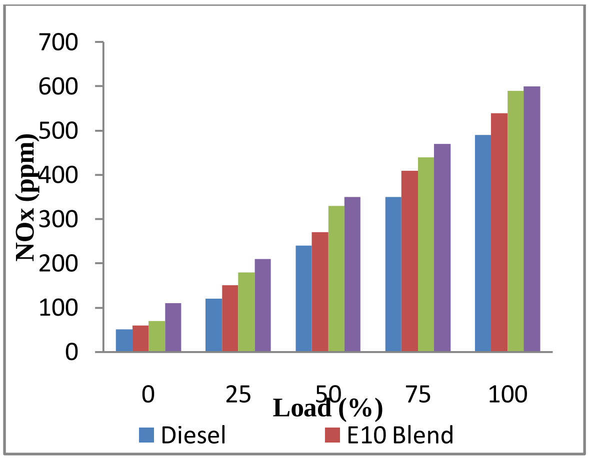

Figure 6.NOx emissions at various engine loads

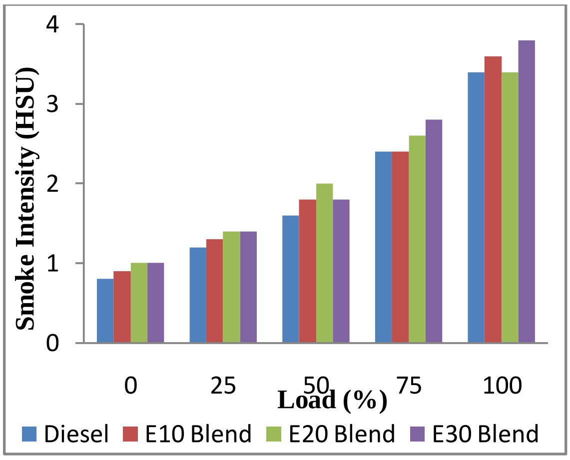

Figure 7 Smoke intensity at various engine loads

The variations of NOx emissions for diesel and biodiesel blends for various engine loads are shown in the figure 6. NOx emission from an engine increases with increase in power output of the engine. The NOx emission from an engine depends upon the maximum combustion temperature and the availability of oxygen. When the combustion temperature inside the engine exceeds a particular limit, atomic nitrogen combines with free oxygen to form oxides of nitrogen (NOx). Since the combustion temperature is higher and the oxygen concentration is greater for biodiesel, it can be seen that the NOx emissions of biodiesel and its blends are higher than those of diesel at all loads on the engine.

Smoke, defined as the visible products of combustion, is due to the poor combustion of the fuel in the engine. The three main operating conditions under which smoke is heavily produced in an engine are acceleration, overloading and during full load operation of the engine. Under these conditions more fuel is burned in the engine and the combustion chamber temperatures become very high. As a result of this extremely high temperature, the fuel molecules undergo thermal cracking leading to soot formation. Figure 7 shows the smoke intensity of the tested diesel and biodiesel fuel blends with respect to various loads on the engine. It can be seen that E30 fuel blend recorded the highest smoke intensity when compared to diesel while E20 fuel blend recorded almost the same smoke intensity as that of diesel fuel, especially at high engine loads. The smokeintensity at lower engine loads is almost the same for diesel and biodiesel blends. The increase in smoke intensity of E30 fuel blend at higher engine loads may be because of the higher viscosity of the fuel blend resulting in a poor atomization, thereby leading to increased smoke production.

V. CONCLUSION

This research aims at determining the suitability of Eucalyptus biodiesel as an alternative fuel for use in Compression Ignition Engines. In this experimental analysis, biodiesel was produced from pure eucalyptus oil by the process of transesterification. The prepared biodiesel was then blended with petrodiesel in three proportions (10%, 20% and 30% by vol.) and then tested in a single cylinder direct injection diesel engine to obtain the performance and emission characteristics. The similarities of various physico–chemical properties of eucalyptus biodiesel with diesel show its suitability for use as an alternative fuel. Following are the main conclusions drawn from this experimental investigation.

- The BSFC increases with increase of biodiesel content in the fuel blend due to decrease in calorific value of the blend.
- The BTE of biodiesel blends are found to be slightly lower than that of diesel at all loads and power outputs of the engine mainly due to the reduced heating value of the blend.
- A significant reduction in the HC and CO emissions was noted whereas NO_x emissions and Smoke intensity recorded an increase while using biodiesel blends as the fuel.

In general, Eucalyptus biodiesel in lower blend ratios was found to be good alternative to be used in direct injection diesel engines. E20 (20% biodiesel + 80% diesel) could be used as a very good alternative fuel with optimum engine performance and reduced emissions.

VI. ACKNOWLEDGEMENTS

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