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Combustion characteristics of diesel engine using blends of simarouba biodiesel

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Abstract
The need for energy grows every day and it is focused on petroleum fuels around the world. Because of their high thermal efficiency, low maintenance cost and increased life service, diesel engines are extensively used worldwide. Petroleum-derived fuel reserves are depleting on a daily basis due to high demand. Several factors such as the depletion of fuels derived from petroleum, the rise in their prices and climate change have stimulated researchers around the world to focus on finding out alternative energy sources. So in this work, an effort is made by using the blends of simarouba biodiesel in a water cooled, single cylinder, four stroke, diesel engine. According to ASTM standards, the fuel properties of simarouba biodiesel and all of its blends were comparable to diesel fuel. The combustion characteristics of diesel engine were found out by using all simarouba biodiesel blends and compared them with the standard diesel fuel. As per determined experimental results of the diesel engine, it is found that the combustion characteristics obtained by diesel engine using all blends of simarouba biodiesel were comparable with that obtained by using diesel fuel.
Keywords: *Diesel engine, Biodiesel blends, Cylinder pressure, Cumulative heat release rate, Net heat release rate.*

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I. INTRODUCTION

Every day the demand for energy particularly petroleum fuels rises around the world. It is forecasted the global energy consumption from 2012 to 2015 by 41% and an increase in the global energy consumption by 30% in last ten years and 52% over last twenty years [1]. In the world the current demand is focussed on petroleum fuels and around 26 to 27% of energy demand was satisfied by petroleum based fossil fuel sources in the sector of transportation. The vehicle used worldwide is diesel engine in the transportation sector and also the energy demand increases as it increases the number of vehicles. Furthermore, EURO VI emission standards imposed stringent regulations on motor vehicle exhaust emissions as well as the pollution caused by them [2]. Because of their high thermal efficiency, low maintenance cost and longer life service, the applications of diesel engines are increasing every day in the world [3]. Alternative fuels will provide 1.6 % of energy demand by 2030 as per the data from Energy Information Administration (EIA) of United states [2]. Respiratory health problems are mainly caused by air pollution worldwide. Vehicle emissions are primarily responsible for the air quality deterioration. Exhaust emissions have recently increased significantly due to the rapid expansion of the transportation industry. But in the machinery and transportation sectors, because of high energy content, readily available and desirable combustion properties, the petroleum derived fuels have been the major energy sources. Greenhouse gases like carbon dioxide, nitrogen oxides and methane are the primary contributors to global warming. An increase of 2°C in average global temperature will result in the death of millions of people worldwide [4].

An emissions produced from burning of fossil fuels have serious effects both on human health and environment. About 38% of increase in emissions is contributed from burning of fuel, coal and gas whereas about 24% increase in emissions is from oil. According to prediction, by 2035 the global emissions of CO_2 will increase by 29%. The global emissions will nearly be doubled in 2035 when compared to 1990. The rapid depletion of fossil fuels along with their price hiking and also worldwide environmental concerns have encouraged the researchers in the world for searching of alternative fuels which will provide cleaner combustions for diesel engines. Therefore, it is now a worldwide concern to develop alternative fuels that are readily available domestically, technically feasible and environmentally acceptable. As per Energy Policy Act, 1992 (EPACT, US), biofuel, natural gas, methanol and electricity are considered as the most suitable substitutes for fossil fuels which can reduce global warming, consumption of fossil fuels and also exhaust emissions [1].

Everyday, the reserves of fuels derived from petroleum are diminishing as their demand rises. Moreover, the combustion products resulting from the burning of these fossil fuels are considered environmentally hazardous. Therefore, for the purpose of continuously supply of energy, protection of the environment and maintenance of domestic economy in stable condition, an alternative fuel is needed to be selected for diesel engine [3]. Biodiesel is considered as one among the best alternative sources of energy because it can reduce the dependency on petroleum-diesel potentially, reduce pollution and it can also be used with minor or without any modifications in diesel engines [5]. The biodiesel can be prepared from oils extracted from vegetable plants, used cooking oil, animal fats and waste grease from restaurants by using the transesterification process. In modern diesel engines**,** it can also be used in its purest form (B100) or blending along with diesel fuel[1]. Because of the main advantages that it is non-toxic, renewable energy source, degrades four times faster compared to diesel fuel and 85-88% in water, has higher flash point which makes storage faster, the biodiesel can be used directly or without any substantial modifications of the engine in diesel engines[6].

II. EXPERIMENTAL PROCEDURE AND SPECIFICATIONS

A water cooled, single cylinder, 4 stroke, direct injected diesel engine is used during the experiments. From no load to full load conditions 3.5 kW(Rated output), the engine was operated.

Table 1: The specifications of the diesel engine

Specifications of diesel engine		
Make	:	Kirloskar
Stroke	:	4 stroke
Cylinder	:	Single
Stroke	:	110 mm
Bore	:	87.5 mm
Cylinder Volume	:	661 cc
Power	:	3.5 kW@ 1500 rpm

The above table.1 shows the specifications of the diesel engine. The biodiesel was prepared from simarouba vegetable oil by following the standard transestrification method and fuel met the standard specifications. The properties of simarouba biodiesel along with diesel fuel are shown in following table.2.

Table 2: Properties of simarouba biodiesel and diesel fuel.

Fuels	Simarouba biodiesel	Diesel	ASTM Standard
Kinematic Viscosity (m^2/sec) @ 40°C	4.89×10^{-6}	2.09×10^{-6}	D 445
Calorific Value (kJ/kg)	39909	45448	D 4809
Density (kg/m^3)	870	830	D 287
Flash Point (°C)	181	53	D 9358T
Cetane number	51.63	52	D 613

The following operating conditions, fuel and blends of biodiesel were used during experimentation.

- **Operating conditions**
  - i) Injection pressure : 210 bar.
  - ii) Compression ratio : 17.5:1.
  - iii) Injection timing : 23° bTDC.

- **Fuel and blends of simarouba biodiesels used**

  Standard diesel fuel
  S-10 – 10% of biodiesel + 90% of diesel fuel.
  S -20 – 20% of biodiesel + 80% of diesel fuel.
  S -30 – 30% of biodiesel + 70% of diesel fuel.

  S -40 – 40% of biodiesel + 60% of diesel fuel.

III. RESULTS AND DISCUSSION

The following combustion characteristics of diesel engine fuelled with all blends of simarouba biodiesel were found out and compared with standard diesel fuel considering it as reference fuel.

3.1 In cylinder pressure

The following Figure.1 shows that the variation of cylinder pressure versus crank angle for all the blends of simarouba biodiesel and also for diesel fuel at full load condition. Here, it is noticed that after top dead centre the maximum cylinder pressure is reached in all the cases. The maximum cylinder pressure reached by all blends of simarouba biodiesel at full load condition are nearly similar to that obtained by diesel fuel. The reason for this is higher viscosity of blends of simarouba biodiesel which in turn increases the ignition delay period. The increased ignition delay period leads to a high concentration of fuel during the pre-mixed combustion phase which causes a rapid increase in cylinder pressure during the pre-mixed phase of combustion. The another reason may be because of increased oxygen quantity in the blends of simarouba biodiesel which results in better combustion process of fuel.

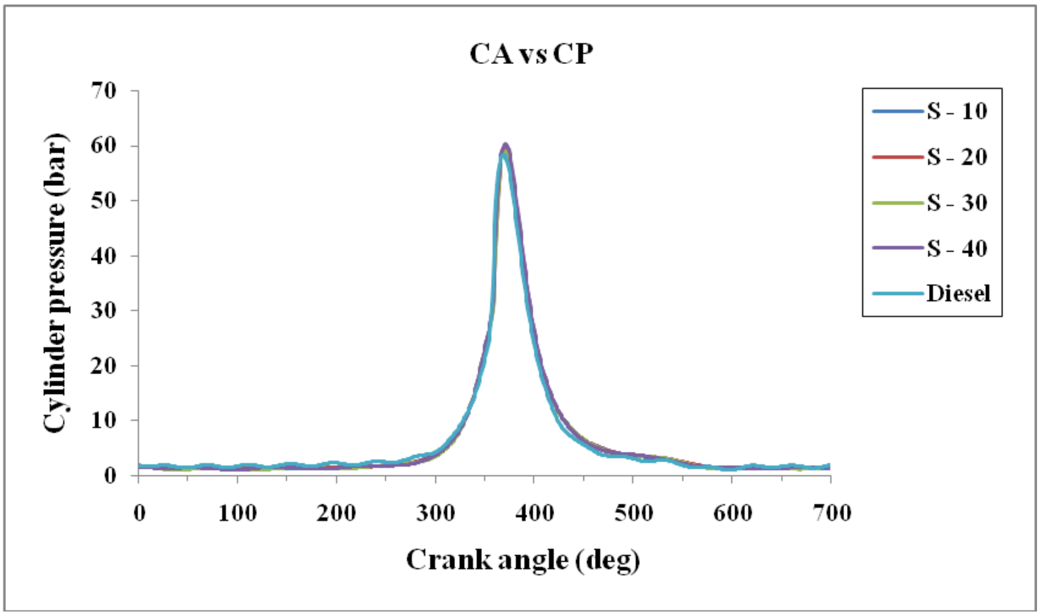

Figure 1. Variation of cylinder pressure versus crank angle for blends of simarouba biodiesel and diesel.

3.2 Net heat release rate

The net heat release rate versus crank angle at full load condition for all the blends of simarouba biodiesel and also for diesel fuel is depicted in the the following Figure.2 The maximum net heat release rate reached by all blends of simarouba biodiesel at full load condition are comparable to that obtained by diesel fuel. This is because of more oxygen content in the blends of simarouba biodiesel compared to diesel fuel which improves the fuel combustion process.

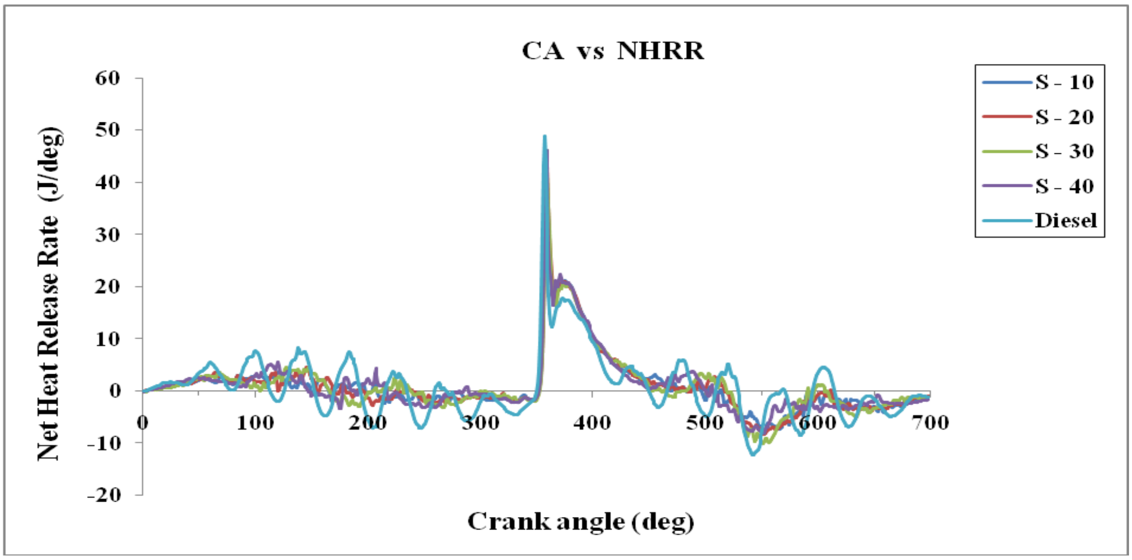

Figure 2. Variation of net heat release rate versus crank angle for blends of simarouba biodiesel and diesel.

3.3 Cumulative heat release rate

The following Figure.3 shows that at full load condition, the cumulative heat release rate versus crank angle for all the blends of simarouba biodiesel and also for diesel fuel. The maximum cumulative heat release rate obtained by for all blends of simarouba biodiesel at full load condition are comparable to that obtained by diesel fuel. It is because of presence of oxygen content in the blends of simarouba biodiesel which mixes with fuel properly causing good combustible mixture.

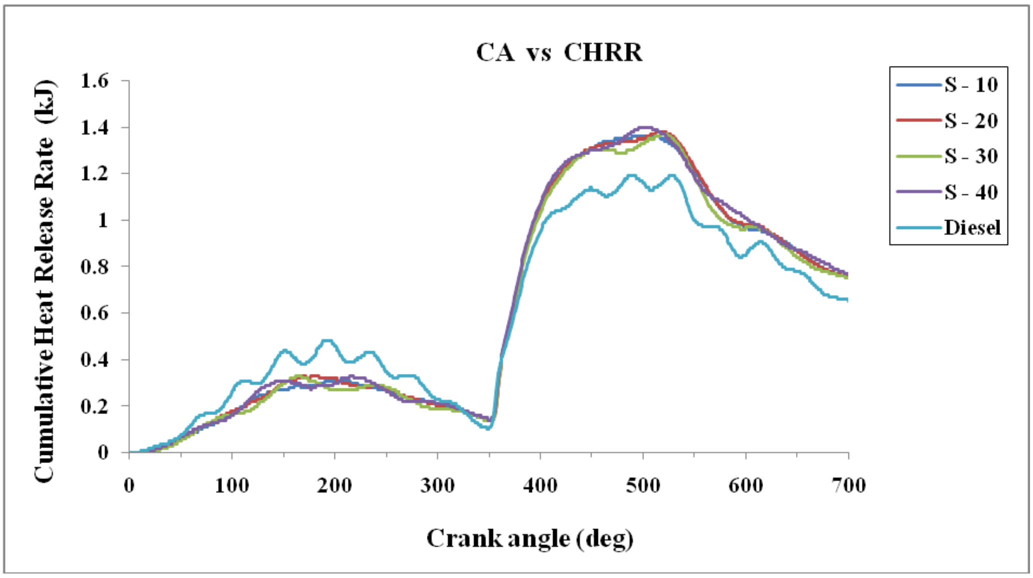

Figure 3. Variation of cumulative heat release rate versus crank angle for blends of simarouba biodiesel and diesel.

3.4 Combustion parameters of diesel engine

The combustion parameters of diesel engine using blends of Simarouba biodiesel and diesel fuel with respect to rate of pressure rise, indicated power, indicated mean effective pressure, start of combustion and end of combustion at full load condition are summarised as in the following table 3.

Table.3. Combustion parameters of diesel engine for blends of Simarouba biodiesel and diesel fuel.

Fuel	Rate of pressure rise (bar)	Indicated Power (kW)	Indicated mean effective pressure (bar)	Start of combustion (deg)	End of combustion (deg)
S-10	4.7	6.75	8.39	19° b TDC	46 a TDC
S-20	4.9	6.81	8.35	22° b TDC	44 a TDC
S-30	4.9	6.72	8.29	16° b TDC	49 a TDC
S-40	5	6.88	8.47	18° b TDC	46 a TDC
Diesel	5.3	5.25	6.75	26° b TDC	31 a TDC

From the above table-3, it is clear that at full load condition with respect to rate of pressure rise, indicated power, start of combustion, indicated mean effective pressure and end of combustion, the results obtained by all blends of simarouba biodiesel are comparable with those obtained by diesel fuel.

IV. CONCLUSIONS

Based on experimental observations, the following conclusions are made.

1) In all the cases, after top dead centre, the maximum cylinder pressure is reached. The maximum cylinder pressure reached by for all blends of simarouba biodiesel at full load condition are nearly similar to that obtained by diesel fuel.
2) The maximum net heat release rate obtained by all blends of simarouba biodiesel are comparable to that obtained by diesel fuel at full load condition.
3) The maximum cumulative heat release rate obtained by all blends of simarouba biodiesel at full load condition are comparable to that obtained by diesel fuel.
4) With respect to rate of pressure rise, indicated power, indicated mean effective pressure, start of combustion and end of combustion at full load condition, the results obtained by all blends of simarouba biodiesel are nearer to those obtained by diesel fuel.

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