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Experimental study of Combustion Characteristics of Diesel Engine Fuelled with Blends of Hemp Biodiesel

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Abstract

In the 21st century one of the biggest challenges is high demand for fossil fuel sources because of the rapid growth of automotive industry. The reduction of fossil fuel sources and environmental degradation are the major problems the world facing in present scenario. Since the petroleum fuel sources are limited and exhaustible in nature, a lot of efforts are needed to reduce the dependency over them. Because of all these reasons, it is very essential to search for renewable environment friendly alternate fuel for replacement of diesel fuel in diesel engines. So, in this regard, an attempt is made by using the blends of hemp biodiesel in a computerised water-cooled, single cylinder, four stroke diesel engine. As per ASTM standards, the determined fuel properties for hemp biodiesel and all its blends are found comparable with diesel fuel. The combustion characteristics of diesel engine fuelled with hemp biodiesel blends are determined and compared to diesel fuel. As per combustion characteristics determined, the maximum cylinder pressure, maximum net heat release rate and maximum cumulative heat release rate fuelled with blends of hemp biodiesel are found comparable with that reached by diesel fuel at full load condition.

Keywords: *Diesel engine, Hemp biodiesel, Net heat release rate, Cylinder pressure, Cumulative heat release rate.*

1.0 Introduction

Typically, population and economic development are the primary factors of energy demand. The overall energy demand is influenced by power generation, transportation, industry and residential use. According to reports all these major demand sectors will grow till 2030. Internal combustion engines contribute to human transportation, commercial transportation and non-road works such as agriculture and construction[1]. "The rapid rise of the automotive industry together with the increasing demand for fossil fuels such as petroleum and commercial diesel fuel has become one of the biggest challenges of the twenty-first century. Over the last two centuries of industrialisation, the fossil fuel basins have already been depleted along with the discharge of harmful engine emissions and a huge amount of heat loss energy into the atmosphere"[2]. Currently, the world faces two significant problems, namely fossil fuel depletion and degradation of environment. Due to the rapid depletion of fuel resources, energy conservation and management as well as environmental preservation, have assumed greater importance today[3]. The increased number of passenger vehicles, heavy-duty trucks, power plants and furnaces has resulted in a rise in fuel consumption and air pollution

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compared to previous years. Both urbanisation and its high population have changed the way people live and contributed to climate change. The excessive consumption of the fossil fuels is responsible for the degradation of the global environment and its subsequent health risks. Due to an increasing concern for environmental protection and stringent regulations on exhaust emissions, it has become a major challenge to reduce exhaust emissions in engine design. In addition a significant amount of effort is required to reduce dependence on petroleum fuels as these sources are exhaustible in nature[4]. Because of their superior fuel economy, durability and efficiency, diesel engines are widely used in a number of industries such as transportation, agriculture, construction and energy generation. The diesel engine releases greater nitrogen oxides, carbon monoxide and sulphur oxides when it is fuelled with fossil fuel. In the past three decades, the air pollution produced by engine exhaust emissions became a social problem and the attainment of low-polluting combustion has been a research topic[5]. According to one estimation in a business-as-usual scenario, coal reserves will be exhausted in 218 years, oil in 41 years and natural gas in 63 years[6].

The world's petroleum sources of energy are limited. The deterioration of petroleum resources and the growth of environmental concerns have stimulated researchers around the world to investigate sustainable and environmentally friendly replacements to petroleum products[7]. Biodiesel is an oxygenated fuel which can be produced by converting triglycerides into esters from extracted vegetable oils or animal fats. Due to the fact that biodiesel has similar properties to petroleum diesel, with minimal or no engine modifications it can be used in diesel engines and produce almost the same performance, but with a decrease in carbon monoxide, smoke emissions, and unburned hydrocarbons, according to reports based on the results of various studies. However, the majority of studies revealed a rise in nitrogen oxides. However, the results will vary depending on the basis of extracted vegetable oil or animal fats, the biodiesel production process and the fuel properties of biodiesel[5]. It is allowed the blends of biodiesel with diesel fuel in diesel engines. In addition to its advantages, biodiesel has disadvantages such as a low calorific value, high viscosity and density and increased production of nitrogen oxides[7].

Table 1: The specifications of the engine

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

2.0 Experimental Procedure and Specifications

A computerised water-cooled, direct-injected, single-cylinder, four-stroke diesel engine is used in the experiments. The engine was run from the no load to full load (at 3.5 kW, Rated output). The diesel engine's specifications are shown in Table 1. The exhaust emissions CO, CO_2, HC, O_2 and NO_X were measured using the AVL DIGAS 444N five-gas analyzer. For measurement of smoke opacity, an AVL 437 smoke metre was used.

The hemp vegetable oil was used to make biodiesel using the standard transestrification method ASTM D6751 and the fuel met the standard specifications. The properties of hemp biodiesel and also diesel fuel are shown in the Table 2.

Table 2: The properties of hemp biodiesel and diesel fuel

Fuels	Hemp biodiesel	Diesel	ASTM standard
Kinematic viscosity (m^2/sec) @ 40°C	4.89×10^{-6}	2.09×10^{-6}	D 445
Flash point (°C)	181	53	D 9358T
Density (kg/m^3)	870	830	D 287
Calorific value (kJ/kg)	39909	42995	D 4809
Cetane number	51.63	52	D 613

During experimentation, the following fuel and blends of biodiesel and operating conditions were used.

Fuel and blends of hemp biodiesel used

Standard diesel fuel

H-10 – 10% biodiesel + 90% diesel fuel.

H -20 – 20% biodiesel + 80% diesel fuel.

H -30 – 30% biodiesel + 70% diesel fuel.

H -40 – 40% biodiesel + 60% diesel fuel.

Operating conditions

(i) Injection timing : 23° bTDC.

(ii) Compression ratio : 17.5:1.

(iii) Injection pressure : 210 bar.

3.0 Results and Discussion

The combustion parameters of a diesel engine operating on hemp biodiesel blends were measured and compared to a diesel engine running on standard diesel fuel.

3.1 In Cylinder Pressure

For all blends of hemp biodiesel and also diesel fuel, the variation in cylinder pressure versus crank angle under full load conditions is depicted in Fig.1. As observed here, the maximum cylinder pressure is reached in all cases after top dead centre. The maximum cylinder pressure achieved at full load by hemp biodiesel blends is comparable to that obtained with diesel fuel. This is due to the longer ignition delay period caused by the increased viscosity of hemp biodiesel blends. A longer ignition delay period results in a higher fuel concentration during the pre-mixed combustion phase resulting in a rapid rise in cylinder pressure during this phase. The presence of higher oxygen in hemp biodiesel blends may be another factor that contributes towards a more efficient fuel combustion process.

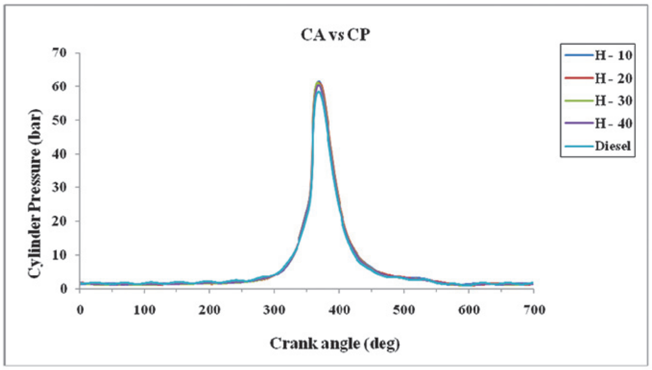

Figure 1: Cylinder pressure versus crank angle for blends of hemp biodiesel and diesel

3.2 Net Heat Release Rate

Figure 2 illustrates the rate of net heat release versus crank angle at full load for blends of hemp biodiesel and also diesel fuel. The maximum net heat release rate from blends of hemp biodiesel at full load is almost the same as that from diesel fuel. It is because of that hemp biodiesel blends have a high oxygen content than diesel fuel which improves the fuel combustion process.

3.3 Cumulative heat release rate

The cumulative heat release rate versus crank angle at full load condition is depicted in Fig.3 for hemp biodiesel blends and also diesel fuel. The maximum cumulative heat release rate obtained by hemp biodiesel blends under full load conditions

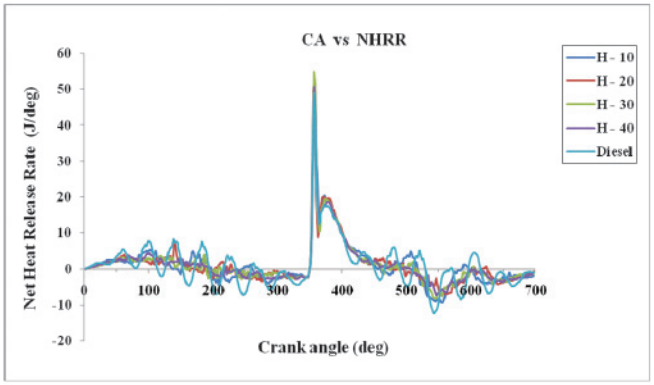

Figure 2: Net heat release rate versus crank angle for blends of hemp biodiesel

is comparable to diesel fuel. It is because of presence of oxygen in blends of hemp biodiesel which results in a good combustible mixture.

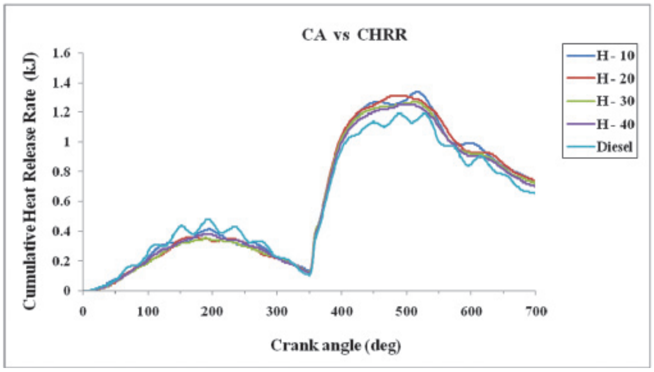

Figure 3. Cumulative heat release rate versus crank angle for blends of hemp biodiesel

3.4 Combustion Characteristics for Hemp Biodiesel

Combustion characteristics of diesel engine under full load condition using blends of hemp biodiesel and diesel fuel with respect to indicated mean effective pressure, indicated power, start of combustion, rate of pressure rise and end of combustion are shown in Table 3. So according Table 3, the results obtained with hemp biodiesel blends are better than those obtained with diesel fuel at full load in terms of rate of pressure rise, indicated power, start of combustion, indicated mean effective pressure and end of combustion.

4.0 Conclusions

Based on the results of the experiments, the conclusions are drawn as the following:

(i) In all cases, the maximum cylinder pressure is reached

Table 3: Combustion characteristics of diesel engine using blends of hemp 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)
H-10	5.3	5.68	7.85	18°b TDC	34 a TDC
H-20	5.6	5.96	8.01	21°b TDC	32 a TDC
H-30	6	5.88	7.75	22°b TDC	34 a TDC
H-40	5.5	5.79	7.53	23°b TDC	34 a TDC
Diesel	5.3	5.25	6.75	26°b TDC	31 a TDC

after top dead centre. The maximum cylinder pressure obtained with hemp biodiesel blends at full load is nearly identical to that obtained with diesel fuel.

(ii) The maximum net heat release rate obtained with blends of hemp biodiesel at full load condition are comparable with that reached with diesel fuel.

(iii) The maximum cumulative heat release rate reached with blends of hemp biodiesel at full load condition are comparable with that reached with diesel fuel.

(iv) With respect to indicated mean effective pressure, indicated power, start of combustion, rate of pressure rise and end of combustion, the results obtained with blends of hemp biodiesel are better than those obtained with diesel fuel.

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