EFFECT OF INJECTION PRESSURE ON THE ROLE OF COMPRESSION IGNITION ENGINE USING WASTE COOKING OIL AS A FUEL

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ABSTRACT It is seen that large progress has been made in the concept of vegetable oils used as alternative fuels for CI engines. In this work non edible oils like waste cooking oil is mixed with various proportions is used for the investigation. Investigations are the influence of injection pressure on the performance, emission and combustion characteristics of methyl ester of waste cooking oil and diesel blends. A single cylinder diesel engine is used to conduct experiments at a constant speed of 1500 rpm under variable load conditions. The experimental results of performance characteristics like brake thermal efficiency, brake specific fuel consumption are recorded and compared with that of diesel. It is noticed that, the brake thermal efficiency of diesel was obtained as 42.3% and that of biodiesel blends was obtained as 43.2%, 35.6%, 35.9%, 36.1% and 38.9% at full load condition.

Keyword: Waste cooking oil, Diesel Engine, Brake thermal efficiency, Injection pressure

I. INTRODUCTION

The world is presently confronted with the twin crisis of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground based carbon resources. The search for an alternative fuel, which promises a harmonious correlation with sustainable development, energy conservation, management, efficiency, and environmental preservation, has become highly pronounced in the present context. The inventor of the diesel engine, Rudolf diesel, in 1885, used vegetable oil (peanut oil) as a Diesel fuel for demonstration at the 1900 world exhibition in Paris. Most important function of IC engine fuel injector is to provide proper mixing of fuel and air in short possible time to produce high relative velocity between the fuel droplets and air. This will enhance the turbulence and thermal efficiency. Many factors contribute for the performance and emission characteristics of the engine. Among them major parameters are injection pressure, injection timing, properties of fuel, compression ratio, type of injector and type combustion chamber etc. Different authors studied performance of CI engine at different injection pressure with biodiesel from different feedstock such as cotton seed oil methyl ester, pongamia methyl ester jatropha methyl ester etc. Rizwanul Fattah et al. [1] reported the BTE for JB20 (jatropha biodiesel) and CB20 (coconut biodiesel) blends is lower by 2.60% and 1.30%, respectively, than diesel. They reported that with increase in injection pressure the performance of the engine increases. Heywood [2] explained effect of spray characteristics; spray angle, injection pressure and injection timing also have a significant role in diesel engine combustion. Yamane et al. [3] reported the properties of bio-diesel are not the same as diesel fuels especially their high viscosity and low volatility. These properties strongly affect injection pressure injection timing and spray characteristics. Mohan et al. [4] conducted study on performance of CI engine at elevated injection pressure and reported that increasing injection pressure to 275 bars and retarding injection timing to 21° BTDC, the BTE increased about 10% and BSFC reduced about 8% on full load compared to that with diesel fuel. Along with BTE and BSFC, NOx emission also increased by 6%, which was accounted as adverse effect. Gumus et al. [5] studied the effect of injection pressure on the increased injection pressure gave the better results for BSFC, BSEC and BTE compared to that of original injection pressure. Finer fuel droplets obtained with increased injection pressure provided more surface area and better mixing with air. This resulted in better combustion, HC, and CO emissions decreased and NOx emissions increased with the increase in injection pressure for the all test fuel blends. Jindal et al. [6] studied the performance of Jatropha Methyl ester as a fuel in CI engine with increase in compression ratio and injection pressure, reported improved performance of the engine. The highest performance is delivered by the engine at 250 bar injection pressure and compression ratio of 18.5 at which BSFC improves by 10% and BTE improves by 8.9% than that with diesel at full load condition.

II. BIODIESL PRODUCTION AND ITS PROPERTIES

Transesterification

Transesterification is the process in which by using an alcohol (e.g. methanol, ethanol or butanol), in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide, to break the molecule of the raw renewable oil chemically into methyl or ethyl esters of the renewable oil, with glycerol as a by product. Transesterified, renewable oils have proven to be a viable alternative a reaction scheme for transesterification is as follows

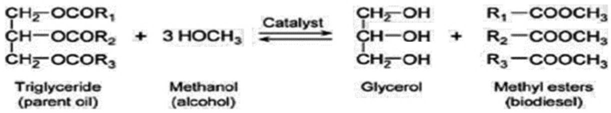

Fig.1: Chemical reaction scheme for transesterification

In fig. 1, R_1, R_2, and R_3 in this diagram represent long carbon chains that are too lengthy to include in the diagram. Waste oil is collected and blended for various proportions and are treated with adequate amount of CH_3OH (methanol) and required amount of NaOH (sodium hydroxide) as a catalyst which are available in chemical laboratories. Since these oils are of high viscosity and low volatility, then direct use of feedstock in diesel engines can cause problems including: high carbon deposits, scuffing of engine liner, injection nozzle failure, and gum formation, lubricating oil thickening and high cloud and pour points. In order to avoid these problems, the feedstock is chemically modified to its derivatives which have properties more similar to petro-diesel. The free fatty acids (FFA) and triglycerides contained in the oil are reduced to Fatty Acid Alkyl Esters (FAAEs). This process is known as Transesterification. Here, we are conducting transesterification process in single stages for the production of biodiesel. Transesterification process is affected by parameters like amount of methanol, concentration of sodium hydroxide (NaOH), reaction temperature and reaction time. One of the most important variables affecting the yield of biodiesel is the molar ratio of alcohol to vegetable oil used. In the present work we have optimized all these variables.

Experimental procedure: The Transesterification process is conducted in single stages for the production of biodiesel from the waste cooking oil.

Esterfication procedure

- NaOH is weighed and dissolved in 30% of methanol using a stirrer.
- 250 ml of WCO is added to the methanol and NaOH mixture.
- The mixture is stirred continuously at 1500 rpm for 90 minutes at a constant temperature of 60°C.

- The mixture then is transferred to the separation flask and kept there for 6 hours. Glycerol is then separated and biodiesel is obtained.

Water wash: Once the biodiesel is separated from the glycerin, the biodiesel is washed gently with warm water to remove residual catalyst, acidic or soapy contents. And then collect it in a storage tank. In some processes this water wash is not necessary. This is normally the end of the production process resulting in a clear amber-yellow liquid with a viscosity similar to petro diesel. In some systems the biodiesel is distilled in an additional step to remove small amounts of colour bodies to produce a colorless biodiesel. After normalizing the pure bio-diesel obtained which removes the acid content presence in the crude bio diesel. Then the crude bio-diesel is heated up to boiling temperature of water, which helps to evaporate moisture content.

Blending bio-diesel with diesel: The pure biodiesel are blended with the diesel in the ratio of B20, B40, B60, B80 and B100. And keep it for minimum of 24 hours to get a homogenous mixture.

Fig. 2: Various blends of biodiesel

Fuel properties measurement: The physical and chemical properties of Waste cooking oil were measured. The calorific value was measured by Bomb Calorimeter, The viscosity was measured by Redwood Viscometer, The flash point and fire point were determined by Pensky-Martens apparatus by closed-cup method. The conversion of waste cooking oil into its methyl ester can be accomplished by Transesterification process. Before Transesterification the properties of waste cooking oil is as shown in the table below.

Properties	Value
Flash point	180 ^{0}C
Fire point	200 ^{0}C
Pour point	50 ^{0}C

Cloud point	140 ^{0}C
Viscosity	46 CST
Calorific value	35000 KJ/KG

Engine Setup: The Test-Rig consists of four stroke Diesel Engine, which is connected to the electrical swinging field dynamometer with the resistive loading. The DC machine is used as motor for starting the engine. Once the engine is started with the changeover of the switch to the generator mode; it will act as a DC generator which is connected to the resistive load Air heaters. The engine and the dynamometers are coupled by a coupling. The exhaust of the engine is connected to the exhaust gal calorimeter. Temperature sensors are fitted at the inlet and outlet of the calorimeter for temperature measurement. The complete set up is mounted on Anti Vibration Mounts. The layout of experimental test rig and its instrumentation is shown in Fig 5, 6 &7. It is a water cooled engine with a rated power of 3.7 kW at 1500 rpm having bore 80mm and stroke 110mm,compression ratio of 16:1 to 25:1. A fuel tank is fitted inside control panel along with fuel measuring unit. An air box is powered for damping pulsation in air flow line. An orifice meter with manometer is fitted at the inlet of air box for flow measurement. Thermocouple type temperature sensors measure cooling water inlet, outlet and exhaust temperatures. These temperatures are digitally indicated on indicator suited on control panel.

Fig 3: Compression Ignition Engine

III. Results and Discussions

Performance graphs at 160 bar injecting Pressure

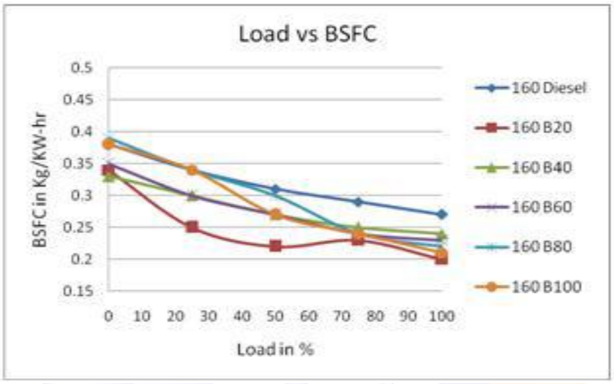

Fig 4: Load v/s BSFC

Fig.4 shows the variation of Load v/s BSFC at the injection pressure of 160 bar for different biodiesel blends from the above figure, it is noticed that, the brake specific fuel consumption of diesel was obtained as 0.27kg/kW-h and that of biodiesel blends was obtained as 0.21, 0.24, 0.23, 0.22 and 0.22 kg/kW-h at full load condition. It is observed that the BSFC of biodiesel B20 (0.21 kg/kW-h) at full load is minimum compared to diesel, this is because uniform distribution of fuel droplets inside the combustion chamber. Hence uniform combustion has been taken place. As a result of that maximum output for Minimum fuel input the BSFC of B20 is decreased by 4.3% over diesel.

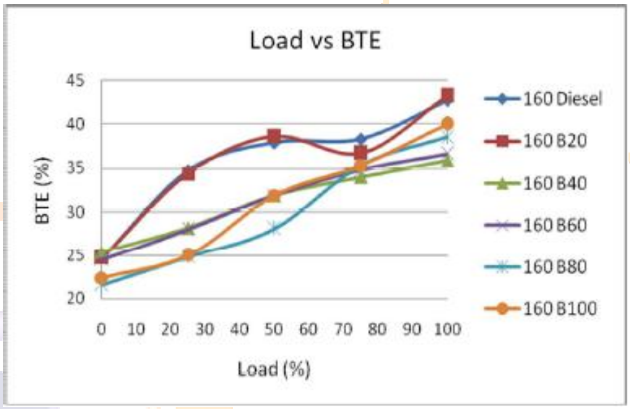

Fig 5: Load v/s BTE

Fig.5 shows the variation of Load v/s BTE at the injection pressure of 160 bars for different biodiesel blends. From the above figure, it is noticed that, the brake thermal efficiency of diesel was obtained as 42.3% and that of biodiesel blends was obtained as 43.2%, 35.6%, 35.9%, 36.1% and 38.9% at full load condition. The maximum brake thermal efficiency for biodiesel blend B20 (43.2%) is high compared to diesel at full load. This is because of the heating value of the B20 is more compared to diesel thus improving the combustion characteristics hence BTE of B20 was increased by 1.7% over diesel. This could be attributed to the availability of oxygen in the mixed biodiesel, which helps in complete combustion of the fuel. However, with increase in load the brake thermal efficiency improved. This is due to spray formed during Injection and improved atomization.

IV. CONCLUSIONS

The performance and emission characteristics of a single cylinder direct injection CI engine fueled with methyl ester of waste cooking oil and diesel blends have been investigated compared with that of standard diesel. The experimental results showed that the BTE, SFC, and emission characteristics are function of biodiesel blend and load. The following conclusions are drawn from this investigation.

It is observed that the BSFC of biodiesel blend B20 (0.21 kg/kW-h) at full load is minimum compared to diesel, this is because uniform distribution of fuel droplets inside the combustion chamber. Hence uniform combustion has been taken place. As a result of that maximum output for minimum fuel input the BSFC of B20 is decreased by 4.3% over diesel. The maximum brake thermal efficiency for biodiesel blend B20 (43.2%) is high compared to diesel at full load. This is because of the heating value of the B20 is more compared to diesel thus improving the combustion characteristics hence BTE of B20 was increased by 1.7% over diesel.

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