Energy-Exergy Analysis of CI Engine Fuelled with Rapeseed/Waste Cooking Oil based Biodiesel

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Abstract - *The present study is carried out in order to do Energy-Exergy analysis of CI engine using waste cooking oil/ rapeseed oil and biodiesel blends. Initially the biodiesel is produced from waste cooking oil and rapeseed oil using transesterification process. Thereafter the properties such as kinematic viscosity, calorific value, flash and fire point of the prepared biodiesel is done. Then performance parameters i.e., brake power, brake specific fuel consumption, brake thermal efficiency are evaluated and compared with mineral diesel. Then the Energy-Exergy analysis is carried out by writing mathematical equations and solved by using MATLAB software. It is observed from the results and discussion that, results obtained in this present work is reasonably accurate.*

Key Words: Biodisel, Energy-Exergy analysis, *MAT LAB*

1. INTRODUCTION

Nowadays, most of our energy demand is provided by fossil fuels. They are generally considered to be nonrenewable resources. The use of fossil fuels raises serious environmental concerns. In order to resolve these problems, various solutions have been proposed by various investigators. Using biodiesel is one of the solutions that improve both of the mentioned concerns simultaneously. Biodiesel can be easily produced from different vegetable oils or animal fat. Numerous studies have been conducted on biodiesel production methods and its effect on engine performance and exhaust emissions, such as biodiesel manufactured from jatrofa, waste cooking oil, palm, cotton seed and animal fats. It has been frequently reported that emissions of CO, HC, soot and particulate matter (PM) reduce when using biodiesel. They reported an inverse trend in NOx emissions. Biodiesel and its blends exhibit a slight reduction in the engine power, compared to Diesel fuel. Biodiesel contains about 10% oxygen in its structure, So, this higher oxygen content also leads to lower heating values (LHVs), which may result in engine power losses and the increase in specific fuel consumption. However, there are some investigations reporting that the power output increases when using biodiesel. They described this increase with the increased cetane number, but a high value of biodiesel viscosity could also be another reason. All these studies were based on the first law of thermodynamics (energy analysis). The thermodynamics details of the process of a thermal system can be clarified by performing an exergy analysis of the system in addition to an energy analysis. The exergy analysis, also known as the second law or availability analysis, of compression ignition (CI) engines has been studied by many investigators.

2. OBJECTIVES OF THE PRESENT WORK

The objectives of the present study are as given below:

- To produce and evaluate the properties of biodiesel produced from WCO (Waste Cooking Oil) & Rapeseed oil.
- To investigate the performance parameters of CI engine for different speed and load conditions.
- To perform the energy-exergy analysis of different biodiesel blends for WCO & Rapeseed oil for different speed and load conditions.

3. ENGINE SETUP

The experiments are conducted on direct injection, single cylinder four stroke Kirloskar diesel engines. The layout of experimental test rig and its instrumentation is shown in Fig.3. It is a water cooled engine with a rated power of 5.2 kW at 1500 rpm having bore 87.5mm and stroke 110mm,compression ratio of 17.5, injection pressure of220 bar at 23obTDC injection time. It consists of a test bed, a diesel engine with a rope brake-drum dynamometer eddy. The engine is connected to rope drum dynamometer. The rope drum dynamometer is mounted on base frame and connected to engine. The engine is subjected to different loads with the help of dynamometer. A rotameter is provided for engine cooling water flow measurement. A pipe in pipe type calorimeter is fitted at the exhaust gas outlet line of the engine. The calorimeter cooling water flow is measured and adjusted by the rotameter. Temperature sensors are fitted at the inlet and outlet of the calorimeter for temperature measurement. The pump is provided for supplying water to rope drum dynamometer, engine cooling and calorimeter. 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. The engine used for this study is a single cylinder, four stroke, direct injection, water cooled, and diesel engine. The engine is coupled to an electrical generator through which load was applied.

A fixed 220 bar injection pressure, normal injection timing 23°bTDC and 17.5 compression ratio are used throughout the experiments. Indicators on the test bed show the following quantities which are measured electrically: engine speed, brake power and various temperatures. The engine is tested at constant rated speed of 1500 rpm throughout its power range using B0, B10, B20, B30, B40, B60 and B80 blends. Speed of the engine can be measured by tachometer

In diesel engine, diesel is used as pilot fuel and then WCO blends are used as main fuel. For each blend all the engine performance and emission characteristics are noted and examined. For each testing of blends fuel is completely removed from tank, then new WCO blend is added as the fuel and engine performance are tested.

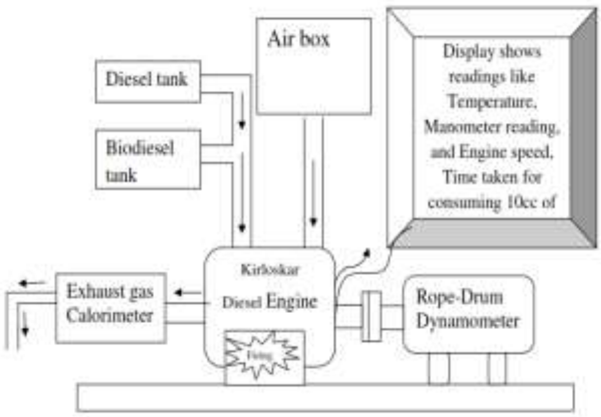

Fig. 3. Layout of the experimental setup

4. PERFORMANCE ANALYSIS AND COMPARATIVE STUDY

4.1 Brake Power

Brake power is the actual or useful power of an engine usually determined from the force exerted on a friction brake or dynamometer connected to the drive shaft. The variation of brake power with respect to load for waste cooking oil and rapeseed is shown in Figs. 4.1 & 4.2, respectively. It is seen from the Figs. 4.1 & 4.2 that, as brake power increases load is also increasing.

4.2 Brake thermal efficiency

The variations of the thermal efficiency (TE) with load for WCO & rapeseed oil are shown in Figs. 4.3 & 4.4, respectively. Thermal efficiency of an engine is defined as the ratio of the brake power output to that of the chemical energy input in the form of fuel supply. It is the true indication with which the thermodynamic input is converted into mechanical work. For all blends tested, thermal efficiency increases with increase in load.

4.3 Brake specific fuel consumption

The variation of the Break specific fuel consumption (BSFC) with load for WCO and rapeseed oil is shown in Figs. 4.5 & 4.6, respectively. It is observed that for all fuel tested BSFC decreases with increase load. BSFC calculated on weight basis, obviously higher densities resulted in higher values for BSFC.

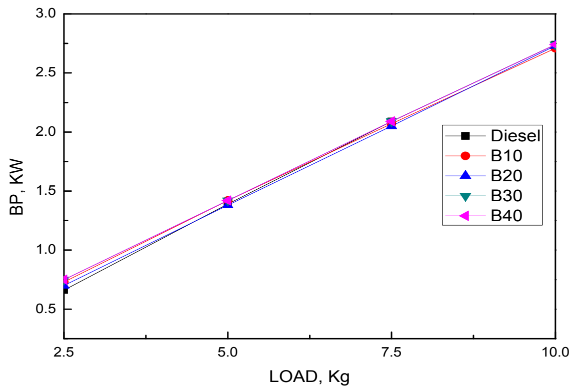

Fig.4.1. Variation of BP V/S Load for waste cooking oil

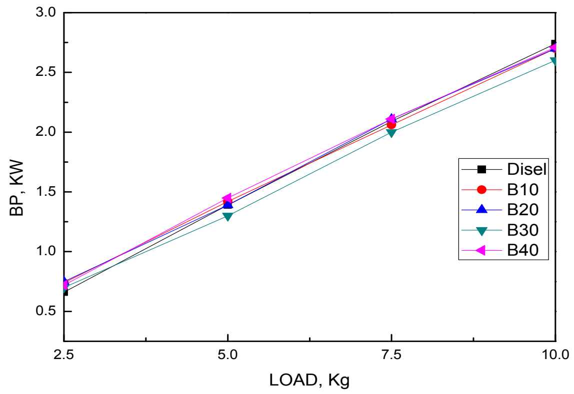

Fig.4.2. Variation of BP V/S Load for rapeseed oil

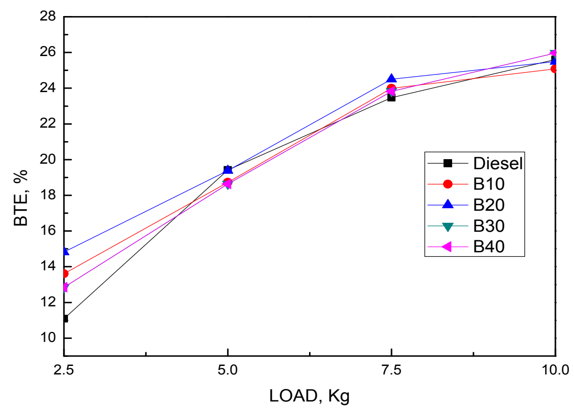

Fig.4. 3. Variation of BTE V/S Load for waste cooking oil

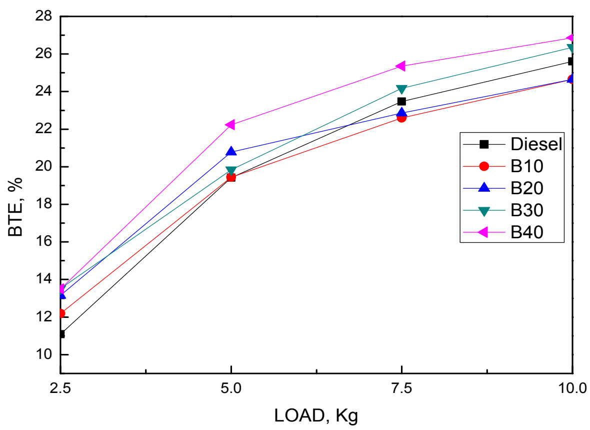

Fig.4. 4. Variation of BTE V/S Load for rapeseed oil

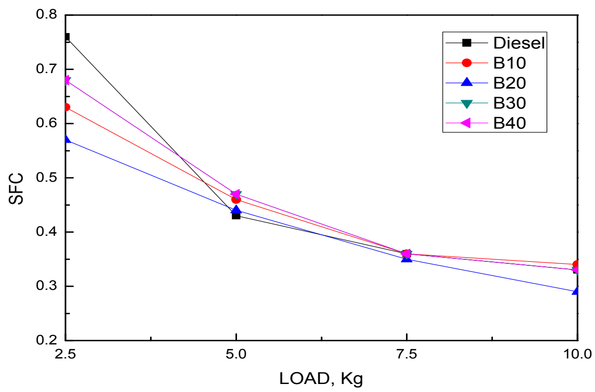

Fig.4. 5. Variation of BSFC V/S Load for waste cooking oil

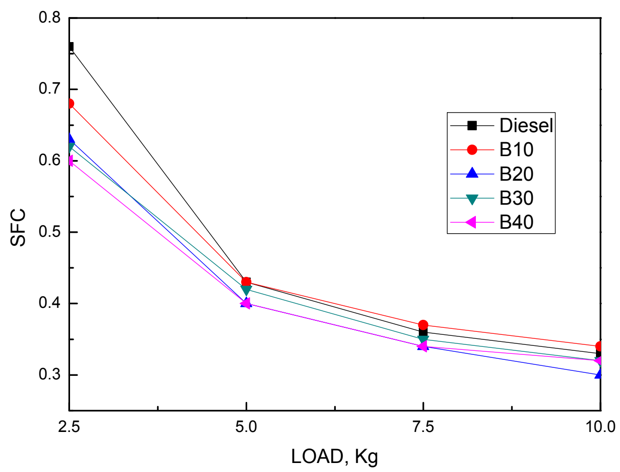

Fig.4. 6. Variation of BSFC V/S Load for rapeseed oil.

5. ENERGY-EXERGY ANALYSIS

Energy analysis of engine is used for engine design so the energy losses can be minimized. The present work includes finding out the major losses through the system and minimization of losses for achieving maximum output. The fuel rate, effective torque, BP, Cooling water loss, exhaust heat are calculated using following equations:

$$Q_f = m_f \times LHV \qquad \text{-----(4.1)}$$

Where, LHV is the lower heating value, and m_f is mass flow rate of fuel, respectively.

$$T = (mg)d \qquad \text{-----(4.2)}$$

$$L = \omega T = \frac{2\pi NT}{60} \qquad \text{-----(4.3)}$$

Where, L is the engine load, ω is the angular velocity and N is the engine speed, respectively.

$$Q_w = m_w C_{pw}\left(T_{w1} - T_{w2}\right) \qquad \text{-----(4.4)}$$

The overall heat in the exhaust gases expressed as a rate of energy flow is given by Eqs. (4.5) & (4.6) is used to calculate heat losses through exhaust.

$$Q_{ex} = \left(m_f + ma\right) C_p \left(T_{ex} - T_a\right) \qquad \text{-----(4.5)}$$

$$Q_{ex} = \frac{m_{gw} C_{pw}\left(T_{w2} - T_{w1}\right)}{T_{e2} - T_{e3}}\left(T_{e1} - T_o\right) \qquad \text{-----(4.6)}$$

Where,

m_{gw} = is the calorimeter mass flow rate,

C_{pw} =is the calorimeter specific heat,

T_{w1} & T_{w2} =are the cooling water temperature inlet & outlet,

T_{e2} & T_{e1} =are the exhaust temperature at engine & inlet to calorimeter,

T_o =is the ambient air temperature,

Further, other losses are determined by using the Eq. (4.7)

$$Q_l = Q_f - \left(BP + Q_w + Q_{ex}\right) \qquad \text{-----(4.7)}$$

These above equations are solved in **MATLAB** software

6. CONCLUSIONS

The present study is carried out in order to compare the performance parameters of CI engine using WCO/Rapeseed biodiesel and mineral diesel. These are the main conclusions of this study:

- In this study, Biodiesel is produced successfully from WCO/ Rapeseed Oil.
- The properties of biodiesel are found very similar to that of mineral diesel. It can be used directly at the place of diesel fuel without any significant alterations in diesel engines.
- Performance characteristics of WCO/Rapeseed biodiesel blends are found to be close comparison to diesel blend.
- Energy-exergy analysis (Using MATLAB) of different biodiesel blends for WCO &Rapeseed oil varied with the different speed and load conditions

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