Evaluation of DI Diesel Engine Performance on Biodiesel from Waste Cooking Oil at Different Load Conditions.

Rajinder Kumar Moom[1], Om Parkash[2], Nimo Singh Khundrakpam[3], Dr. S.K. Mahla[4]

[1,2]Mechanical Engg. Deptt., KC College of Engg. & IT, Nawanshahr.
[3] Mechanical Engg. Deptt, Rayat Institute of Engineering & IT, Railmajra
[4]Mechanical Engg. Deptt., Thapar University, Patiala.

Abstract

Biodiesel is more attractive than petroleum diesel because of its environmental benefits and the reality that it is made from renewable resources and has lower emissions. Present research work deals in the preparation of biodiesel from waste cooking oil, obtained from KC College of Engineering and IT, Nawanshahr, Punjab messes. The performance of a direct injection (DI) diesel engine has also been carried out when fuelled with blends of Diesel-biodiesel, biodiesel-ethanol and diesel-ethanol-ethyl acetate over the entire range of load on the engine.
The experimental results showed that the highest brake thermal efficiency (BTE) 31.12% was observed for D80/E13/EA7 at full load i.e. 7.26% higher than from D100 (28.86%). The higher BSFC for B100 (262.4 g/kWh) is about 14.9 % higher than diesel (223.2 g/kWh) at full load.

Keywords: *Biodiesel, Waste Cooking Oil, Engine Performance. Ethanol, Transesterification,*

I. INTRODUCTION

The demand of energy around the world is increasing at a faster rate as growing on new trends in industrialization and modernization. However, most of the energy consumed in today world is mostly depend on fossil fuel. With rapid increase in the population of vehicles, air quality problems in cities in are major warning to the biodiversity. The oil crisis of the 1970s generated a high interest in biofuels as a possible replacement for fossil liquid fuels used in transportation. Transportation consumes 30% of the global energy, 99% of which is supplied by petroleum [1].

The global warming due to increased Carbon Dioxide (CO_2) emissions, increasing air pollution, increasing in crude oil prices & depletion of fossil fuels are the major problems in the present century. However, a major challenge for a conventionally fuelled CI engine is the simultaneous reduction of NOx. The bio fuels can play an important role towards the switch to a lower carbon economy. Biodiesel can be used in diesel-fueled vehicles without any modification of the engine.

The American Society of Testing and Materials (ASTM) defines biodiesel fuel as monoalkyl of long chain fatty acids derived from renewable lipid feedstock, such as vegetable oil or animal fat for use in diesel engines. “Bio’ represents its renewable and biological source in and “diesel” refers to its use in diesel engines.

CO_2 produced by combustion of biodiesel can be recycled by photosynthesis, thereby minimizing the impact of biodiesel combustion on the greenhouse effect [2]. Also, biodiesel does not pose a threat to human health due to reduction in carbon dioxide emissions as compared to petroleum diesel fuels.

Biodiesel has a relatively high flash point (150^0 C), which makes it less volatile and safer to transport or handle than petroleum diesel [3]. It provides lubricating properties that can reduce engine wear and extend engine life [4]. In short, biodiesel is a good alternative to petroleum based fuel and have led to its use in many countries, especially in environmentally sensitive areas. At present, the high cost of biodiesel due to the cost of virgin vegetable oil [3] is the major blockage to its commercialization.

The use of waste cooking oil instead of virgin oil to make biodiesel is an effective way to reduce the raw material cost because it is estimated to be about half the price of virgin oil [5]). In addition, the problem of waste oil disposal can also help to solve by using waste cooking oil [6].

Vegetable oils cannot uses directly as a fuel due to higher viscosity 10-20 times higher than of petroleum fuel that can cause engine problems like injector fouling and has some drawbacks such as deposits at the injection system with consequent plugs or low atomization, hardening of seals, and low lubricating properties [7].

To reduce the viscosity of vegetable oils, following four ways can be considered: dilution, pyrolysis, microemulsion and transesterification. Transesterification is the most positive way of the fuel viscosity-reduction process. In presence of a catalyst, transesterification process transesterify vegetable oil with an alcohol to fatty acid alkyl esters. Transesterification can be alkali-catalyzed, acid-catalyzed or enzyme-catalyzed. Sodium hydroxide or potassium hydroxides are the commonly used alkali catalysts; sulfuric acid is the typical acid catalyst; and lipase is used for the enzyme-catalyzed system. The transesterification process is as shown in Fig. I.

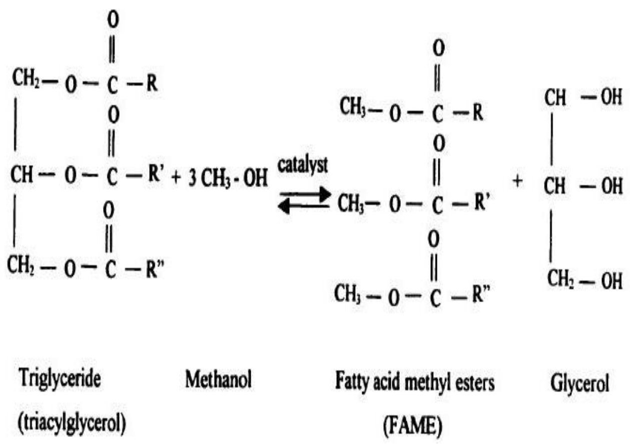

FIG.1: TRANSESTERIFICATION REACTION [8]

Therefore, one of the main tasks of researchers is to comply with the stricter vehicle emission regulations without compromising the economy, reliability and performance of engines. Due to recent advances of diesel engines, compression ignition (CI) direct injection engines show great promise for reducing fuel consumption. However, a major challenge for a conventionally fuelled CI engine is the simultaneous reduction of NOx and particulate emissions to meet the more stringent regulations in the near future.

The oil crisis of the 1970s generated a high interest in biofuels as a possible replacement for fossil liquid fuels used in transportation. In the 1980s and 1990s, increased consciousness of climate change also contributed to the popularity of biofuels as an alternative to fossil fuels. Biodiesel can become an excellent alternative fuel for diesel engine it is free from aromatic compounds and sulfur [9].

Consequently, these countries have to spend their export income to buy petroleum products. The climate changes occurring due to increased Carbon Dioxide (CO_2) emissions and global warming, increasing air pollution and depletion of fossil fuels are the major problems in the present century. Waste cooking oils, restaurant grease and animal fats are potential feedstocks for biodiesel [10]. However, many of these alternative feedstocks may contain high levels of free fatty acids (FFA), water, or insoluble matter, which affect biodiesel production [11]. Many researches have been carried out on biodiesel from waste cooking oil [12-16].

The objective of this study is to produce biodiesel from waste cooking oil obtained from KC College of Engineering and IT, Nawanshahr, Punjab messes. Also performance of DI Diesel engine has been evaluated by conducting various tests when fuelled with blends of Diesel-biodiesel, biodiesel-ethanol and diesel-ethanol-ethyl acetate over the entire range of load on the engine.

II. MATERIALS & EXPERIMENTAL SETUP

Waste cooking oil is collected from KC College of Engineering and IT, Nawanshahr, Punjab messes. It is expressed chemically as triglyceride (or triacylglycerol). The biodiesel or Fatty acid methyl esters (FAME) is produced by transesterification process using methanol as alcohol, sodium hydroxide as catalyst with a by-product of Glycerol. The fuel supply to the engine is measured by graduated glass cylinder having stopcock at the bottom. The glass cylinder is connected to engine by Polyvinylchloride pipe. The properties of diesel, waste cooking oil and biodiesel are given in Table I.

TABLE I

PROPERTIES OF DIESEL, WASTE COOKING OIL AND BIODIESEL

Property parameters	Diesel fuel	Waste cooking Oil	Biodiesel
Density at 20 ^{0}C, g/cm^3	0.88	0.936	0.83
Viscosity at 40 ^{0}C, mm^3/s	2.8	46.4	4.2
Calorific value (kJ/kg)	42000	34500	35600
Flash Point, ^{0}C	68	165	22
Auto-ignition temperature, ^{0}C	210	320	460
Pour Point, ^{0}C	1	3	6
Cetane number	45	56.2	10

The fuels are with blends of conventional biodiesel and ethanol, diesel ethanol and ethyl acetate over the entire range of load on the engine.

A Kiloskar make, single cylinder four strokes DI diesel engine is selected for the present work. The specification of the diesel engine is given in Table II.

TABLE II

SPECIFICATIONS OF THE DIESEL ENGINE

Make	Kirloskar model AV1
No. of Strokes per cycle	4
Type	DI
Output	4.8/6.5 KW/bhp
No. of Cylinders	Single
Combustion chamber position	Vertical
Cooling method	Water cooled
Starting condition	Cold start
Ignition technique	Compression Ignition
Bore Diameter (D)	85 mm
Stroke Length(L)	110 mm
Rated speed	1500 rpm
Rated power	5 hp (3.72 kW)
Compression ratio	16.5 : 1

A single-phase synchronous generator of 2 kVA rating directly coupled to diesel engine. The schematic diagram of the engine test rig is shown in Fig. II.

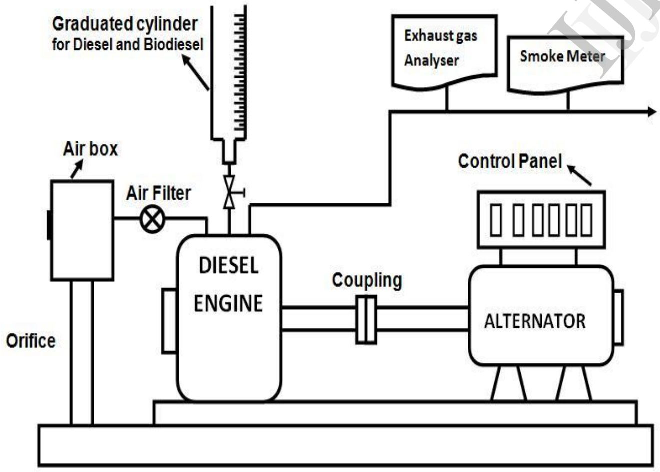

FIG II: Schematic Diagram of Engine Test Rig.

All the experiment is conducted at a speed of 1400 rpm without any change in fuel injection. The full load is run at 5kW. The engine can be loaded up to 5 kW using luminescent bulbs of 100W each. For the experiment engine is loaded by 0%, 20%, 40%, 60%, 80% and 100% (Full Load) of 5kW.

III. OBSERVATION AND RESULTS

The engine was subjected to a pilot runs to find no knocking and trouble on different selected fuel blends of biodiesel-Diesel blends, Biodeisel-ethanol blends and Diesel-ethanol-Ethyl acetate. It is experimentally observed that fuel blends of D50/E27/E23, B70/E40 and higher substitution of diesel (or biodiesel) with ethanol and ethyl acetate produced knocking and unstable engine operations due to lower cetane number and lower calorific values. But all Diesel-Biodiesel blends ran engine smoothly. From the above pilot test some fuel blend is selected to investigate the performance of engine for different load conditions. The selected blends are shown in Table. II

TABLE II

SELECTED FUEL BLENDS

Type of Blend	Code
Biodiesel-diesel Blends	B100
	B40/D60
	B20/D80
	D100
Biodiesel-Ethanol Blends	B60/E40
	B75/E25
	B90/E10
Diesel-Ethanol-Ethyl Acetate blends	D70/E17/EA13
	D80/E13/EA7

Brake thermal efficiency (BTE):

The Brake thermal efficiency is defined as the ratio of output energy available at the engine shaft to the input energy given to the engine. Fig. III shows the variations of Brake thermal Efficiency (BTE) for different load conditions. The brake thermal efficiency (BTE) is increased with the increase of load and dropped abruptly for higher loads for pure diesel and for all of its blends.

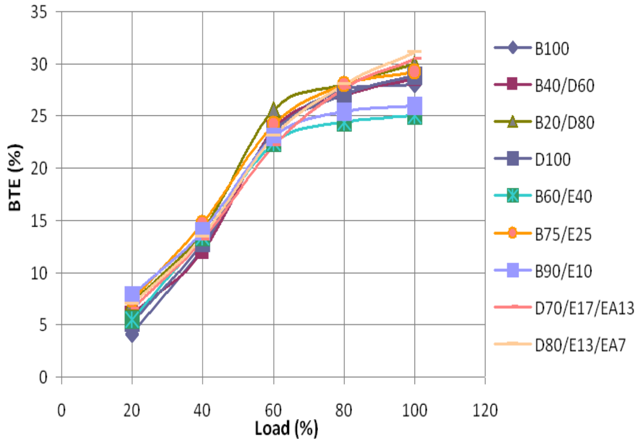

FIG. III: LOAD VS BTE(%)

It is found that value of BTE of pure diesel (D100) is closer to D80/E13/EA7, D70/E17/EA1, B20/D80, B40/D60 and B75/E25. Besides, ethanol has lower viscosity which helps in reducing the viscosity, thus improving the atomization of fuels. Maximum BTE is 31.12 % for D80/E13/EA7 at full load i.e. 7.26% higher than from D100 (28.86%).

Brake specific fuel consumption (BSFC):

Fuel consumed by engine in gm for per kW per hour known as Brake specific fuel consumption (BSFC) at different load is shown in Fig IV. It is obtained that BSFC decreases as the load increases for all type of fuel blends. This result is due to increase in cylinder wall temperature by increasing load reduces the ignition delay.

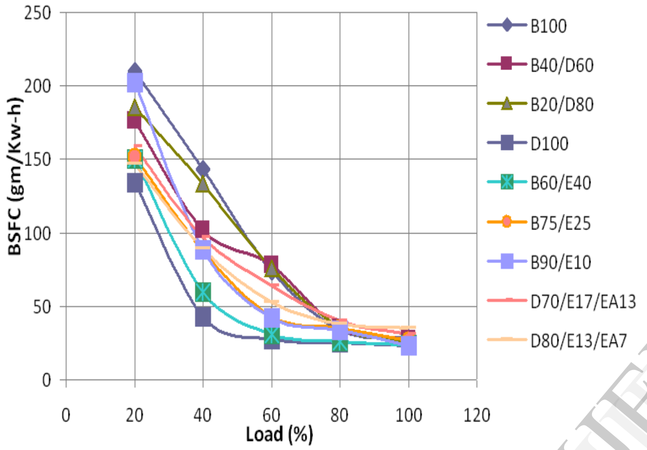

FIG. IV: LOAD VS BSFC

From the Fig. IV, it is found that value of BSFC of pure diesel (D100) is closer to D80/E13/EA7 and B60/E40. The higher BSFC for B100 (262.4 g/kWh) is about 14.9 % higher than diesel (223.2 g/kWh) at full load.

Brake specific energy consumption (BSEC):

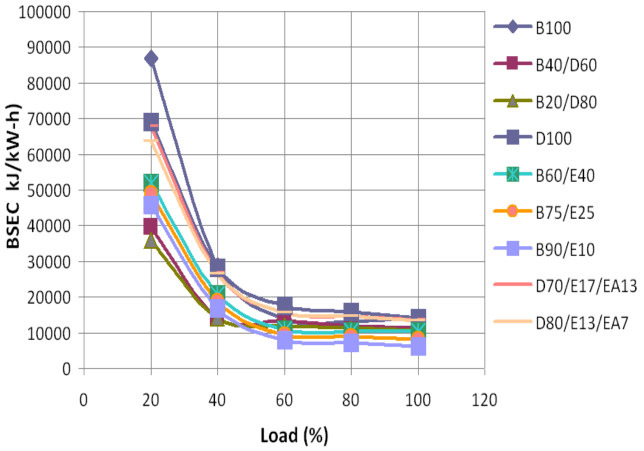

FIG. V: LOAD VS BSEC

Fig. V shows the variations of Brake specific energy consumption (BSEC) for different load conditions. It is found that value of BSEC of pure diesel (D100) is almost lower and closer to all blends of fuels except B100 blend. It is also obtained that at higher at higher load the difference in BSEC is less pronounced which is due to deterioration in the combustion quality of ethanol at higher loads. BSEC of B100 (14458 kJ/kW-h) is about 10% higher than diesel (12868 kJ/kW-h) at full load.

Brake Mean Effective Pressure (BSEP):

Brake Mean Effective Pressure is the average (mean) pressure which, if imposed on the pistons uniformly from the top to the bottom of each power stroke, would produce the measured (brake) power output. The Brake Mean Effective Pressure for different fuel at different load is reported in Fig. VI. It is found that value of BSEP of pure diesel (D100) is closer to D80/E13/EA7, D70/E17/EA13 and B60/E40. B20/D80 has maximum BSEP.

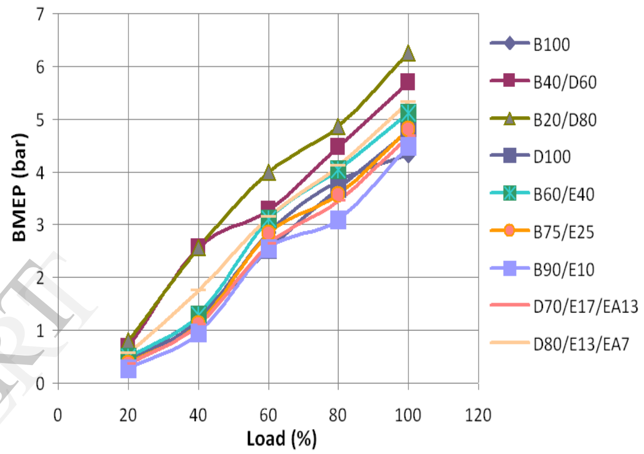

FIG.IV: LOAD VS BMEP

IV. CONCLUSION

The present study effect of various parameters on engine loading was evaluated from waste fried oil obtained from KC College of Engineering and IT, Nawanshahr, Punjab messes. Based on the experimental results, the following conclusion can be concluding:

1. BTE of pure diesel (D100) is closer to D80/E13/EA7, D70/E17/EA1, B20/D80, B40/D60 and B75/E25. Maximum BTE is 31.12 % for D80/E13/EA7 at full load i.e. 7.26% higher than from D100 (28.86%).
2. BSFC of pure diesel (D100) is closer to D80/E13/EA7 and B60/E40. The higher BSFC for B100 (262.4 g/kWh) is about 14.9 % higher than diesel (223.2 g/kWh) at full load.
3. BSEC of B100 (14458 kJ/kW-h) is about 10% higher than diesel (12868 kJ/kW-h) at full load.
4. The biodiesel produced from waste cooking oil obtained from KC College of Engineering and IT, Nawanshahr messes will be 102.5 liters per month. That can be used to run the Diesel generator Set to supply electricity during power shade hours.
5. The emission performance can be studied for the future work.

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