Performance and Emission Study of Diesel Engine Fuelled with Diesel-Biodiesel-Alcohol Blends

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Abstract— Current biodiesel production technologies are not sufficient to produce biodiesel for replacement of diesel entirely. Biodiesel and alcohol may be used in small proportions along with diesel to reduce dependency on diesel. The aim is to study the performance and emission characteristics of diesel-biodiesel-alcohol blends. The blends are chosen with diesel at major proportion to reflect practical conditions. Diesel is blended with animal fat derived biodiesel and alcohol additives such as methanol and ethanol. The engine performance test was carried out and the parameters like brake power, brake thermal efficiency, mechanical efficiency, brake specific fuel consumption and emission characteristics like HC, NOx, CO, CO2 emissions were determined for pure diesel and for the blends. The results indicate that biodiesel-alcohol at low proportions blended with diesel show similar characteristics of performance and emissions as that of neat diesel.

Key words: Diesel Engine, Performance, Emission, Biodiesel, Alcohol Fuel

I. Introduction

The energy needs of human population rising exponentially. Fossil fuels reserves are limited and are depleting at enormous rate. Developments on alternate fuels are not sufficient to meet fuel crisis. The replacement of fossil fuels should be done gradually. One such approach is the addition of alternate fuel with fossil fuel to reduce depletion. The primary fossil fuels are gasoline, diesel and natural gas. For the replacement of diesel, various biodiesel and alcohols have been tested on diesel engine. The problem associated with running diesel engine on biodiesel alone is the requirement of specific alteration to the engine or its components and it makes the approach expensive. The solution to this problem involves mixing these alternate fuels at low proportions to diesel. In this way, diesel consumption is reduced along with minimal impact on the engine.

Previous research articles reviewed for this work are quoted below. Cengiz Oner et al experimentally investigated and evaluated the effects of using biodiesel from animal tallow and its blends with diesel on the engine performance, emission and combustion characteristics of a direct injection diesel engine under variable operating conditions. Biodiesel blended at 20% proportion to diesel was found best of all blends [1]. Metin Guru et al investigated the effects of synthesized nickel and magnesium additives on performance and emission characteristics of diesel engine run on biodiesel form waste animal fat. They also studied various conditions that influenced esterification and trans-esterification of animal fat [2]. Nadir Yilmaz et al analyzed the operation of diesel engine on biodiesel-ethanol and biodiesel-methanol blends. They found that NO_x emissions reduced but CO, HC emissions increased on methanol and ethanol addition to biodiesel [3]. Ivana B.BankovicIlic et al studied the biodiesel production capabilities of waste animal fat from feedstocks. They reviewed and compared biodiesel production from waste fat of various animals. Biodiesel production cost from animal fat processing was found to be cheaper than that for vegetable oil [4]. Atilla Koca et al studied the engine performance and exhaust emissions of single-cylinder, direct injection diesel fueled with chicken fat biodiesel-diesel blends using synthetic Mg additive. Results indicated that brake power lowered and specific fuel consumption with increase in biodiesel proportions [5].

In this paper, the effects of using diesel-biodiesel-alcohol blends on engine performance and emissions had been studied. The blends are prepared with diesel at major proportion aiming to achieve similar performance and emission characteristics of engine that ran on diesel only. For experimental investigation biodiesel was prepared from animal fat and short chain alcohols such as methanol and ethanol are used.

II. Methodology

A. *Experimental Setup*

The physical characteristics of Diesel and Blended fuels are studied. Initially the performance analysis is carried out with base fuel (Diesel) and then with the blended fuel of different proportion. Also the emission analyses for the various blends of fuel are carried out using exhaust gas analyzer in IC engine, and finally they are compared with diesel and blended fuel.

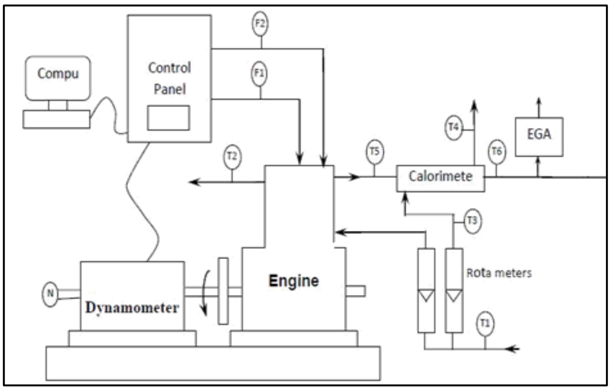

Fig. 1: Line diagram of experimental setup

F1 - Diesel and other blends
F2 - Air inlet
F3 - Engine cooling water supply
F4 - Calorimeter water supply
T1 - Engine water inlet temperature
T2 - Engine water outlet temperature
N - Rpm
T3 - Calorimeter water inlet temperature
T4 - Calorimeter water outlet temperature

T5 - Exhaust gas temperature at calorimeter inlet
T6 - Exhaust gas temperature at calorimeter outlet
Wt – Load

The engine used was kirloskar DI-diesel engine. The smoke meter used for analyzing the exhaust gas is I3SYS EDM 1601. It has the capability to measure four exhaust gas emissions namely CO_2, CO, HC, NO_x. CO and CO_2 is measured in % of sample and HC, NO_x are measured in ppm. Smoke meter has range of 0-99.99% and resolution of 0.01%.

Manufacturer	Kirloskar Oil Engines Ltd., India
Type of Engine	Direct Injection Diesel Engine
Number of Strokes	Four Stroke
Number of Cylinders	Single Cylinder
Cooling	Water Cooled
Engine Speed	1500 rpm, Constant
Rated Power	3.5 kW @ 1500 Rpm
Bore Diameter	80 mm
Stroke Length	110 mm
Type of Loading	Eddy Current Dynamometer
Method of Starting	Manual Cranking
Compression Ratio	16.5:1
Dynamometer Arm Length	0.185 m
Orifice Diameter	0.02 m

Table 1: Experimental engine specifications

B. *Preparation Biodiesel and Blends*

Animal Fat was heated to 60˚C in a conical flask. Simultaneously, methanol (30:1 of animal molar ratio) was heated in another flask with sulphuric acid (25%). Then two solutions were mixed in a flask fitted with magnetic stirrer. Temperature was maintained at 60˚C for entire reaction time of 45 minutes. After that, the mixture was transferred to separating funnel. After 12 hours in separating funnel, the biodiesel moved to upper portion of the funnel and the glycerol settled down. The biodiesel was separated from the funnel by drowning the glycerol from the funnel. Then the oil was mixed with distilled water about half the volume of oil. Then 2-3 drops of Ortho-phosphoric acid was added and bubbled for half an hour and repeated until clean water deposited under the funnel. Then the washed biodiesel was heated above 110˚C for 15mins. It was accompanied by continuous stirring by magnetic stirrer and allowed to cool.

The biodiesel from animal fat, diesel, alcohols were mixed at various proportions in order to obtain test fuels to be fuelled in engine. The fuel blends prepared are:

– D100 =100% diesel
– D80B20 =80%diesel+20% biodiesel
– D80B10E10=80%diesel +10%biodiesel+10%ethanol
– D80B15E5 =80% diesel+15%biodiesel+5% ethanol
– D80B10M10=80%diesel+10%biodiesel+10%methanol
– D80B15M5=80%diesel+15%biodiesel+5% methanol

III. RESULTS AND DISCUSSION

A. *Properties of Blended Fuels*

The viscosity (at 40°C) of oil samples was measured using Redwood viscometer and expressed in cSt according to ASTM D6751 (2003) standard. The flash point and fire point of the oil sample was measured using Pensky Martin's open cup apparatus.

Fuel blend	Viscosity	Density	Calorific Value	Flash Point	Fire Point
Unit	cSt	kg/m^3	MJ/kg	˚C	˚C
D100	3.4	830	42.86	63	72
D80B20	3.64	840	41.46	68	79
D80B10E10	3.29	831	40.36	61	69
D80B15E5	3.47	836	40.88	64	74
D80B10M10	3.24	832	39.57	57	66
D80B15M5	3.44	835	40.44	59	68

Table 2: Measured properties for the blends

B. *Performance characteristics*

Brake specific fuel consumption (BSFC) is the amount of fuel consumed per unit brake power. The lowest specific fuel consumption is for diesel. It is due to the fact that calorific value of diesel is higher than that of biodiesel and alcohols.

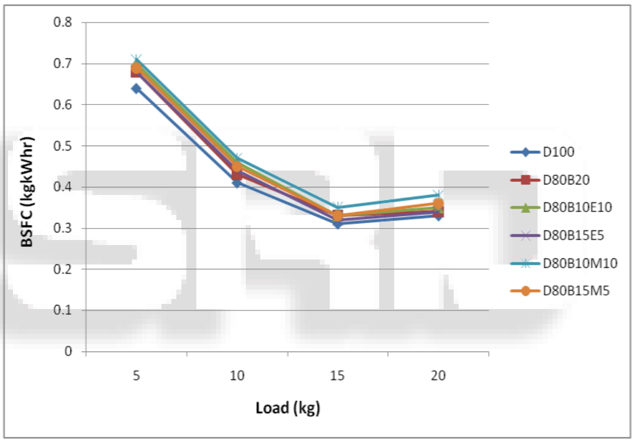

Fig. 2: Brake Specific Fuel Consumption Vs Load

Similarly, Brake thermal efficiency (η_{BT}) is higher for diesel. Thermal efficiency depends on factors such as calorific value, cetane number, density, viscosity of fuel and its atomisation technique. From the graphs, it is evident that addition of alcohol fuel lowers performance parameters. But the effect is mitigated at lower proportions of alcohols.

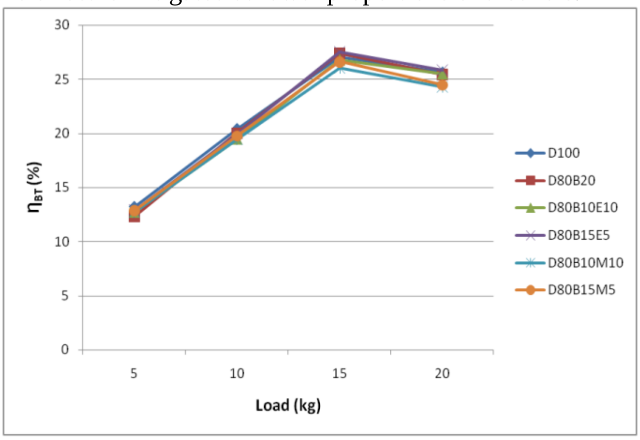

Fig. 3: Brake Thermal Efficiency Vs Load

C. Emission characteristics

Major emissions are Carbon monoxide (CO), Carbon dioxide (CO_2), Hydrocarbon (HC) and Nitrous oxide (NO_x). Exhaust emissions from engines are the major contributors of air pollution. Emissions from exhaust gases increase due to incomplete combustion of fuel and higher cylinder temperature. Incomplete combustion results from lack of oxygen and low residence time. Higher cylinder temperature is result of higher load on engine and higher compression ratios.

Carbon monoxide emissions are the result of incomplete combustion which is due to the lack of oxygen and lower combustion temperature. Although CO emissions are increased by addition of alcohols due to lower combustion temperature because of their high latent heat of vaporization, this effect is subdued by rich oxygen content of alcohols which reduce CO emissions by providing excess oxygen for combustion.

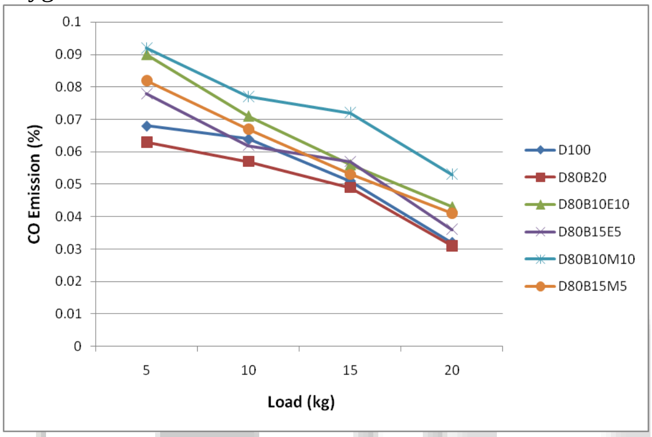

Fig. 4: Carbon monoxide content Vs Load

Carbon dioxide emissions increase with complete combustion. Lower CO_2 levels by addition of biodiesel and alcohols indicate incomplete combustion. The addition of alcohols to diesel-biodiesel blends improves combustion which is indicated by increased CO_2 emissions. CO_2 increases as CO gets oxidized more by excess oxygen from alcohol fuels.

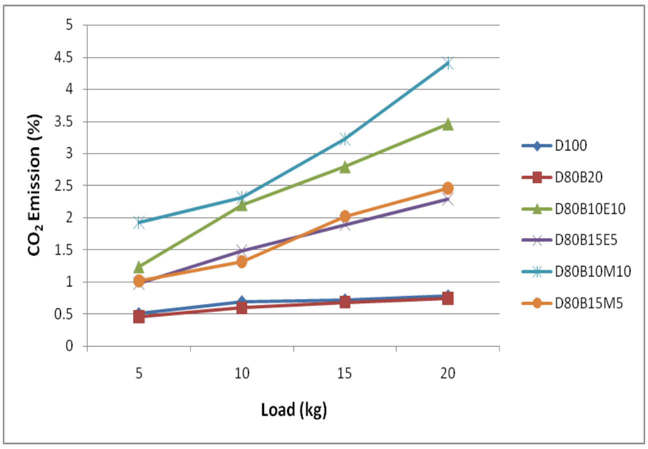

Fig. 5: Carbon dioxide content Vs Load

Hydrocarbon emissions are due to inadequate combustion. The HC emissions are roughly at same levels irrespective of the blends. This indicates that type of fuel has minimal impact on unburned hydrocarbon emission.

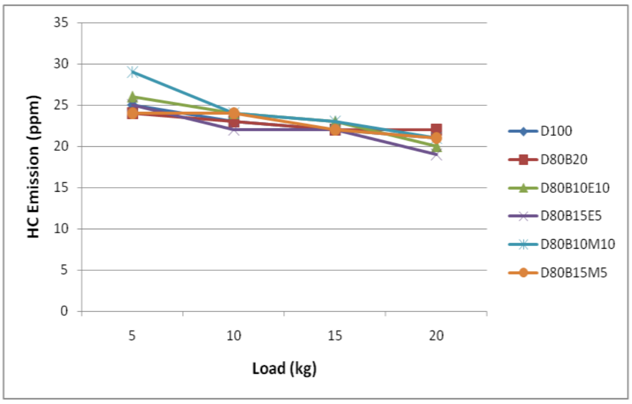

Fig. 6: Hydrocarbon content Vs Load

Nitrous oxide emissions are the result of high temperature resulting from combustion. Very high temperature results the oxidation of nitrogen to oxides of nitrogen. The alcohols added in fuels reduce ignition temperature due to high latent heat of vaporization. The alcohol addition results in huge reduction of NO_x emission. As seen from graph, diesel and biodiesel blends show higher NO_x emission and the addition of alcohols reduces nitrous oxide emission drastically.

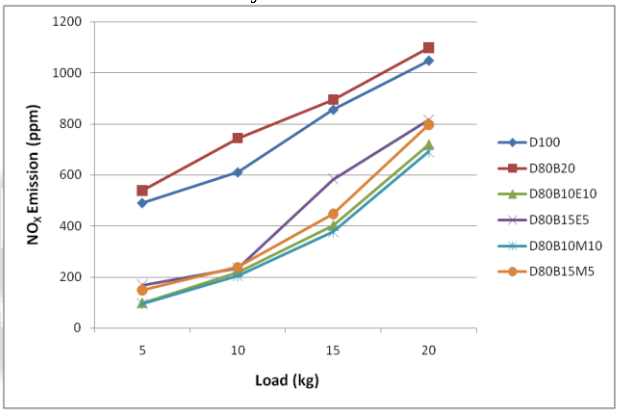

Fig. 7: Oxides of Nitrogen content Vs. Load

IV. CONCLUSION

Brake Specific Fuel Consumption increases with alcohol percentage in blends and this may be attributed to low calorific values of alcohols. Thermal efficiency seldom deviates below 4% of maximum. Carbon monoxide contents in the emission increased while using alcohols and are lower for D80B20 blend. Hydocarbon content in emission from blends does not deviate much from that of diesel. Nitrous oxide emission drastically reduced with use of alcohols which was highest on D80B20 blend. Addition of alcohols to diesel-biodiesel blends shows decreased performance and increased CO, HC emissions. But NO_x emissions are reduced on these blends due to lower ignition temperature resulting from high latent heat of vaporization of alcohols. Ethanol addition showed better characteristics than methanol addition. Results indicate that alcohols may be used as oxygenated additives in small proportions (5%) on diesel-biodiesel blends to reduce nitrous oxide emissions at the cost of slightly increased CO, HC emissions.

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