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Performance Characterization of Single Cylinder DI Diesel Engine Blended with castor oil and Analysis of Exhaust Gases

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Abstract

Continuous increase in fuel prices and fast depletion of the available petroleum reservoirs has renewed an interest in the field of biodiesel. In this contest an experimental investigation has been conducted on single cylinder diesel engine fuelled with the blends of castor (B20, B40, and B60) and diesel. Engine performance is also evaluated using castor fuel without any modification in a present engine. Experimental test have been carried out for performance characterization of water cooled DI diesel engine. The effect of these fuel blends is studied experimentally using 3.75 kW DI diesel engine. Experiments were conducted for different blends and its effect on break power, fuel consumption, break thermal efficiency, volumetric efficiency exhaust gas temperature etc with respect to the load on the engine are reported.

1. Introduction

Low fuel consumption and better efficiency are the facts that attracts towards the use of diesel engine. Increasing consumption rate of diesel fuel and environmental issues has renewed an interest of the researchers to explore the alternative fuels to diesel fuel. Presently petroleum fuel including diesel is depleting at an increased consumption rate of 3% [10]. Easy availability, renewable and greener to the environment is the three major advantages of the biodiesels to attract major researchers. Because of similar properties with the diesel fuel bio diesel can be considered as a better alternative to the diesel fuel [9]. Also the biodiesel has lower sulphur and aromatics contents and reduced CO_2 emissions compared with diesel fuel [2]. 20% blend of biofuels with diesel has been approved by the Gov. of India in 2009. About 38 million tones of petroleum products are consumed in India in the year 2007. It is expected that it may be doubled by the end of 2030. This implies a larger scope of production and use of biofuels in India. [3-6]. Biodiesel are produced by transesterification process. Transesterification is a process in which esters of saturated and unsaturated monocarboxylic acids of common vegetable oil and animal fats are react with alcohol in Presence of catalyst.

2. MATERIALS AND EXPERIMENT

Commercial diesel fuel used in India which was obtained locally is used as a base line fuel for this study. Test fuel samples are prepared at I.O.K.College of engineering and properties are tested from the third party Renata precision Services, Chemical Lab at Pune (MS). Density and Heating value of test fuels is as given in the table 1

Table – 01 Property of Fuel Samples

FUEL	Density (Kg/m3)	Calorific Value (KJ/Kg)
Diesel	861	47216.4
B20	864.3	44500
B40	870.3	44780
B60	926.6	37900.8

Experiments were performed with Kirloskar make single cylinder diesel engine. This is a single cylinder, water cooled open combustion chamber diesel engine. Technical details of the engine are given in Table 2. All experiments were performed after ensuring the full warm-up. A plan was designed for the experimental investigation. Different blends of fuels were tested. The tests were conducted for different blends and were repeated for four times for every kind of fuel, in order to increase the reliability of the test results. For each of the fuel blend, the engine was run on five different loads, i.e. idle 0 kg, 2kg, 4kg, 6kg and 8kg of break load on dynamometer. The engine load was controlled by dynamometer.

Table – 02 Engine Specifications

Sr.No.	Parameter	Specification
1	Make	Kirloskar AV1
2	Number of Cylinder	1
3	Number of Stroke	4
4	Bore	85mm
5	Stroke	110mm
6	Power	3.75KW
7	Compression Ratio	18:01

The engine performance tests were conducted with a rope brake-diesel engine set up. The Parameters like speed of engine, fuel consumption and torque were measured at different loads for diesel and with various combinations of dual fuel. Brake power, brake specific fuel consumption and brake thermal efficiency was calculated using the collected test data. The engine was sufficiently warmed up at every stage and the cold water temperature was maintained at 52 °C. The fuel injection pressure was maintained at 200 bar throughout the experiment. A Honey Well Chromel-Alumel thermocouple with a digital display meter was used to measure the exhaust gas temperature. Fig. 01 shows the photograph of the DI Diesel engine and set-up.

Fig.01 Experimental setup diagram of Diesel Engine

3. ENGINE TEST RESULTS AND DISCUSSION

3.1. Brake Thermal Efficiency

Brake thermal efficiency is defined as break power of a heat engine as a function of the thermal input from the fuel. Brake thermal efficiency for 20% blend of castor oil is very close to that of diesel. Maximum brake thermal efficiency is obtained at 4 kW loads. Brake thermal efficiency for 40% and neat castor oil is lower compared to diesel at rated load. Brake thermal efficiency for B20, B40 and B60 is observed as 8.50%, 8.39% and 10.41% while diesel has 9.38%.This may be caused due to lower calorific value, high viscosity coupled with density of the fuel.

The detail graphs for brake thermal efficiency of B20, B40 and B60 are as follows:

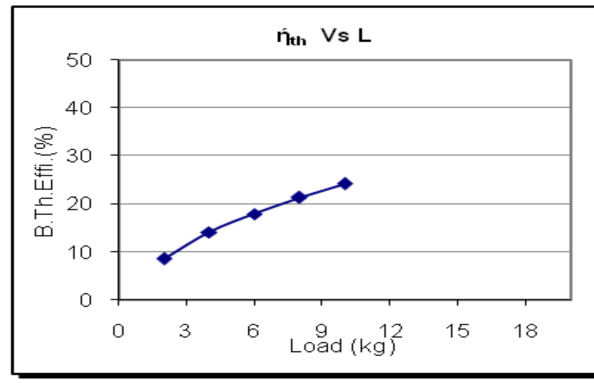

Fig.02 Brake thermal efficiency vs. load on the engine for (B20)

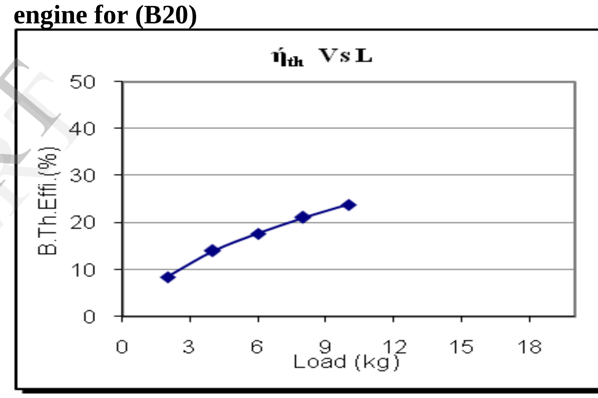

Fig.03 Brake thermal efficiency vs. load on the engine for (B40)

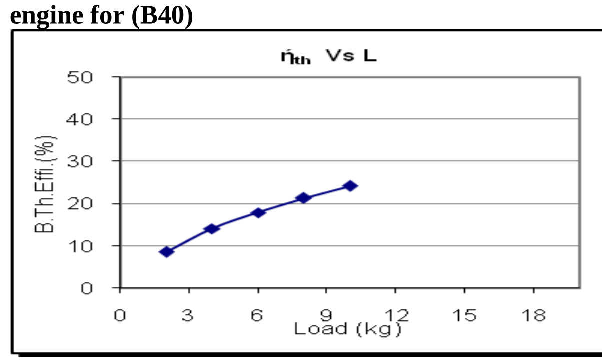

Fig.04 Brake thermal efficiency vs. load on the engine for (B60)

3.2. Brake specific fuel consumption (bsfc)

Brake specific fuel consumption (bsfc) is a measure of fuel efficiency within a shaft reciprocating engine. It is the rate of fuel consumption divided by the power produced. It may also be thought of as power-specific fuel consumption, for this reason. Bsfc allows the fuel efficiency of different reciprocating engines to be directly compared. Any engine will have different bsfc values at different speeds and loads. The variation of brake specific fuel consumption with brake power output for castor oil and its blends in the test engine. 60% blend of castor oil has the lowest bsfc compared to its other blends. bsfc for 60% blend of castor oil is slightly similar than that of diesel. At rated load, bsfc of Neat castor oil is 0.325 Kg/kw-hr, where as for diesel it is 0.210 Kg/Kw-hr. At rated load, bsfc of neat castor oil is higher by 54.76% compared to diesel. Graph shows the effect of fuel consumption on the engine for various blends. Results shows that about 20 % loading of the engine fuel consumption for castor fuel for all the blends is smaller compare with higher load on the engine. For a blend of B40 it is observed that the fuel consumption is less than that of pure diesel. At maximum loading 70% the fuel consumption for pure diesel is lower than any other blend. Graph represents break specific fuel consumption bsfc with respect to the loading of the engine. Brake specific fuel consumption (bsfc) for B20 is observed as 0.95 kg/kgh while brake specific fuel consumption (bsfc) for B40 is observed as 0.96 kg/kgh.The difference is obtained in case of B60 and it is 0.91 kg/kgh.The brake specific fuel consumption (bsfc) for diesel is 0.91 kg/kgh.Graph shows the effect of brake specific fuel consumption with respect to the load on the engine. No any significant changes are observed over the entire range of the loading of the engine and different blend %.This observed phenomenon is may be due to higher viscosity of the fuel.

The detail graphs for bsfc are as follows:

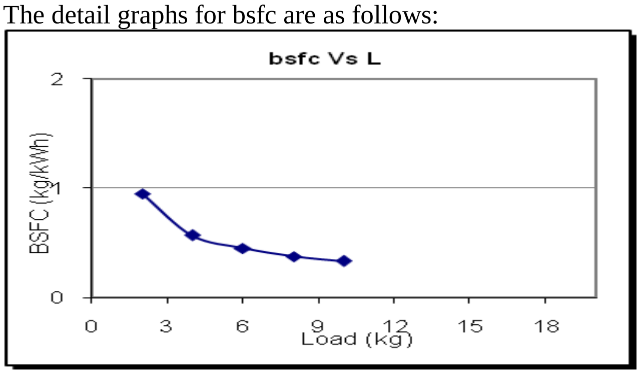

Fig. 5 Brake specific fuel consumption (bsfc) vs. load on the engine for (B20)

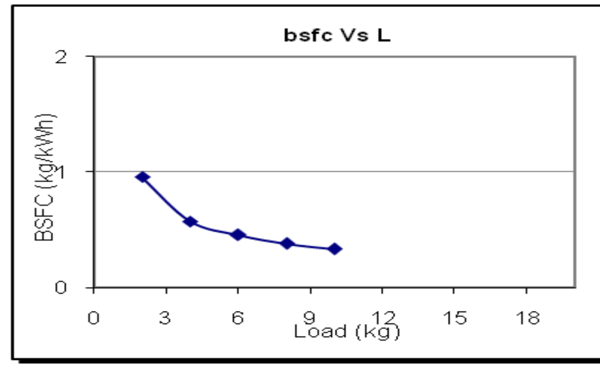

Fig. 6 Brake specific fuel consumption (bsfc) vs. load on the engine for (B40)

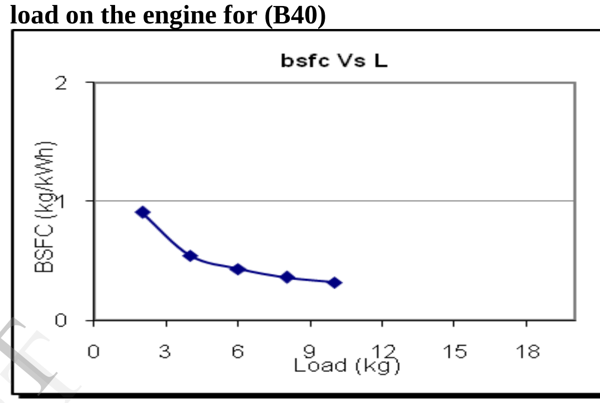

Fig. 7 Brake specific fuel consumption (bsfc) vs. load on the engine for (B60)

3.3. Exhaust gas temperature

EGT represents the exact temperature of the fuel mixture after it "combusted" in the cylinder. This should be measured as close to the outlet valves as possible. It is common believe that EGT on diesel engines that exceed 720°C, may cause permanent engine component damage. This may vary slightly as different engines are made from different alloys that have varying heat properties. The rule of thumb is to keep EGT below the 720°C mark. Under normal driving conditions the EGT may vary between 250 to 680°C. It will increase when driving up-hill and may even pass the "safe-point 720°C" if you really push the motor hard. The EGT monitor consists of the following components probe that will measure the exhaust gas temperature in the exhaust manifold. We may go wild and install a probe for each cylinder, but for practical ease it is decided to measure a sample of the combined exhaust gas in the manifold. An electronic chip that will receive the input from the probe and translate it into a low voltage output, typically translating 10 mille-volts per 1°C. The variation of exhaust gas temperature with brake power output for castor oil and its blends in the test engine is calculated. EGT for 20 % blend of castor oil is lower at no load and higher at rated load. However all other blends of castor oil have higher egt

compared to diesel. 20% blend of castor oil has higher performance than other blends. Fig.c-1 to c-3 shows the effect on the exhaust gas temperature of the engine. With increase in load on the engine the exhaust gas temperature increases however for castor biodiesel the gas temperature is lower than that of the diesel fuel at higher load, whereas at low and part load operation it is observed to be greater than that of the diesel fuel. For other blends not much more variation is observed for the gas temperature except for the higher loading. The exhaust gas temperature for the diesel fuel is higher than that of castor fuel. However for the blends of B40 and B60 are observed to be lower than that of diesel. This may be the results of high A/F. The lower exhaust gas temperature indicates that the effects of dissociation are significantly reduced that may reduces the pollutant CO. Exhaust gas temperature forB20; B40 and B60 are expressed in terms of graphs. This type of variation may be occurred due to reduction in exhaust heat loss and also may be the results of high A/F.
The detail graphs for EGT of B20, B40, and B60 are as follows:

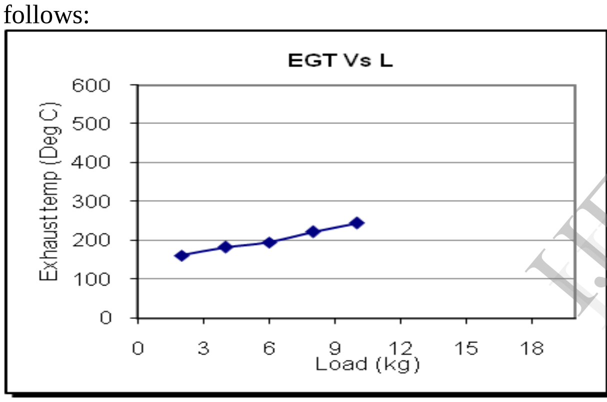

Fig. 8 Exhaust gas temperature vs. load on the engine for (B20)

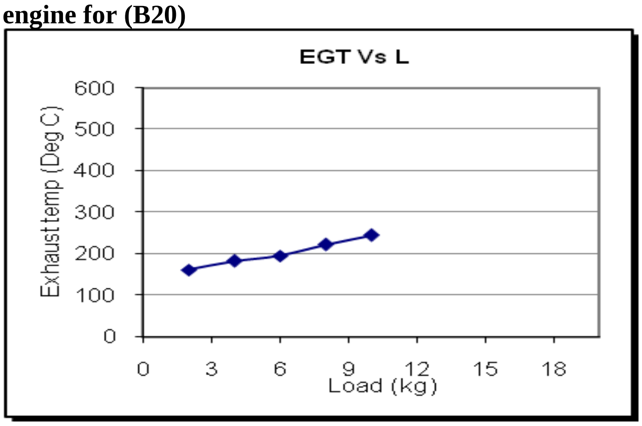

Fig. 9 Exhaust gas temperature vs. load on the engine for (B40)

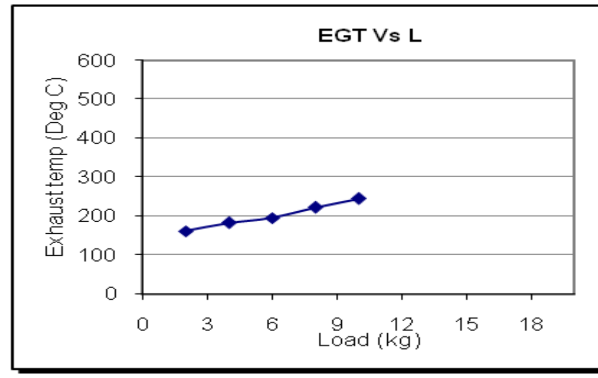

Fig. 10 Exhaust gas temperature vs. load on the engine for (B60)

3.4. Volumetric Efficiency

Volumetric efficiency is a technical term used for comparing performance or some other measurable parameter per unit of physical volume. Volumetric efficiency in internal combustion engine design refers to the efficiency with which the engine can move the charge into and out of the cylinders. More specifically, volumetric efficiency is a ratio (or percentage) of what quantity of fuel and air actually enters the cylinder during induction to the actual capacity of the cylinder under static conditions. Therefore, those engines that can create higher induction manifold pressures - above ambient - will have efficiencies greater than 100%. Volumetric efficiencies can be improved in a number of ways, but most notably the size of the valve openings compared to the volume of the cylinder and streamlining the ports [5]. Engines with higher volumetric efficiency will generally be able to run at higher speeds (commonly measured in RPM) and produce more overall power due to less parasitic power loss moving air in and out of the engine**.** The variation of volumetric efficiency with brake power output for castor oil and its blends with diesel in the test engine is calculated. Volumetric efficiency for 20% blend of castor oil is almost same as diesel. Diesel has high volumetric efficiency. Compared to all other blends. Volumetric efficiency of castor oil is 75.20% at rated load and that of diesel is 75.35%. Volumetric efficiency of neat castor oil is lower by 0.19 % compared to diesel at rated load. This is due to higher exhaust gas temperature released after the combustion process. Graph shows the effect on volumetric efficiency of the engine. Efficiency of the engine with pure castor biodiesel is observed to be greater than that of the diesel fuel [4]. Irrespective of the load on the engine volumetric efficiency is observed to be maximum for the blends of B 40 and B60. Volumetric Efficiency for B20 blend is observed as 81.21%, Volumetric Efficiency for B40 blend is observed as 81.22% while

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for B60 it is observed that 82%.This may be due to low exhaust gas temperature.

The detail graphs for volumetric efficiency of B20, B40, and B60 are as follows:

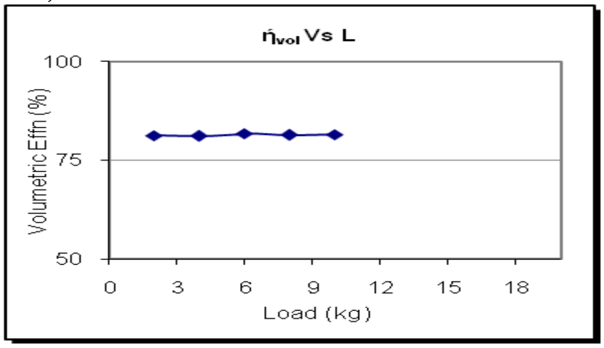

Fig. 11 Volumetric Efficiency vs. load on the engine for (B20)

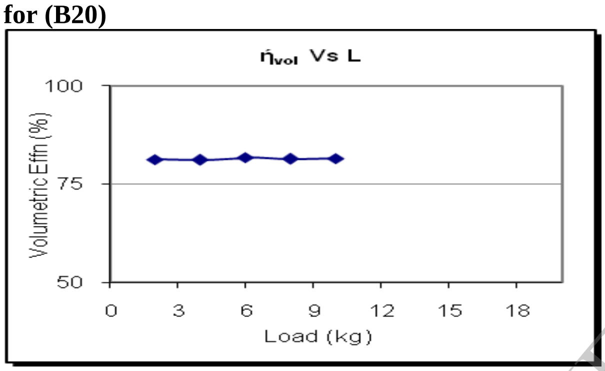

Fig. 12 Volumetric Efficiency vs. load on the engine for (B40)

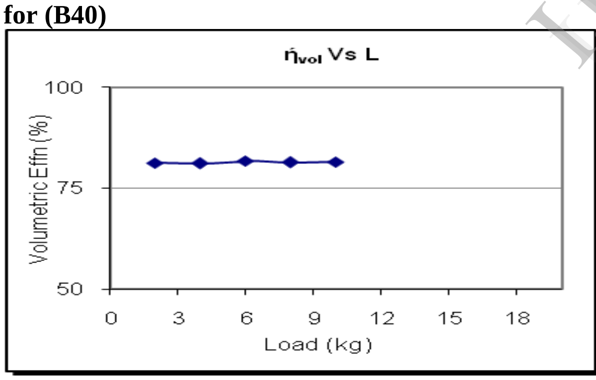

Fig. 13 Volumetric Efficiency vs. load on the engine for (B60)

4. Exhaust gas analysis

The high viscosity of the castor biodiesel limited maximum blend ratio to 20% only by volume. The emissions of CO_2, CO, NO_X, and SO_2 against fuel type are studied. With exception to the increases in carbon dioxide and oxides of nitrogen emissions with more biodiesel blended in the fuel mixtures, all other pollution parameters were found to decrease in general. Results were similar to those reported by other research workers In diesel engines without exhaust gas recirculation (EGR), the combustion of bio diesel almost always results in higher CO_2 in exhaust gases in comparison to diesel fuel combustion regardless of fuel injection type used. This is due to the presence of more carbon atoms as well as higher oxygen content in biodiesel fuel. In addition, bio diesel is more fuel-rich than diesel fuel thus resulting in higher combustion temperatures and high exhaust gas temperatures .These reasons result in less oxygen content in exhaust gases obtained from the combustion of bio diesel fuel in comparison to mineral diesel fuel.

4.1 Carbon Monoxide

The variation of Carbon monoxide emissions with Brake power output for castor oil and its blends with Diesel in the test engine. CO emission for 20% blend of castor oil is compared with diesel at all loads. Castor oil has the highest CO emission for all loads compared to all other blends. CO emission for castor oil at rated load is higher by 96% compared to diesel. This is the result of incomplete combustion of the fuel.

4.2 Carbon Dioxide

The variation of Carbon Dioxide emission with brake power output for castor oil and its blends with diesel in the test engine is analyzed. 20% blend of castor oil has lower CO_2 compared to all other blends. Castor oil has the highest CO_2 emission for all loads. CO_2 emission for castor oil at rated load is higher by 19.18% compared to diesel. Excess supply of oxygen is the influencing criterion.

4.3 Un-burnt Hydrocarbons

UHC emission for 26.25% blends and castor oil is 79 ppm and 89 ppm, where as for diesel it is 74 ppm. UHC emission for 20% blend and castor oil at rated load is higher by 6.75% and 20.27% respectively compared to diesel. In this phenomenon formation of rich air–fuel mixture plays a vital role.

4.4 Nitrogen oxides

Nitrogen oxide can refer to a binary compound of oxygen and nitrogen, or a mixture of such compounds. NO_x (often written NO_x) refers to NO and NO_2. They are produced during combustion, especially at high temperature. The variation of Nitrogen Oxide emission with brake power output for castor oil and its blends with diesel in the test engine is studied. Diesel has higher NO_x blends. NO_x emission compared to all other emission for 25 % blend of castor oil is well compared with diesel at all loads .NO_x emission for 25% blend of castor oil at rated load is 55 ppm, where as for diesel it is 58 ppm [11].The difference is 3 ppm. i.e. castor oil NO_x emission is lower by 5.45% compared to diesel.

Lower peak combustion temperature in the combustion chamber influences this factor.

5. Conclusion

Experimental investigations were performed on single cylinder DI diesel engine. Test where conducted on water cooled 3.75 kW diesel engine. Different fuel blends of Castor biodiesel, diesel and Castor biodiesel only were tested. Result shows that the break power of the engine was almost same for all the loads. However break thermal efficiency of the Castor biodiesel where improved by 3 to 8%, Volumetric efficiency is also improved with reduction in exhaust gas temperature. Results obtained here shows that the Castor biodiesel can itself directly used in the engine without any major modification. It is also observed that the blends of B 40 and B 60 will have the optimum performance for the given conditions as explained earlier.

6. References

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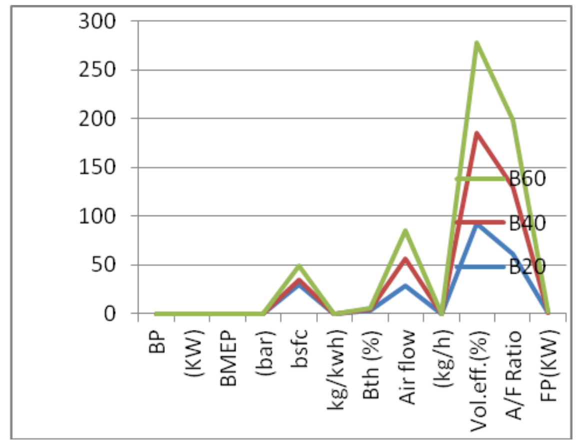
7. Result Tables and Graphs

Comparative results analysis of fuel

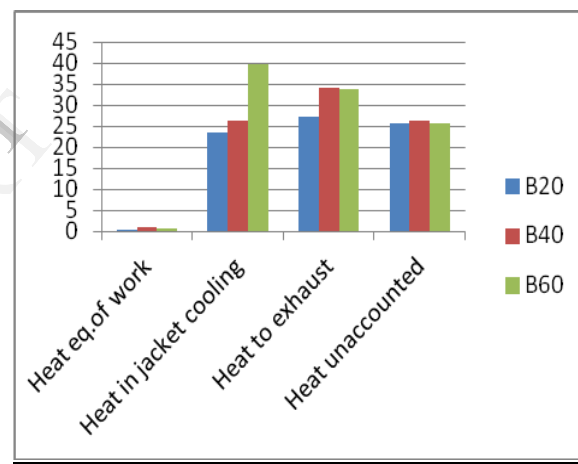
Parameter	B20	B40	B60
BP (KW)	0.152	0.096	0.03
BMEP (bar)	0.197	0.118	0.035
bsfc kg/kwh)	30.26	4.52	14.03
Bth (%)	2.834	1.89	0.61
Air flow (kg/h)	28.34	28.26	28.26
Vol.eff.(%)	93	92	93
A/F Ratio	61.66	68.49	68.92
FP(KW)	0.4596	0.41	0.75

Comparative Heat balance sheet analysis of fuel

Parameter	B20	B40	B60
Heat eq. of work	0.28	0.89	0.61
Heat in jacket cooling	23.58	26.18	39.88
Heat to exhaust	27.33	34.12	33.75
Heat unaccounted	25.76	26.33	25.76



Comparative results analysis of fuel



Comparative Heat balance sheet analysis of fuel