Comparative Study of Performance of a Dual Fuel Compression Ignition Engine with LPG and Biodiesel

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Abstract-Energy is an essential and vital input for economic activity. Energy demand is increasing due to ever increasing number of vehicles employing internal combustion engines. Building a strong base of energy resources is a pre-requisite for the sustainable economic and social development of a country. The world is presently confronted with the twin crises of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction their underground resources. The Alternative fuels have become very important for both Spark Ignition (SI) and Compression Ignition (CI) engines owing to increased environmental protection concern, the need to reduce dependency on petroleum and even socioeconomic aspects. Fuels that are most used at present are Natural Gas, Liquefied Petroleum Gas (LPG) and biofuels, such as transesterified vegetable oils and alcohols. Liquefied Petroleum Gas is a mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles. LPG can be a major energy resource of the future due to its clean burning nature and eventual availability from renewable sources. LPG is widely regarded as a promising transportation fuel because it is clean and renewable. Biodiesel, as an alternative fuel, has many merits. It is derived from a renewable, domestic resource, thereby relieving reliance on petroleum fuel imports. It is biodegradable and non-toxic. Biodiesel has a relatively high flash point, which makes it less volatile and safer to transport. It provides lubricating properties that can reduce engine wear and extend engine life. These merits of biodiesel make it a good alternative to petroleum based fuel and have led to its use in many countries, especially in environmentally sensitive areas. The present work is an experimental investigation on 4 stroke CI engine in dual fuel mode with diesel as injected fuel, LPG as inducted fuel. The engine is also run with biodiesel (Waste Cooking Oil) separately. The engine is run under different operating conditions and in each case the optimum flow rates of LPG and biodiesel is determined for best efficiency. At each operating condition, the efficiency, exhaust gas temperature and other performance parameters are obtained and compared.

Keywords – Alternative fuels, LPG, Biodiesel

I. INTRODUCTION

Over the last two centuries, human activity has transformed the chemistry of Earth’s water and air, altered the face of Earth itself, and rewoven the web of life. The reasons for these environmental changes are many and complex. But a major influence surely is the use of fossil fuels, which has made far more energy available to more people than had ever been available before. Compression ignition engines are preferred prime movers due to their excellent drivability and higher thermal efficiency. In order to meet the norms and also the fast depletion of oil reserves have necessitated a search for alternate fuels for diesel engines. On the other hand, due to the rapid growth of automotive vehicles in transportation sector, the consumption of oil keeps increasing. The merits of diesel engines, compared to other internal combustion engines, are lower fuel consumption, and unburned hydrocarbons, due to the overall lean and better energy release efficiency due to a controlled nonhomogeneous combustion at high pressures. Over the past two decades there has been a considerable effort to develop and introduce alternative transportation fuels to replace conventional fuels, gasoline and diesel. Environmental issues are the principal driving forces behind this effort. The internal combustion engines are an indispensable and integral part of our present day life. Energy is an essential requirement for economic and social development of any country. Sky rocketing of petroleum fuel costs in present day has led to growing interest in alternative fuels like vegetable oils, alcoholic fuels, CNG, LPG, Producer gas, biogas in order to provide a suitable substitute to diesel for a compression ignition (CI) engine. The vegetable oils present a very promising alternative fuel to diesel oil since they are renewable, biodegradable and clean burning fuel having similar properties as that of diesel.

II.EXPERIMENTAL SETUP

A single cylinder four stroke diesel engine was retrofitted with additional equipment and instrumentation so as to run as LPG – Diesel dual fuel engine. It is fitted with data acquisition system which in turn is interfaced with a personal computer. Fig 2.1 shows a schematic diagram of the experimental setup of LPG – Diesel dual fuel engine. It consists of a single cylinder four-stroke water-cooled CI engine connected to an eddy current dynamometer. It is provided with temperature sensors for the measurement of jacket water, calorimeter water and calorimeter exhaust gas inlet and outlet temperatures. Pressure sensors are provided for the measurement of combustion gas pressure and fuel injection pressure. The signals from these sensors are interfaced with a computer to an engine indicator to display pressure-crank angle, pressure-volume plots. Provision is also made for volumetric liquid fuel flow measurement. A differential pressure transducer detects the air pressure difference across the orifice. This information is fed into the computer for calculation of the air flow rate. The LPG cylinder is connected to the inlet manifold through a rubber hose provided with a control valve. The volumetric LPG flow is measured by a gas flow meter. The waste cooking oil is collected from the source. Various tests like Visual Inspection, Testing for Water, Quantitative Water Test, and Titration Test are conducted. The tested oil is now converted to ester by transesterification process. Six grams of NaOH (catalyst) is dissolved in 200mL methanol to prepare alkoxide, which is required to activate the alcohol. Then stirring is done vigorously for about 20 minutes in a covered container until the alkali is dissolved completely. Mixture is protected from atmospheric Carbon dioxide and moisture as both destroy the catalyst. The alcohol-catalyst mixture is then transferred to the reactor containing 700 ml moisture free double refined vegetable oil. The mixture is refluxed on water bath at about 70^0C for one and a half hour using water cooled condenser. The mixture is heated for another half an hour without refluxing condenser to remove the excess methanol. Once the reaction is complete, two major products glycerol and methyl esters are obtained. After four hours the top methyl layer is separated from reaction mixture using separating funnel as shown. The separated esters are washed 3-4 times with distilled water to remove the impurities like soap and other residues. Finally methyl esters are dried using anhydrous Sodium sulphate.

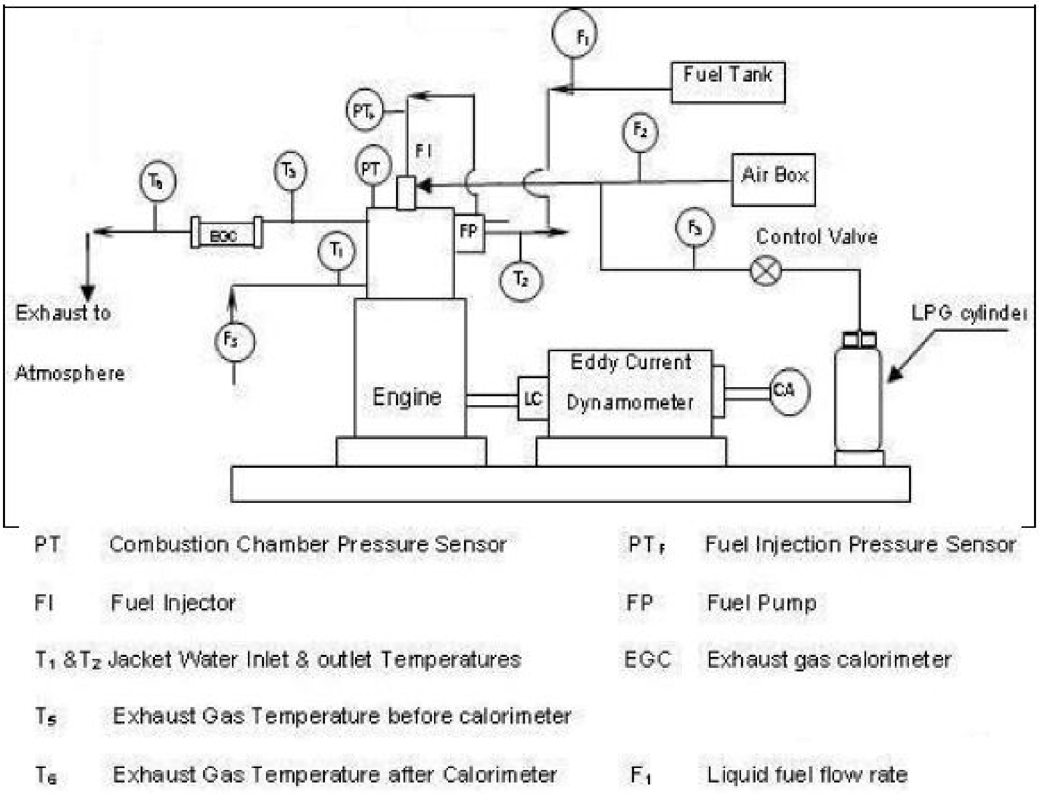

Fig 1. Experimental Setup

III. RESULTS AND DISCUSSIONS

A. Brake Thermal Efficiency-

The variation of brake thermal efficiency with different LPG flow rates at various loads, are shown in Fig 2 for diesel as injected fuel. It can be seen that in each case except at very low loads, there is an optimum combination of nducted to injected fuel, at which the efficiency is maximum. At lower flow rates of LPG, the thermal efficiency is ower throughout the low load spectrum than that of neat diesel operation. The lean LPG-air mixture does not encourage flame propagation resulting in pockets of incomplete combustion. At higher proportions of LPG, the onset of knocking tends to reduce the efficiency. At very low loads the reduced number of ignition centers decreases the chances of LPG combustion which in turn causes continuous reduction in efficiency with increase in LPG flow rate.

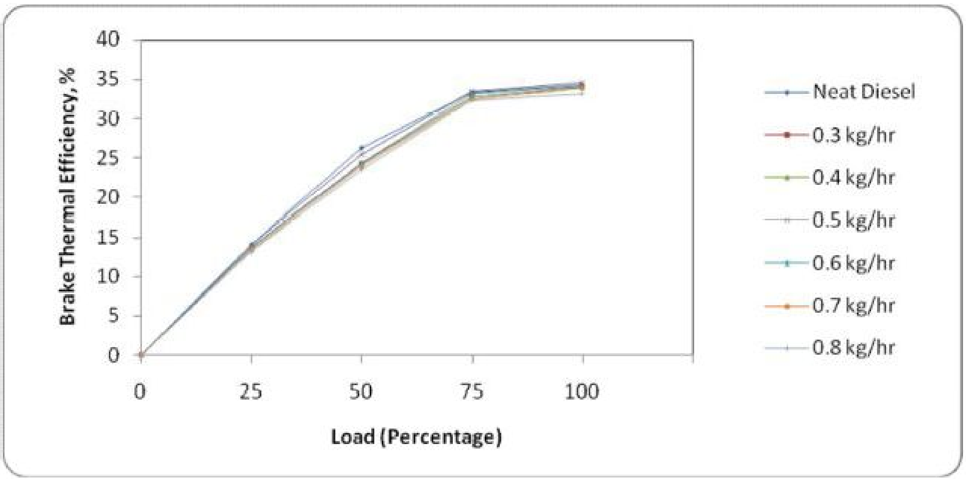

Fig 2. Variation of Brake Thermal Efficiency with load for various LPG flow rates in dual fuel mode

It is observed from Fig 2 that for all WCO-biodiesel blends Break Thermal Efficiency will be less compared to neat diesel. The poor performance of WCO-diesel may be attributed to its higher viscosity and lower cetane index. Viscosity of WCO–biodiesel is almost double that of diesel. Because of its higher viscosity its spray characteristics are greatly affected. The high viscous nature of fuel minimizes the fineness of atomization and on the other hand, the cetane index of the WCO-biodiesel is lower than that of diesel, hence both factors combine to increase the physical delay, which result in poor engine performance. The Break Thermal Efficiency is found to be maximum for 20% WCO-biodiesel blend.

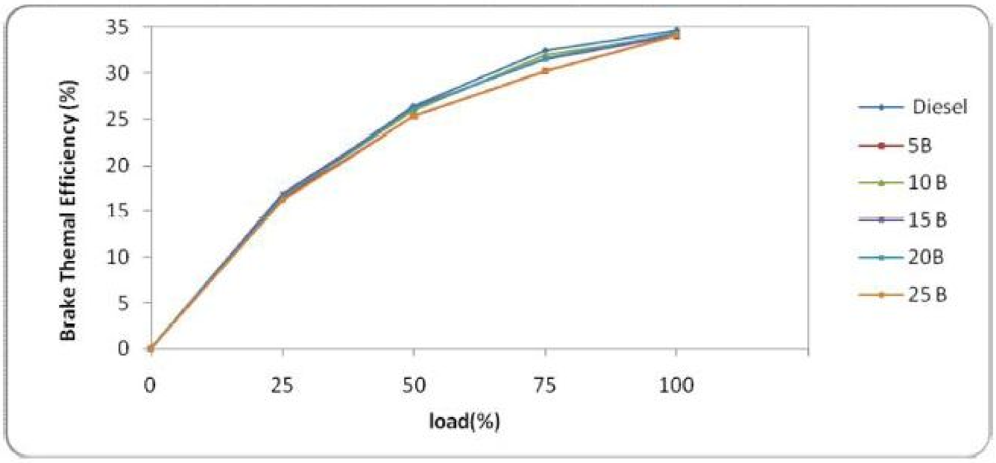

Fig 3. Variation of Brake Thermal Efficiency with load for various WCO blends in dual fuel mode

B. Exhaust Gas Temperature-

The variation of exhaust gas temperature with load for different flow rates of LPG is shown in Fig 4. In the dual fuel mode, at higher loads, the exhaust temperature increases with increase in LPG flow rate. As load increases, fuel quantity increases which lead to produce higher combustion temperature, hence exhaust gas temperature also increases.

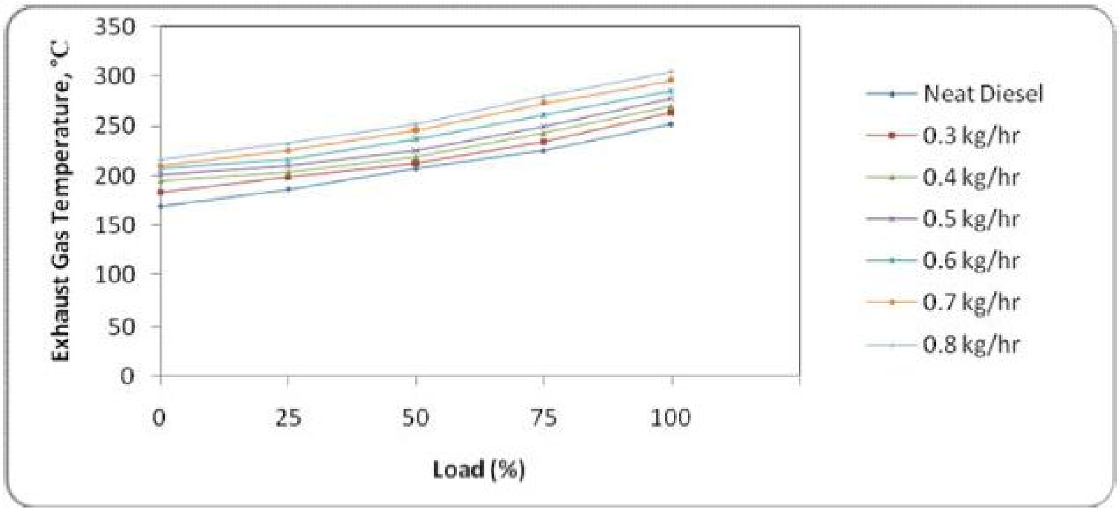

Fig 4. Variation of Exhaust Gas Temperature with load for various LPG flow rates in dual fuel mode

From the Fig 5, it is seen that exhaust gas temperature increases with increase in load. As the load increases fuel air ratio increases and therefore the operating temperature increases which results in higher exhaust temperature. The exhaust gas temperature is a convenient scale to study the extent of afterburning. And it was observed that the exhaust gas temperature was reasonably higher for WCO-biodiesel compared to baseline diesel.

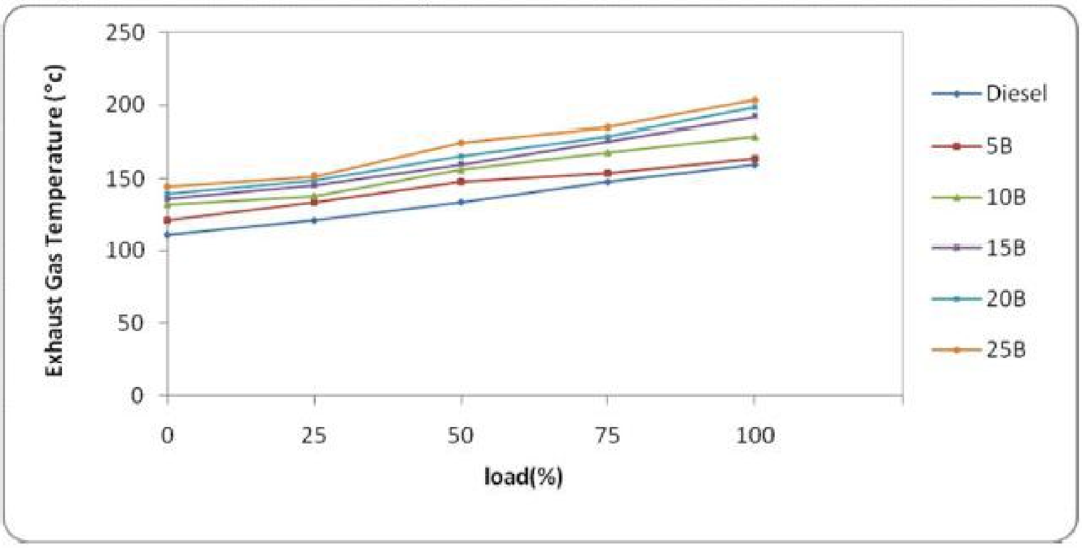

Fig 5. Variation of Exhaust Gas Temperature with load for various WCO blends in dual fuel mode

C. *Brake Specific Energy Consumption-*

Fig 6 shows the variation of specific energy consumption with load for different values of LPG enrichment. It can be observed that BSEC decreases as load is increased. The reduction in BSEC is due to the operation of LPG fueled engine with more homogeneity.

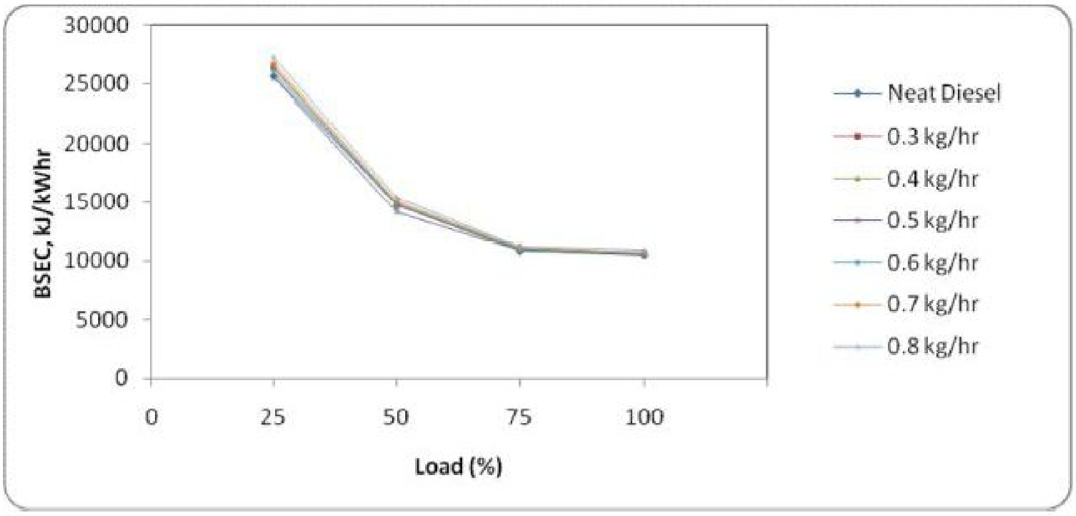

Fig 6. Variation of Brake Specific Energy Consumption with load for various
LPG flow rates in dual fuel mode

From the Fig 7, it is seen that the Brake Specific Energy Consumption decreases with load in all cases. Since, the performance of the WCO-biodiesel is marginally poor than the base line diesel, thus engine requires higher input energy per kilowatt output.

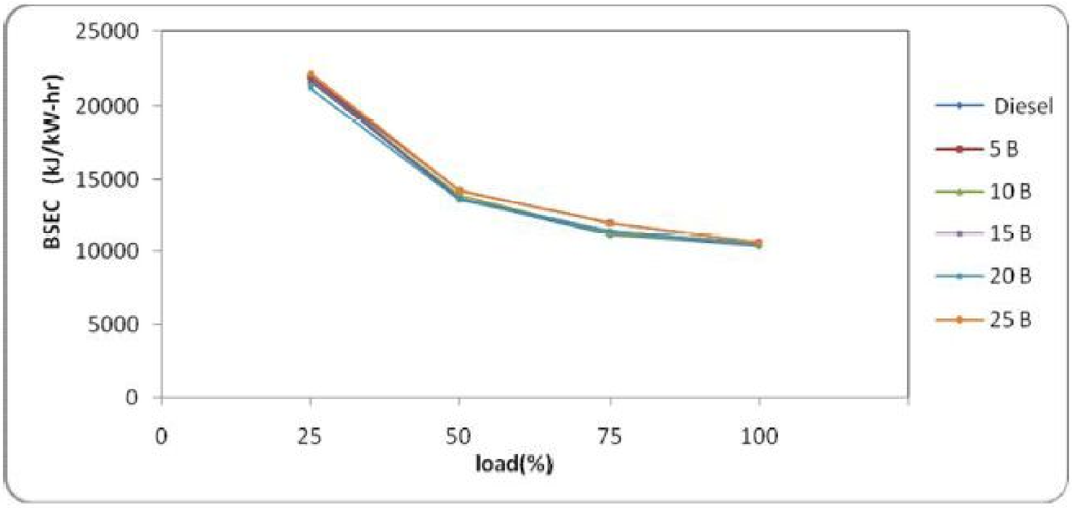

Fig 7. Variation of Brake Specific Energy Consumption with load for various
WCO blends in dual fuel mode

D. Air Fuel Ratio-

The air-fuel ratio is estimated based on mass basis. From the Fig 8 it is observed that the Air Fuel Ratio decreases with load in all cases. The fuel mass flow rate increases with the increase in the engine load, as a result, AFR decreases. For the same load, as LPG increases air fuel ratio increases because of high energy content of LPG.

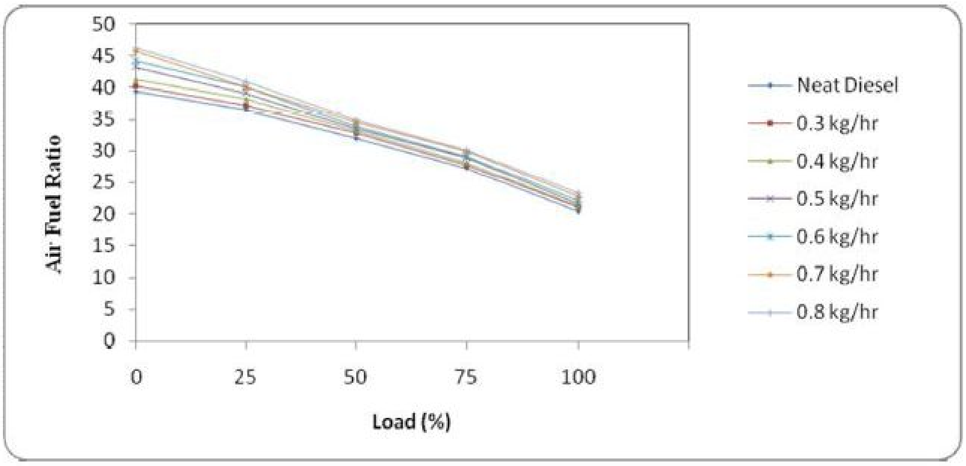

Fig 8.

Variation of Air Fuel Ratio with load for various LPG flow rates in dual fuel mode

From the Fig 9, it is observed that the Air Fuel Ratio decreases with load in all cases. The fuel mass flow rate increases with the increase in the engine load, as a result, AFR decreases. For the same load, as WCO increases air fuel ratio decreases because of low calorific value of WCO.

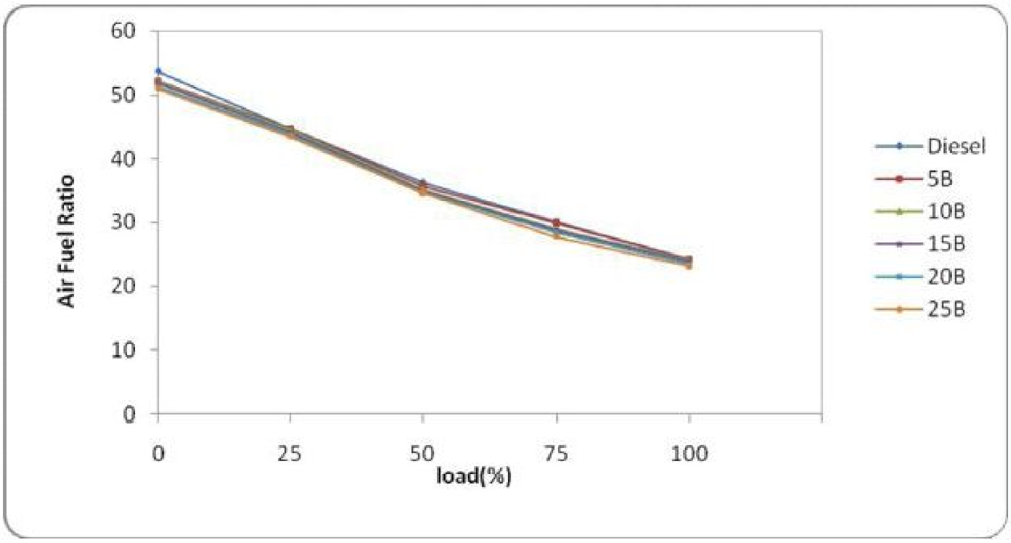

Fig 9 Variation of Air Fuel Ratio with load for various WCO blends in dual fuel mode

IV. CONCLUSION

At lower LPG flow rates, combustion of lean LPG- air mixture will be slow; it results in lower thermal efficiency. At higher LPG flow rates, rich mixture of LPG-air results in excellent combustion, good flame propagation and quicker heat release nearer to TDC, hence efficiency is higher. However, beyond the optimum LPG flow rate of 0.5kg/hr, the knocking tendency brings down the efficiency. It is found that the dual fuel engine is most suitable at higher load operations, with the optimum combination of diesel and LPG. Performance of the 20 % WCO-biodiesel blend was only marginally poorer at part loads compared to the neat diesel performance. At higher loads with WCO blends, engine suffers from nearly 1 to 1.5 % brake thermal efficiency loss.

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