Performance Studies of LHR engine using 20% Biodiesel Blend by Varying Engine Parameters

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Abstract*—Experiments are conducted on single cylinder water cooled diesel engine using diesel and 20% blend of dairy scum oil biodiesel (B20) to study the performance characteristics. Even after transesterification viscosity of biodiesel is higher than diesel. In order to make bio diesel blend to burn efficiently, in-cylinder temperatures are in- creased by creating adiabatic / semi adiabatic conditions within the engine cylinder. The piston crown of conventional engine is coated with 300 microns of PSZ without altering compression ratio. Experiments are conducted on semi adiabatic engine using B20 at rated injection pressure and timing and results are compared with conventional engine. Effects of injection timing (21^oretard, 23^orated and 25^oadvanced before top dead centre) and injection pressures(180bar, 200bar-ratedand220bar)in semi adiabatic engine using B20 are also analyzed. Results are compared based on Brake Thermal Efficiency (BTE), Brake Specific Energy Consumption (BSEC) and emissions (CO, UBHC, NOX, and smoke opacity). Combustion studies are also carried out by observing variation of cylinder pressure and heat release rate with crank angle degrees.

Keywords: LHR Diesel Engine, Biodiesel, PSZ, Injection Timing, Injection pressure, Engine performance, Combus- tion and Emissions.

I Introduction

Present Scenario of Renewable Energy

The rapidly diminishing of petroleum fuels; their raising costs and environmental pollution have led to an intensive search for an alternative fuel such as bio oils/biodiesels. It is known fact that about 30% of energy supplied to the diesel engine is lost through the coolant and 30% is waste through friction, exhaust and other losses. Only 40% of energy is utilized for useful work. Reduced heat rejection from the engine results in increased combustion chamber temperature which helps in better combustion of high viscous biodiesel, improves thermal efficiency and reduces exhaust emissions [1]. The energy required to run these engines has to be produced onsite, i.e., inside the combustion chamber, unlike producing electricity at one place and using it somewhere else. This requirement can only be met by using fossil fuels like oil and gas. We can't avoid the use of petroleum in those sectors, however we can reduce them by using efficient engines and biodiesel, which not only reduces the requirement of diesel but also helps in reducing the environmental pollution [2].

A. Biodiesel

Annual production of milk in India is 150 million tons per year. Thousands of large dairies are engaged in handling this milk across the country. In large dairies while cleaning the equipment, the residual butter and related fats which are washed and get collected in effluent treatment plant as a scum. Scum is a less dense floating solid mass usually formed by a mixture fat, lipids, proteins, packing materials etc. This scum is collected in tanks by skimming. Most of the dairies dispose this scum in solid waste disposal site or by incinerating. Waste scum was collected from effluent area and scum oil is extracted from it. Scum oil transestrified to produce SOME, which have fuel properties similar to diesel. Scum is basically a less dense floating solid mass usually formed by mixture fats, lipids, proteins etc. Most of the dairies dispose this scum to the waste disposal yard and which in turn results in environmental issues. If it is treated and converted as biodiesel it will improve country's economy[4].

The effect of biodiesel blended fuels on atomization and combustion characteristics of a CI engine. It was reported that higher surface tension and viscosity of biodiesel causes lower Weber number and decreases injection velocity of biodiesel- blended fuels respectively, and result in increased mean droplet size diameter with increasing biodiesel blend ratio. The spray tip penetration was observed to be longer for higher injection pressure. Higher cetane number of biodiesel causes shorter ignition delay, which was responsible for increased peak combustion pressure with increasing biodiesel blend ratio. With increasing biodiesel blend ratio, lower HC and CO, whereas NOx emissions increased, possibly because of fuel oxygen in biodiesel coupled with shorter ignition delay of biodiesel [5].

Low Heat Rejection (LHR) Engine

The main purpose of LHR engine is that to reduce heat loss to the coolant by providing heat resistance in the heat flow to the coolant. The heat generated inside the cylinder during chemical combustion of the fuel develops work by moving the piston downwards and some of the heat is lost to cylinder walls, overcome friction, exhaust gases, cooling water etc. thus the load on the engine varies, the magnitude of the heat losses also vary. In this context, the theoretical adiabatic engine can be treated as an heat loss engine. LHR can be achieved by Coating the combustion chamber walls, piston crown, exhaust valve etc. with ceramic materials [3].

Fig. 1: Conventional Engine Piston.

Fig. 2: PSZ/YSZ coated piston.

B. Effect of various Engine Parameters

1) Injection Pressure: It is the pressure at which the fuel is injected into the combustion chamber through an injector. It is an important factor as it directly affects the performance of an engine. Increased injection pressure results in better mixing of air and fuel, thus improving combustion, which leads to reduced BSFC and increased BTE. Increase in injection pressure results in increased heat release rate which leads to increase in NOx emission and decrease in soot formation. By increasing injection pressure, it helps in atomization of higher fuels.

2) Injection Timing: In the CI engines injection timing is one of the most important parameter that affects the performance and the emissions. Here injection timing is changed by changing the thickness of the shims. If the injection timing is earlier it is observed that the initial air pressure and the temperature will be low which results in the increase of the ignition delay, on the other hand when the injection starts later, the initial air pressure and the temperature will be slightly higher which result in the decrease of the ignition delay. This shows that injection timing has strong effect on both emissions and performance parameters especially on NOX, BSFC, and BTE.

I. EXPERIMENTALSTUDIES

The figure shows the Kirloskar AV1 diesel engine, which is used for experimentation to determine the performance, combustion and emission characteristics of the engine, tested using biodiesel as fuel.

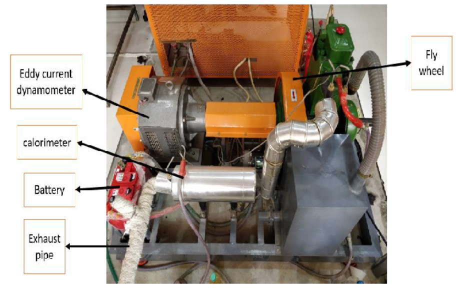

Fig. 3. Kirloskar AV1 engine.

Fuel is stored in the fuel tank and is channeled to the injector through a small fuel pipe line, where in between a burette is attached to measure the rate of fuel flow i.e.10cc of fuel to the engine. Once the valve is open and console in on the fuel flow is started to the injector. There is an eddy current dynamometer attached to the engine shaft to change the load on the engine by varying torque. A digital load indicator is present which gives the load acting on the engine. Since this engine is water cooled, a calorimeter has been equipped on the exhaust gas pipe. Pressure and temperature sensors are mounted to get the information about the pressure and temperature is at different crank angles inside the cylinder block to evaluate combustion characteristics of the engine. These sensors accurately measure the pressure and temperature rise at every half degree rotation of crank. Also, thermocouples are mounted at various positions to get the data useful for the heat balances sheet.

TABLE I

ENGINE SPECIFICATIONS

Make	Kirloskar AV1
Engine Rated Power:	3.500 kW
Engine Rated Speed:	1500.000 rpm
Diameter of Cylinder:	87.500 mm
Stroke Length:	110.000 mm
Clearance Volume:	38.000 cc
Crank Length:	210.000 mm
Number of Cylinders:	1.000
Arm Length:	150.000 mm

A. Properties of Biodiesel (dairy scum)

As above table 4.4 states the basic properties of the diesel, biodiesel (dairy scum) and 20B biodiesel (dairy Scum) where these all properties are required to update in the data logger system but data so from there the software takes the values and calculate the performance and brake power of the CIengine.

TABLE II

PROPERTIES OF THE DIESEL, B100 AND B20BIODIESEL

Properties	Diesel	Biodiesel	B20
Density(kg/m3) at 25°C	825	875	840
Viscosity at 40°C(mm2/s)	3.4	4.5	3.64
Calorific value (MJ/kg)	42.05	39.74	40.8
Flash Point (°c)	45	132	63
Fire Point (°c)	56	140	72

II. RESULTS ANDDISCUSSIONS

A. Performance characteristics of Conventional Engine.

1) Brake Thermal Efficiency (BTE):: The variation of BTE with % load for Diesel and 20% blend of Dairyscumbiodiesel(B20)atdifferentinjectionpressure(200,180and220bar)anddifferent injection timings (21° , 23°and 25° btdc) is shown in the Figures 4 and 5.

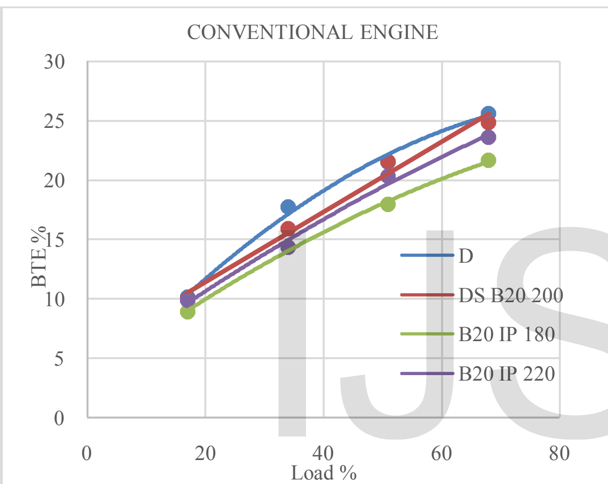

Fig. 4. BTE with % Load at different Injection Pressures.

From the Figure 4 it is observed that that BTE of B20 at Injection Pressure (IP) of 180, 200 and 220 bar is 21.69%, 24.86% and 23.63% at 68% of load and the values are lower than BTE of diesel (25.62%). Amongst the IPs tested 200 bar shows better performance as BTE at this pressure is closer to diesel. Higher IP (220 bar) may not be suitable for B20 due to very fine atomization resulting in Sauter Mean Diameter (SMD) of smaller size than the required. With lower IP (180bar) SMD may be bigger. In both cases combustion is sluggish resulting lower BTE[3]. Variations of the BTE with% load for diesel and B20 at different injection timings (21°, 23°and 25° btdc) at IP of 200bar is shown in the Fig. 5. From the graph it is observed that BTE of B20 at IT of 21°, 23° and 25° btdc for B20 is 22.42%, 24.86% and 26.92% at 68% of load respectively. BTE of B20 at advanced timing of 25° btdc shows higher BTE compared to BTE of diesel. The probable reason for increase in BTE with increase in injection timing (early timing) can be because of longer combustion duration resulting from early start of combustion [1]. With increase in combustion duration, premixed reaction time (ignition delay) increases thereby enhancing oxidation reactions and resulting in efficient burning of the fuel.

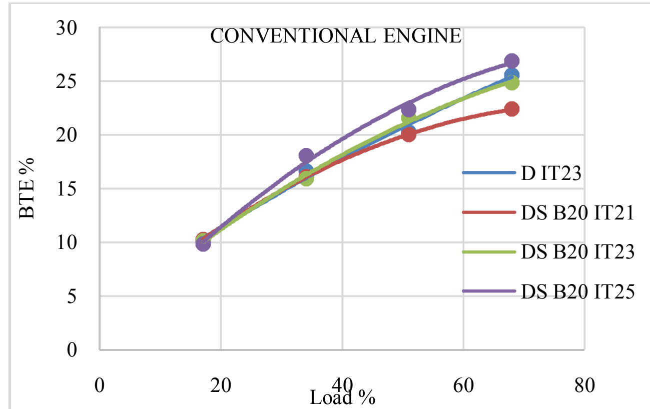

Fig. 5. BTE with % Load at different Injection Timings.

*2) Brake Specific Fuel Consumption (BSFC):*The varia- tion of BSFC with % load for Diesel and B20 at different IPs anddifferentITsareshownintheFigures6and7.

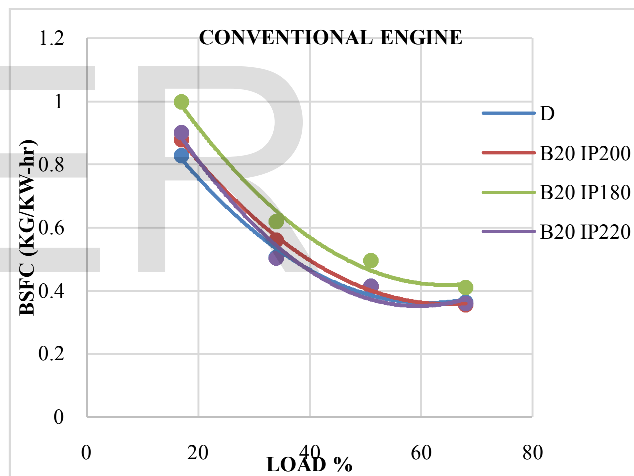

Fig. 6. BSFC with % Load at different Injection Pressures.

From Figure 6 it is observed that BSFC decreases with increase in load for all the fuels tested. At 68% of load the values of BSFC are 0.362, 0.412, 0.373, 0.384 kg/kW-h for diesel and B20 at different injection pressures of 180, 200 and 220 bar respectively. BSFC of B20 at IPs of 180 and 220 bar are higher compare to IP of 200 bar and the same is evidenced by lower BTE at those IPs.

From Fig 7 it is noticed that at 68% of load the values of BSFC are 0.362, 0.397 and 0.376 for B20 at IT of 21°, 23° and 25° btdc respectively. BSFC of B20 at advanced timing (25° btdc) is found to be lower than that of diesel (kg/kW-hr).

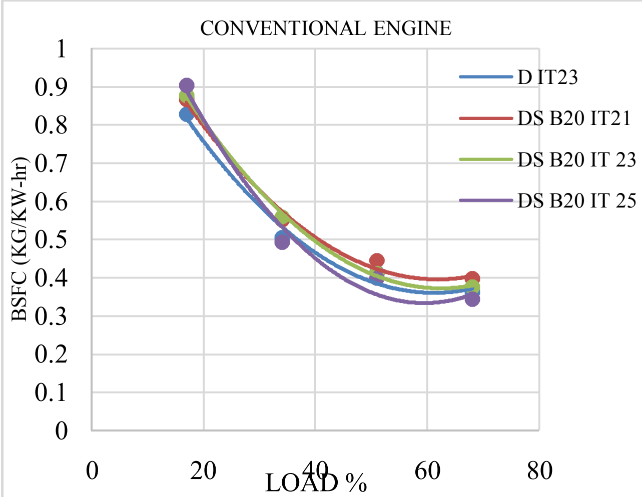

Fig. 7. BSFC with % Load at different Injection Timings.

When injection timing is retarded, fuel injection starts later. As a result, combustion duration decreases which results in lower peak cylinder pressure and incomplete combustion occurs because of that BTE decreases and BSFC increases. Advancement in injection timing resulted reduction in brake specific fuel consumption of 5.2% compared to diesel as shown in Figure 7 [2, 4].

B. Effect of LHR condition on Performance characteristics.

1) Brake Specific Fuel Consumption (BSFC): Fig. 8 shows the variation of BSFC for conventional Engine and LHR enginefordieselandB20atITof25˚btdcandIPof200bar.

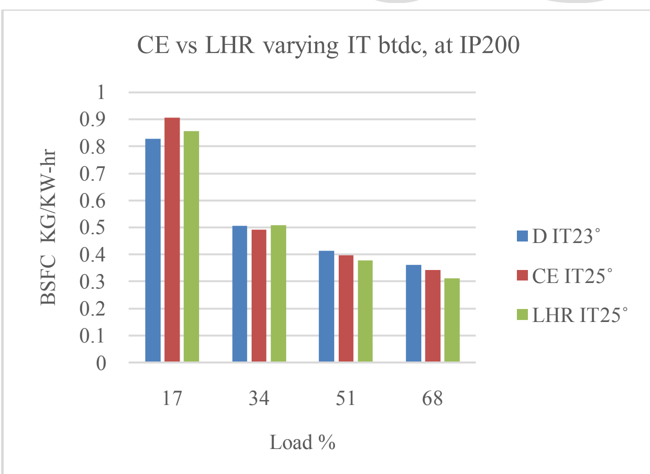

Fig. 8. Variation of BSFC with % Load.

At 68% of load the values of BSFC are 0.362, 0.343 and 0.313 kg/kW-h for diesel and B20 in CE and B20 in LHR engine respectively. Reason for decrease in BSFC in LHR engine with advance timing is due to higher in-cylinder temperatures due to coating and early start of combustion followed with longer combustion duration during advance injection timing [5].

2) Brake Thermal Efficiency (BTE): Figure. 9 shows the variation of the BTE with %Load for conventional engine LHR engine for diesel and B20 at IP of 200 bar and IT of 25° btdc.

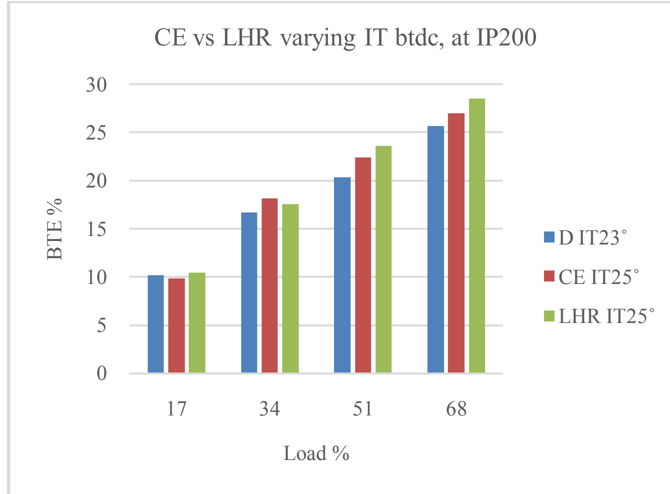

Fig. 9. Variation of BTE with % Load

From the Figure 9 it is found that BTE of B20 in LHR engine at 25° btdc is found to be 28.46% at 68% load and is higher compared to BTE (26.92%) of B20 in CE at same injection timing. The reason for increase in BTE with advance in injection timing (early timing) can be because of longer combustion duration resulting from early start of combustion. Coating (insulation) increases cylinder wall temperature and it leads to decrease in heat transfer and contributes positively to improved thermal efficiency [7]. With increase in combustion duration, premixed reaction time (ignition delay) increases thereby enhancing oxidation reactions and resulting inefficient burning of the fuel.

3) Exhaust Gas Temperature (EGT): Fig.10 shows the variation of EGT with % load for B20 in conventional and LHR engine. EGT of B20 is higher at all load conditions in LHR engine compared to conventional engine. This is an indication of higher in-cylinder temperature due to coating and the same is evidenced by higher BTE in LHR engine.

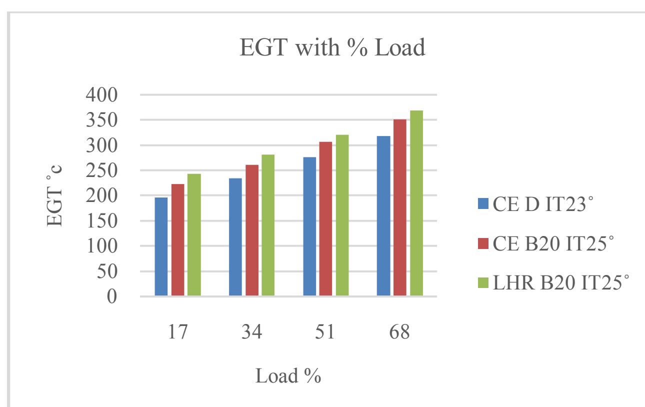

Fig. 10. Variationof EGT with % Load

Emissions:

Figures 11, 12 and 13 shows Smoke, UBHC and NOx emission variations with % Load for conventional and LHR engine.

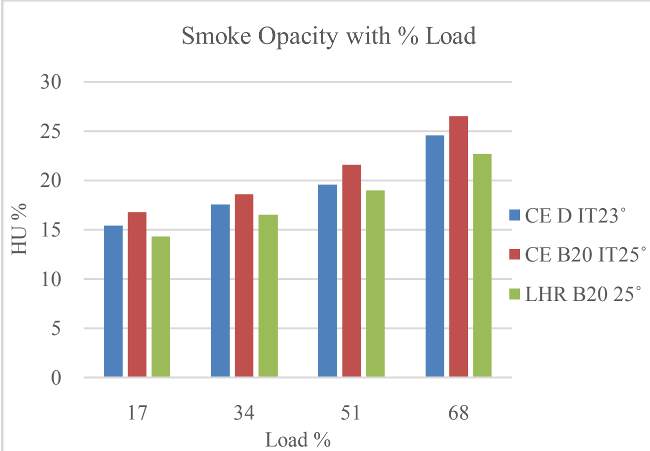

Fig. 11. Variation of smoke opacity with % Load.

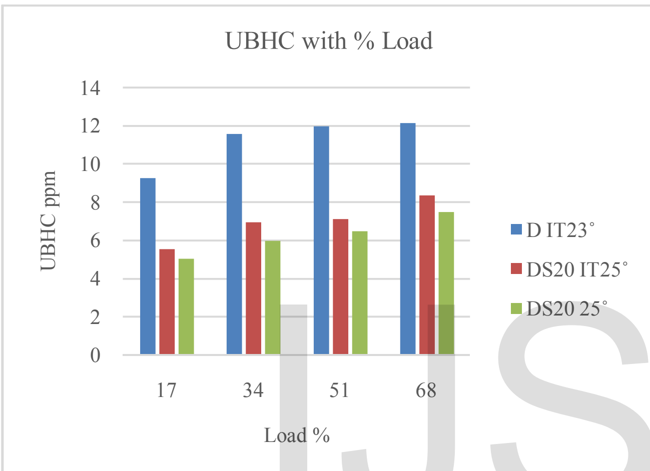

Fig. 12. Variation of UBHC with % Load.

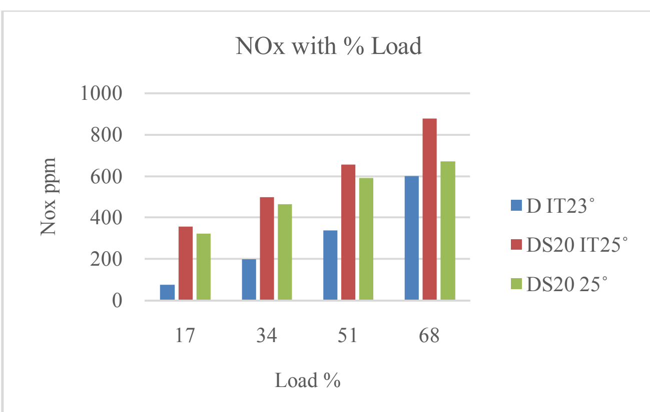

Fig. 13. Variation of NOx with % Load.

From Fig.11 it is noticed that smoke content in advance injection timing is lower for B20 than the diesel. Advancing Injection timing results in air-fuel mixture to burn effectively in combustion chamber along with LHR condition (higher in- cylinder temperature).

From Fig. 12 it is observed that UBHC emissions are lower at all load conditions for B20 in LHR engine at IT of 25˚btdc compared to diesel. Presence of inherent oxygen molecule in the biodiesel aids in better combustion compared to diesel in spite of having slightly lower calorific value. Advance injection timing in addition to LHR condition aids in improved combustion and reduces UBHC.

Increased EGT due to LHR condition, additional oxygen and more combustion duration due to advance timing results in more heat release rate and hence more oxides of nitrogen emission for B20 compared to diesel as shown in Fig.10.

III. CONCLUSIONS

A. Engine performance

1. Amongst the fuel Injection Pressures tested in LHR engine (180, 200 and 220bar) 200 bar (rated pressure) has shown better performance.
2. Amongst three injection timings tested in LHR engine, 25^{o} btdc (advanced injection) is found to be more suitable for B20 as it shown improved BTE and reduced emissions.
3. Early injection timing provides shorter ignition delay, longer combustion duration, and better diffusion burning (after combustion) and hence gives improved performance.
4. At 200 bar IP and injection timing of 25^{o} btdc, BTE of B20 in LHR engine is found to be highest (26.85%) at 68%loadwhichhigherthandiesel.
5. LHR condition along with early injection timing (25^{o}btdc) hasgiven better performance for B20 tested.

B. Emissions

1) Filter smoke number is relatively lower for B20 in LHR engine with an early advanced injection timing compared to conventional engine.
2) Oxides of nitrogen emissions are increased in case of LHRengineusingB20withadvancedinjectiontiming.

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Nomenclature

IT-Injection Timing

IP-Injection Pressure

BSFC-Brake Specific Fuel Consumption BTE-Brake Thermal Efficiency

HU-Smoke Opacity

UBHC-Unburnt Hydrocarbons

NOx-Oxides of Nitrate

EGT-Exhaust Gas Temperature

CE-Conventional Engine

LHR-Low Heat Rejection

PPM-Parts per Million

kW-Kilo Watt.