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Effect of Injection Timing on Heat Release Rate and Emissions in a Biodiesel Fuelled & Nano Powder Coated CI Engine

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The injection timing variation has a robust effect on emission formation in direct combustion diesel engine with thermal barrier coating. The piston head and cylinder were coated with Zirconium at 40 micron thickness. Low Heat Rejection (LHR) engine has high heat with standing capacity inside the combustion chamber, so the in-cylinder temperature is very high in part load and full load condition, which leads to increase the NO_X emission. In the present investigation neat Jatropha oil methyl ester (JME) as well as the blends of varying proportions of Jatropha methyl ester and diesel were used to run a LHR-CI engine with standard injection timing and retarded injection timing. Significant improvements in engine performance and emission characteristics were observed for JME fuel. The addition of JME to diesel fuel has significantly reduced HC, CO emissions but it increases the NO_X emission slightly with standard injection timing. The NO_X emission was decreased with retarded injection timing with negligible effect on fuel consumption rate. Similar trend in brake thermal efficiency and exhaust gas temperature were observed with retarded injection timing, while maximum cylinder gas pressure and ignition delay were decreased.

Keywords: Biodiesel, LHR, JME

Introduction

Biodiesel is a non-toxic, biodegradable and renewable, low cost fuel and can be used neat or blends with diesel fuel. Biodiesel fuel can be produced by Trans-esterification process. Biodiesels are characterized by their heating value, cetane number, viscosity, density, cold flow properties. The engine power decreased with the utilization of biodiesel .The reasons are less calorific value of biodiesel and poor combustion of biodiesel[1]. The concept of low heat rejection (LHR) engine aims to reduce the heat transferred to cooling system. So this energy can be converted to useful work. Some of the major advantages of LHR engines are better fuel economy, reduction in HC, CO emissions and ability to operate with low cetane fuels[2]. The literatures were reviewed critically and comprehensively in order to justify the future possibilities of the LHR engine from the view point of new Thermal Barrier Coating materials, coating techniques, combustion, performance, heat losses, and emissions while operating on diesel, biodiesels, and vegetable oils[11]. The trends were more pronounced in case of biodiesels and vegetable oils than the diesel fuel[13]. The coolant heat losses were decreased and the exhaust heat losses were increased in LHR engine for all fuels and at all loads[10]. The engine emissions have improved (except NOx) in LHR engine for all fuels[9]. NOx emissions were higher in LHR engine for all fuels especially for the biodiesels and vegetable oils due to enriched oxygen and increased combustion temperature[3].

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Thermal Barrier Coating (TBC)

Thermal Barrier Coating is a new technique used at present. It is a thin layer of ceramic coating given to the combustion chamber components like piston head, cylinder head, cylinder walls and valves. TBC is for increasing thermal insulation for combustion chamber components[4]. TBC increases the temperature inside the chamber by reducing the heat transfer to the combustion chamber walls. Thermal insulation reduces the components structural temperature, which in turn results in greater durability[5]. TBC increases the wear resistance, thermal efficiency and it minimizes pollutants in the exhaust of the engine[12]. Reduction in emissions from the engine exhaust is very important because of stringent emission regulation and to maintain the environment[6].

There is lot of techniques available for the thermal coatings and here Plasma spray coating technique is used for coating the piston head and cylinder[8]. Plasma spraying is used to deposit a wide range of ceramics and metals and their combinations. Homogeneous coatings can be formed for any composition, but the plasma spray coating gives fine microstructure with equiaxed grains and without any type of columnar defects[7,8] .

Engine Test Procedure

The Single cylinder, four stroke water cooled direct injection diesel engine was used. The engine was connected with combustion analyzer, proximity sensor and Di-gas analyzer. The pressure sensor was used to measure the pressure trace from the combustion chamber. The proximity sensor was used to detect the crank shaft position in terms of crank angle. The Di-gas analyzer is used to measure the emissions in the exhaust gas. The pressure sensor and proximity sensors were connected to combustion analyzer with LAB VIEW software. The engine was started and allowed to warm-up for about 15 minutes. The readings on dynamometer scale (load) time taken for 10cc of fuel consumption were measured. The smoke measurement was made by the Hartridge type smoke meter. This procedure was repeated by changing the loads from No load, 5 Nm, 10 Nm, 15 Nm, and 20 Nm.

Results and Discussions

Figure-1 shows the Variation of Carbon Monoxide with the brake power. The LHR engine with diesel fuel has the CO of 0.07% of volume at part load conditions. The B20-LHR biodiesel blend has a 0.06% of volume at part load and full load conditions for the standard injection time of 23°BTDC,when the injection was retarded by 5°CA, has the same value of CO of 0.06% volume at all load conditions. The B40-LHR biodiesel blend has a 0.05% of volume part load and full load conditions at standard injection time of 23°BTDC. When the injection was retarded by 5°CA, at 18°BTDC has the same value CO of B40 blend at all load conditions. The LHR diesel fuel has maximum of 0.07% of volume at part load conditions. The B60-LHR biodiesel blend has a 0.04% of volume at minimum load conditions in standard injection time of 23°BTDC.By retarding the injection timing, the time available for the combustion will reduce and CO emissions will be increased. The CO emission of B60-LHR retarded injection time is higher at low load condition as compared with the base engine and B60-LHR standard injection time. At full load condition the CO emission of diesel and B60-LHR blend has same value. The B80-LHR retarded injection time has maximum of 0.07% by volume at low load conditions. The CO emission of diesel and B80-LHR retarded injection time has a 0.06% by volume at part and full load conditions. The B80-LHR biodiesel blend has low CO emission at standard injection timing. The CO emission of B100-LHR standard and retarded injection time has a 0.05% of volume at part and full load conditions. At minimum load condition, the B100-LHR blend has low CO emission at standard injection timing. The variation of unburned hydrocarbon emission with the Brake Power is shown in figure 2.

Table 1—Engine specification

Make	Kirloskar (AV1)
Engine speed	1500rpm
No.of.cylinder(s)	1
Bore and Stroke	80 and 110mm
Max.Power	3.74kW
Compression ratio	16.5:1
Type of cooling	Water cooling
Injection Timing	23°BTDC
Clearance volume	35.67cc
Stroke volume	552.92cc

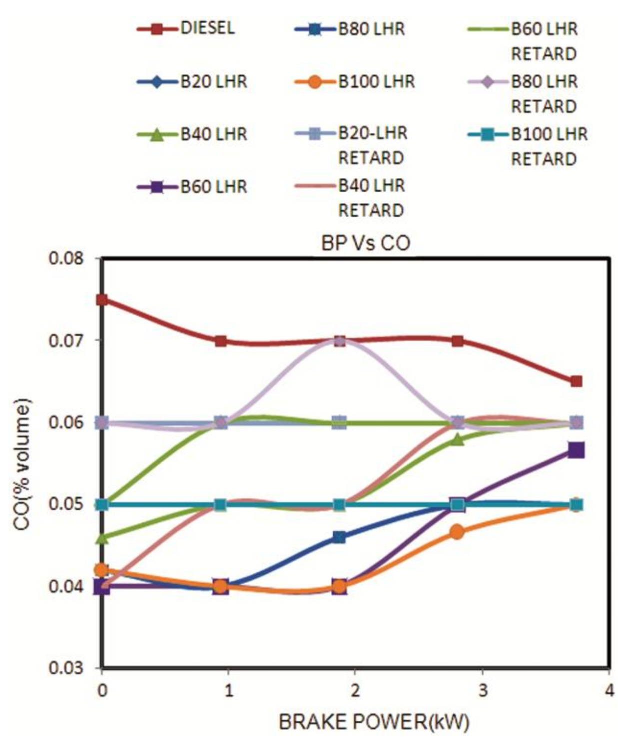

Fig. 1–Brake Power with Carbon monoxide

The non coated retarded diesel has a higher HC as compared to all other engines at all loads. At low load condition, the B20-LHR retarded injection time engine has HC emission close to diesel fuelled engine. At full load condition, B20-LHR standard injection time is close to LHR retarded injection time engine. Increased biodiesel blends at standard injection time, the B40-LHR engine the HC emission was higher. With retarded injection timing, it has low HC emission at all load conditions as compared to diesel and B40-LHR standard injection time. Over all, the LHR diesel engine has a higher HC emission for the B40-LHR standard and retarded the injection time engine. Increased biodiesel blends at standard injection time, the B60-LHR engine has more HC emission compared with non coated engine. With retarded injection timing, the B60-LHR has a low HC emission at all load conditions. By keeping in to a nut shell the LHR diesel engine has a higher HC emission as compared to B60-LHR standard and retarded the injection time at all loads. Increased biodiesel blends at standard injection time, the B80–LHR engine has more HC emission. With retarded injection timing, the HC emission for the B80-LHR engine has 50% less HC emission when compared with no-load condition. At full load, B80-LHR retarded injection has less HC emission and 50% reduction as compared with B80-LHR standard injection time engine. Over all, the LHR diesel engine has a higher HC as compared to B80 -LHR standard and retarded injection time engine at all load conditions. Increased biodiesel blends at standard injection time, the B100-LHR engine has HC emissions at higher side. With retarded injection timing, the HC emission for B100-LHR engine has 61% reduction compared to diesel at no-load condition. At full load, B100-LHR retarded injection time engine has reduced HC emission as compared with B100-LHR standard injection. Over all, the LHR diesel engine has a higher HC as compared to non-coated standard and retarded injection time engines at all loads. The variation of Oxides of Nitrogen with brake power is shown in figure 3. Using biodiesel and biodiesel blends

Table 2—Fuel properties

Properties	Diesel	Jatropha
Density @ 20°C g/m3	0.820	0.860-0.900
Net Calorific Value (MJ/kg)	44.9	38.5
Viscosity @40°C(mm2/sec)	2.71	52.76
Flash Point°C	52-96	176
Cetane Number	45-51	38-42

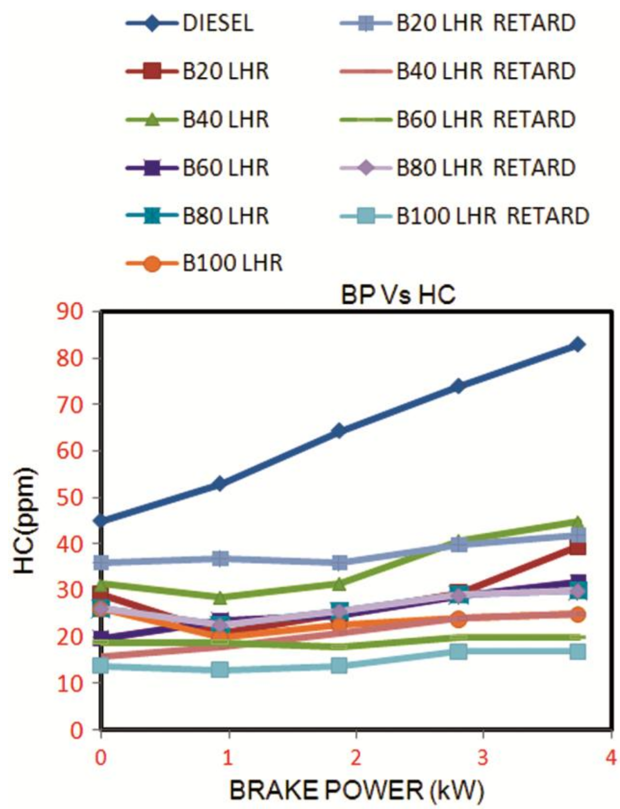

Fig. 2–Brake Power with Hydro Carbon

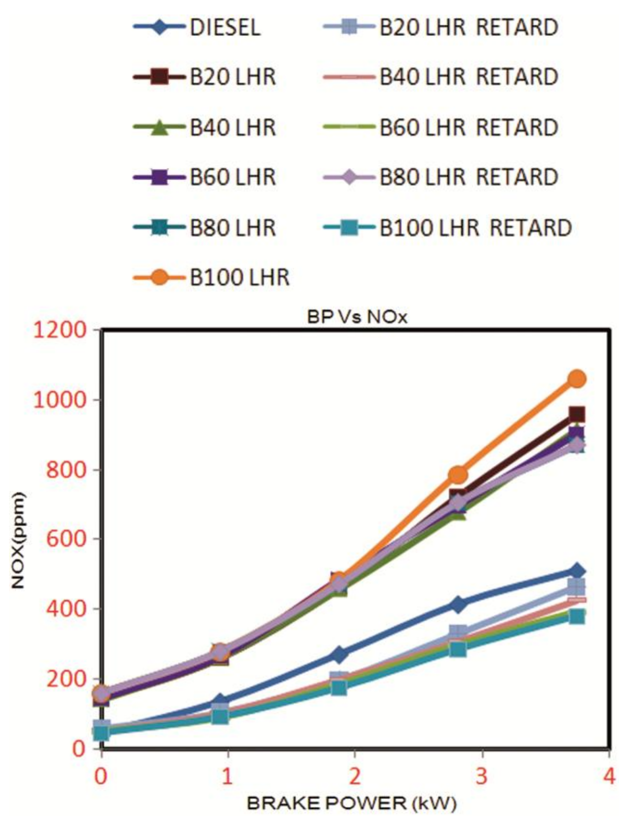

Fig. 3–Brake Power with Oxides of Nitrogen

seems to have higher NOx emission as compared to diesel fuel in LHR engines. The B20-LHR standard injection time engine has higher NOx emission for diesel fuel at part load and full load condition. With retarded injection timing, the B20 fuel has NOx emission with 62% less than the diesel fuel. At full load, the B20- LHR retarded injection time the NOx emission was reduced by 47% as compared to diesel fuel and compared to standard injection time the NOx emission was reduced by 51%. So, retarded injection time engine mainly reduces NOx emission. The B40-LHR standard injection time has higher NOx emission at full load condition as compared to diesel fuel. With retarded injection timing, the B40-LHR NOx emission was reduced by 67% for the diesel fuel at no load condition and compared to standard injection time the NOx emission was reduced 64% at no load condition. At full load, the B40-LHR retarded injection time the NOx emission was reduced by 52% as compared to diesel fuel and compared to standard injection time engine, the NOx emission was reduced by 53%. So, retarded injection time mainly reduces the NOx emission. The B60-LHR standard injection time has higher NOx emission at full load condition as compared to diesel fuel. With retarded injection timing, the B60-LHR NOx emission was reduced by 68% of diesel fuel at no load condition and compared to standard injection time, the NOx emission was reduced by 66% at no load condition. At full load, the B60-LHR retarded injection time, the NOx emission was reduced 55% as compared to diesel fuel and compared to standard injection time, the NOx emission was reduced 56%. So, retarded injection time mainly reduces the NOx emission. The B80-LHR standard injection time has higher NOx (705 ppm) emission at part-load condition as compared to diesel fuel. With retarded injection timing, the B80-LHR NOx emission was reduced by 66% of diesel fuel at no load condition and compared to standard injection time the NOx emission was reduced by 66% at no load condition. At full load, the B80-LHR retarded injection time, the NOx emission was reduced by 60% as compared to diesel fuel and compared to standard injection time the NOx emission was reduced by 61%. So the retarded injection time mainly reduces the NOx emission. The B100-LHR standard injection time has higher NOx (1060 ppm) emission at full load condition as compared to diesel fuel. With retarded injection timing, the B100-LHR NOx emission was reduced by 70% of diesel fuel at no load condition and compared to standard injection time the BTE was reduced by 71% at no load condition. The variation of brake thermal efficiency with the brake power is shown in figure 4. The LHR-diesel has maximum brake thermal efficiency of 29.33% at full load condition as compared with B20-LHR standard and retarded injection. With retarded injection timing, B20- LHR engine has the brake thermal efficiency reduced by 1.3% when compare with diesel at minimum load condition and compared with standard injection the BTE reduced 6.89%. At full load condition, with retarded injection timing, the B20-LHR, brake thermal efficiency was reduced by 8.97% as compared to diesel fuel and compared to standard injection time and the BTE was reduced by 6.25%. So, retarded injection time affects the thermal efficiency. The LHR-diesel has maximum brake thermal of 29.33% at full load condition as compared with B40-LHR standard and retarded injection. With retarded injection timing, B40- LHR the brake thermal efficiency reduced by 2.7% of diesel at minimum load condition and compared with standard injection the BTE reduced by 3.57%. At minimum load condition, the BTE of retarded injection was 2.32 % higher as compared with standard injection of B40- LHR. At full load condition, the B40-LHR retarded injection time the brake thermal efficiency was reduced by 9.57% as compared to diesel fuel and compared to standard injection. The LHR-diesel has maximum brake thermal efficiency of 29.33% at full

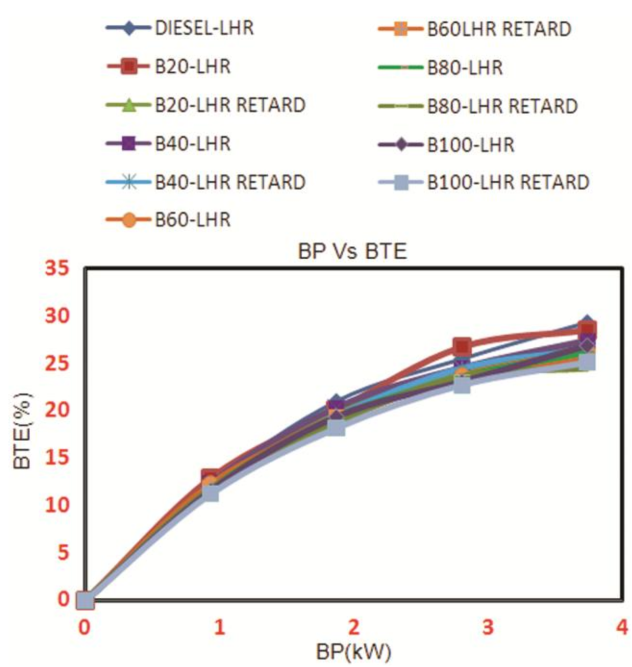

Fig. 4–Brake Power with Brake thermal efficiency

load condition as compared with B60- LHR standard and retarded injection time engine. With retarded injection timing, B60-LHR the brake thermal efficiency reduced by 2% of diesel at minimum load condition and compared with standard injection the BTE reduced by 3.57%. At full load condition, with retarded injection timing the B60-LHR the brake thermal efficiency was reduced by 13.14% as compared to diesel fuel and compared to standard injection time the BTE reduced by 3.33%. The LHR-diesel has maximum brake thermal efficiency of 29.33% at full load condition as compared with B80-LHR standard and retarded injection. With retarded injection timing, LHR-B80 engine has the BTE reduced by 10% of diesel at minimum load condition and compared with standard injection the BTE reduced by 2.27%. At part load condition, the BTE of retard injection and standard injection of B80-LHR was same. At full load condition, with retarded injection timing the B80- LHR, the BTE reduced by 16.62% as compared to diesel fuel and compared to standard injection time the BTE reduced by 6.66%. The LHR-diesel has maximum brake thermal of 29.33% at full load condition as compared with B100-LHR standard and retarded injection. With retarded injection timing, the B100-LHR,the BTE reduced by 7.46% of diesel at minimum load condition and compared with standard injection the BTE reduced by 3%. At full load condition, with retarded injection timing the B100-LHR, the BTE was reduced by 14.25% as compared to diesel fuel and compared to standard injection time the BTE reduced by 6.45%.

Conclusions

The NOx emission has reduced effect with retarded injection timing, due to the reduction in local in-cylinder temperature. The reduction in NOx emission was observed with 5°CA retarded injection timing as compared to diesel at standard injection timing. Similarly the NOx reduction was observed at various loads for all blends of JME at retarded injection timing as compared to all blends of JME at standard injection timing. The unburned hydrocarbon emission drastically increased for retarded injection time engine for LHR- biodiesel blends. The brake thermal efficiency was higher for LHR-diesel at all load conditions as compared with all blends of LHR standard injection and retarded injection timing. Jatropha oil Methyl Ester and its blends produces shorter ignition delays at retarded injection timing as compared to diesel and standard injection.

References

1 Parlak A, Yaşar H, Haşimogˇlu C & Kolip A, The effects of injection timing on NOx emissions of a low heat rejection indirect diesel injection engine, *Appl Therm Eng*, **25** (2005) 3042–3052.

2 AlirezaValipour, Effect of Injection Pressure on Ignition Delay and Combustion Duration of Diesel Engine with Biodiesel (Jatropha Oil) and Its Blends, *Int J Of Moder Eng Res*, **Vol. 4** (2014).

3 Prasath B R, Tamilporai P & Shabir M F, Analysis of combustion, performance and emission characteristics of low heat rejection engine using biodiesel, *Int J of Therm Sci*, **49** (2010) 2483-2490.

4 Haşimoğlu C, Ciniviz M, Özsert I, İçingür Y & Parlak A, Performance characteristics of a low heat rejection diesel engine operating with biodiesel, *Renew Ener*, **33** (2008) 1709–1715.

5 EkremBuyukkaya & MuhammetCerit , Experimental study of NOx emissions and injection timing of a low heat rejection diesel engine, *Int J of Therm Sci* , **47** (2008) 1096–1106.

6 HanbeyHazar & UgurOzturk., The effects of Al2O3eTiO2 coating in a diesel engine on performance and emission of corn oil methyl ester, *Renew Ener*, **35** (2010) 2211-2216.

7 HüseyinAydin, Combined effects of thermal barrier coating and blending with diesel fuel on usability of vegetable oils in diesel engines, *Appl Therm Eng*, **51** (2013) 623-629.

8 Cerit M, Ayhan V, Parlak A & Yasar H, Thermal analysis of a partially ceramic coated piston: Effect on cold start HC emission in a spark ignition engine, *Appl Therm Eng*, **31** (2011) 336-341.

9 Abedin M J, Masjuki H H, Kalam M A & Sanjid A., Energy balance of internal combustion engines using alternative fuels, *Renw and Sust Ener Rev*, **26** (2013)20–33.

10 Shahabuddin M & Liaquat A M, Ignition delay, combustion and emission characteristics of diesel engine fueled with biodiesel, *Renw and Sust Ener Rev*, **21** (2013) 623–632.

11 Abedin M J, Masjuki H H, Kalam M A & Sanjid A, Combustion, performance, and emission characteristics of low heat rejection(LHR) engine operating on various biodiesels and vegetable oils, *Ener Conv and Manage*, **85** (2014) 173–189.

12 Mittal N, Athony R L, Bansal R & Kumar C R, Study of performance and emission characteristics of a partially coated LHR SI engine blended with n-butanol and gasoline, *Alexandria Eng J*, **52** (2013), 285–293.

13 Hoekman S K, Broch A, Robbins C & Ceniceros E, Review of biodiesel composition, properties, and specifications, *Renew and Sust Ener Rev*, **16** (2012) 143– 169.