Performance of Used Cooking Oil Based Biodiesel in a Low Heat Rejection Diesel Engine

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Abstract- Rapid industrialization of developing countries is resulting in increased demand for diesel worldwide, leading to depletion of traditional fossil fuels apart from higher pollution levels caused by them. Alcohols and vegetable oils are important substitutes for diesel fuel and are renewable in nature. Biodiesel derived from feedstock is renewable, bio degradable and provide energy security besides addressing environmental issues. Alcohols have low cetane number and energy content in comparison with diesel fuel. Though vegetable oils have comparable energy content and cetane number, these fuels have high viscosity and low volatility. Hence low heat rejection (LHR) engine is gaining momentum for burning high viscous fuels. These LHR engines have significant characteristics of higher operating temperature, maximum heat release, and ability to handle low calorific value fuel. High grade LHR engine consists of ceramic coated cylinder head, air gap insulated piston and air gap insulated liner. Waste fried cooking oil collected from various restaurants was converted to biodiesel through esterification process. Tests were conducted on 3.7kw, 1500 RPM conventional diesel engine (CE) and LHR engine with used cooking oil biodiesel as fuel instead of diesel fuel as a total substitute. The experimentation work was carried out at manufacturer specified injection timing of 27^0bTDC only but injection pressures include 230 and 270 bar apart from the recommended 190 bar pressure. Performance parameters and Pollution levels were investigated at full load and observed that biodiesel operation on LHR engine showed better performance in terms of efficiency and smoke levels but increased NO_x levels which can be dealt with selective catalytic reduction technique.

Keywords – LHR engine, Biodiesel, used cooking oil, performance parameters

I. Introduction

The prominent areas of research, nowadays includes alternative fuels, since we are sure of extinction of conventional fuels, and the pollution levels caused by them. Throughout the world and more particularly in India, diesel consumption was heavy, in cultivation and goods transshipment sectors because of its fuel efficiency and any replacement for diesel fuel will be a major breakthrough. In this aspect vegetable oils holds a special promise, since their cetane number is near to the diesel fuel. Vegetable oils possess low volatility and more viscosity. Edible oils are of high demand and costlier also. Non-edible oils should only be used as fuel, but at the same time nowadays they have their own applications. In this connection the operational problems involved with vegetable oils can be effectively dealt to a major extent, if these oils are esterified to obtain biodiesel. In the present experimental work the used cooking oil (which otherwise had to be discarded) was gathered from different hotels, canteens and converted to biodiesel. Biodiesels have advantages compared to conventional fuels as they are renewable, bio degradable; provide energy security apart from addressing environmental issues. Experiments were conducted on conventional engine fuelled with biodiesel [1-4] and it was reported that performance was compatible. The drawbacks associated with biodiesel for use as fuels in compression ignition engine call for a Low Heat Rejection (LHR) engine. The concept of low heat rejection engine is to reduce the heat flow to the coolant by providing thermal insulation in the path of the heat flow to the coolant. The achieved results were compared to that of biodiesel operation on conventional engine (CE) at manufacturers recommended values of 27^0 bTDC injection timing, and 190 bar injector opening pressure.

II. MATERIALS AND METHODOLOGY

The test engine used for the present study is a 5 H.P engine whose rated speed is 1500RPM with bore and stroke of 80 and 110 mm respectively. The values recommended by manufacturer are 27^obTDC injection timing and 190 bar injector opening pressure. The engine was attached to an electrical type dynamometer for measurement of power. The engine is designed for water cooling system and the injector opening pressure was varied, during testing from 190 to 230 and then to 270 bar with the nozzle pressure testing device. The pressure was restricted to 270 bar because of practical difficulties associated. Thermocouples made of iron and iron constantan were employed to record exhaust gas temp.

The conventional engine combustion chamber was subsequently modified/ replaced with a new set of insulated piston, insulated liner and also ceramic coated cylinder head which was treated as engine with LHR combustion chamber or LHR engine in short. The purpose of the LHR engine is to restrict the heat flow to the surroundings, so that that heat can be utilized effectively for burning viscous fuels.

The low heat rejection diesel engine consists of a two-part piston - the crown made of low thermal conductivity material, superni-90, was screwed to aluminum body of the piston, providing a 3 mm-air gap in between the crown and the body of the piston. Figures 1,2 and 3 represent the photographic views of the air gap insulated piston, air gap insulated liner and ceramic coated cylinder head respectively. A superni-90 insert was attached to the top portion of the liner, using threads such that an air gap of 3mm was obtained between the insert and the liner body. For obtaining better performance, the optimum thickness of air gap, in the air gap piston was identified to be 3 mm [5] with superni inserts with diesel as fuel. Partially stabilized zirconium (PSZ) of 500 microns thickness coating was carried out, using plasma spray technique on inside portion of cylinder head. In both cases AVL Company make smoke meter and NETEL make analyzer was used to record smoke in Hartridge units and NO_X values in PPM

Fig.1 AIR GAP INSULATED PISTON

Fig.2 AIR GAP INSULATED LINER

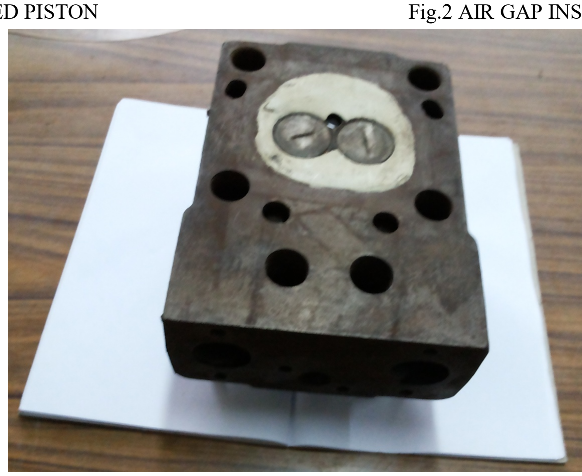
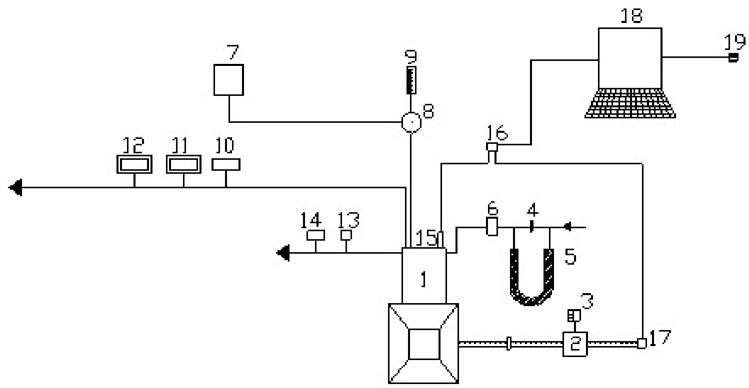


Fig.3.CERAMIC COATED CYLINDER HEAD

The experiments were conducted on conventional engine (CE), as well as on LHR engine. The investigations were carried out with waste fried oil based biodiesel at different operating conditions i.e. recommended as well as by varying injector opening pressures. To convert waste fried cooking oil into biodiesel a process known as esterification was employed. Figure 4 shows the schematic diagram of the experimental set up employed



1.Engine, 2.Electical Dynamo meter, 3.Load Box, 4.Orifice meter, 5.U-tube water manometer, 6.Air box, 7. Vegetable oil tank, 8 Pre-heater, 9.Burette, 10. Exhaust gas temperature indicator, 11.AVL Smoke meter, 12.Netel Chromatograph NOx Analyzer, 13.Outlet jacket water temperature indicator, 14. Outlet-jacket water flow meter, 15.Piezo-electric pressure transducer, 16.Console, 17.TDC encoder, 18.Pentium Personal Computer and 19. Printer.

FIG.4. EXPERIMENTAL SET UP EMPLOYED FOR BIO-DIESEL OPERATION

III. RESULTS AND DISCUSSIONS

The various results obtained for performance parameters and pollution levels for the case of biodiesel operation was compared on conventional engine as well as on LHR engine, for various pressures and conclusions were drawn. Tests were conducted at full load operation, and at recommended values of 190 bar and other pressures of 230, 270 bar but at an injection timings of 27^0bTDC only.

Figure 5, shows the variation of peak Brake thermal efficiency(BTE) in CE as well as LHR engines at different injection pressures. The LHR engine using biodiesel operation increased peak brake thermal efficiency by 7% at recommended injection timing in comparison to diesel operation, the reason being better combustion of biodiesel in the hot environment provided by LHR engine. Biodiesel is not only an efficient fuel in ordinary engine but also in LHR engine because it has got high cetane number in comparison to waste fried oil. We can also observe from the table that brake thermal efficiency increased with rise in injector opening pressure in both engines as fuel spray characteristics were improved. Similar trends were observed by earlier researcher [6]

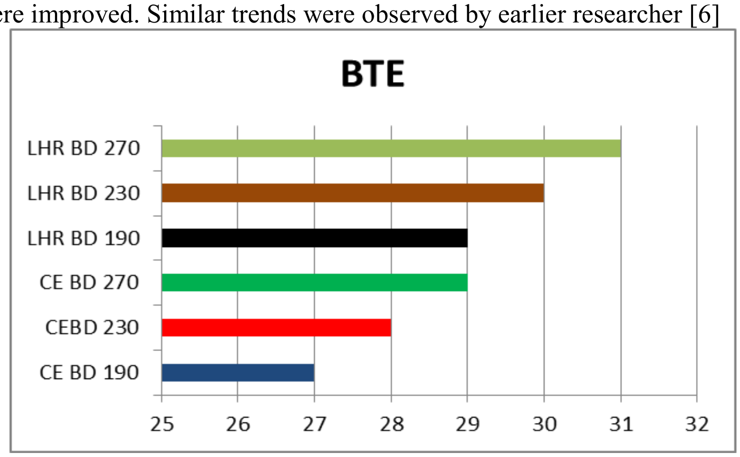


Fig.5 Variation of BTE for Biodiesel operation

Figure 6, shows the variation of Brake Specific Energy Consumption (BSEC in kW/kW)) in both engines at various values of injection pressures for biodiesel operation. From the figure we can observe that

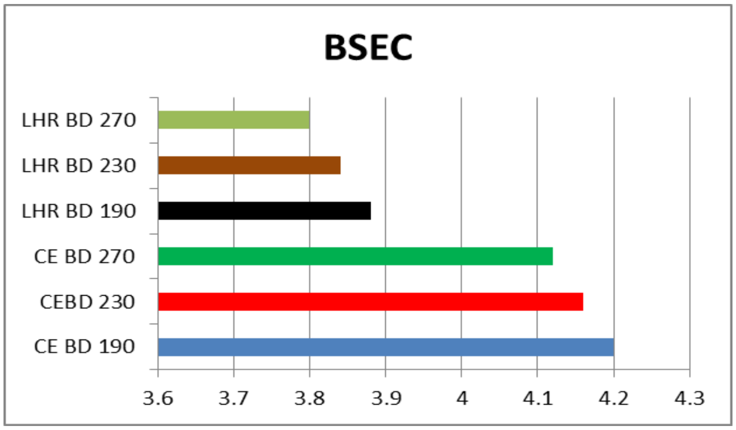


Fig.6. Variation of BSEC for Biodiesel operation.

LHR engine with biodiesel operation reduced BSEC at full load at 27^0 bTDC by 8% in comparison with CE operation. This was due to efficient energy utilization with biodiesel with LHR as high peak pressures were observed because of increase of bulk modulus of fuel. Similar trends were noticed by earlier researcher[7].This was because of higher cetane number, lower viscosity, density, molecular weight of biodiesel with presence of oxygen in its composition. BSEC reduced with increase of injector opening pressure. Bulk modulus of fuel increased with increase of injector opening pressure leading to generate high peak pressures leading to reduced BSEC at full load

TABLE-1

	BTE (%)			BSEC(kW/kW)		
	190bar	230bar	270bar	190bar	230bar	270bar
CE-Biodiesel	27	28	29	4.2	4.16	4.12
LHR-Biodiesel	29	30	31	3.88	3.84	3.8

Figure 7, shows the variation of Exhaust Gas Temperature in ^{0}C, for both engines at recommended and other values of injection pressures and 27^0bTDC for biodiesel operation. From the figure we can observe that LHR engine with biodiesel operation reduced exhaust gas temp by 8% in comparison to CE. Heat rejection was lower with biodiesel operation as most of the heat was utilized to be converted into work in comparision with used cooking oil operation. This was because of improved combustion in which BTE increased leading to reduction in EGT at full load for biodiesel operation. Similar observations were quoted by previous researcher [7]. Due to improved combustion in LHR efficiency increased leading to reduction in EGT at full load with biodiesel. EGT decreased with increase in injector opening pressure in both engines. This proves that CE is more suitable for diesel and LHR is more suitable for biodiesel.

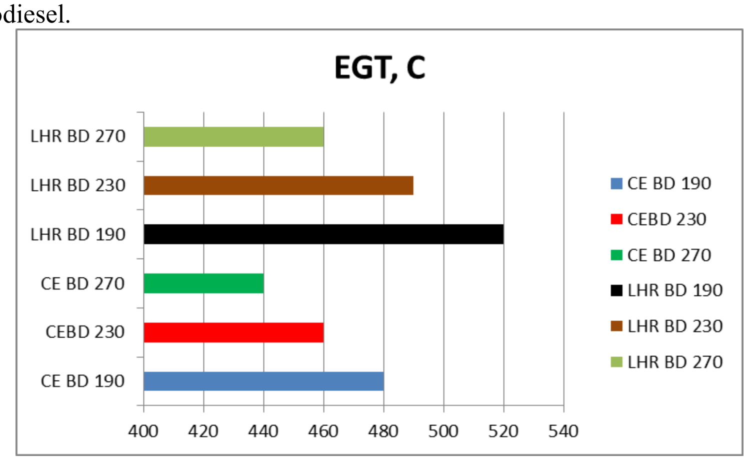


Fig.7 Variation of EGT for Biodiesel operation

Figure 8 shows the variation of coolant load for both engines with biodiesel operation at recommended injection timing and various injection pressures. LHR engine with biodiesel operation reduced coolant load by 24% at 27^0 bTDC when comp to ordinary engine. This was not only due to provision of thermal insulation but also due to improved combustion of biodiesel in the presence of oxygen in the hot environment available in LHR engine. Similar trends were observed by earlier researcher [7]. Reduction of fuel deposits was the main cause for reduction of coolant load with biodiesel operation in LHR engine. Reduction of coolant load in LHR was not only due to provision of insulation but also due to increase of air fuel ratios causing decrease of gas temperatures and hence the coolant load. Similar trends were observed by earlier researcher [6,9]

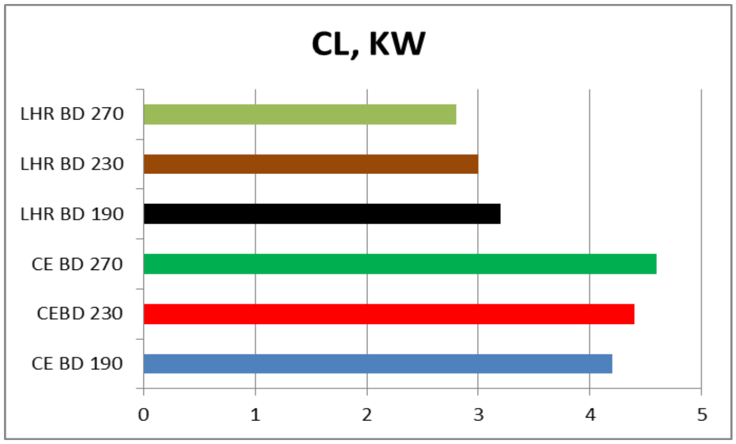


Fig .8. Variation of Coolant Load for Biodiesel operation

Table 2 shows the values of exhaust gas temperature and coolant load values for both conventional and LHR engines at different injection pressures for biodiesel operation.

TABLE-2

	EGT(^{0}C)			CL(kW)		
	190bar	230bar	270bar	190bar	230bar	270bar
CE-Biodiesel	480	460	440	4.2	4.4	4.6
LHR Biodiesel	520	490	460	3.2	3.0	2.8

Fig. 9 shows the bar chart drawn for variation of volumetric efficiency at different values of injection pressures for biodiesel operation .Volumetric efficiency depends upon density of charge which in turn depends on temperature of combustion chamber walls. LHR engine with biodiesel operation reduced volumetric efficiency by 6% when compared with CE. Heating of air with hot insulated components of LHR combustion chamber leads to reduced density and hence volume of air inhaled into engine. Volumetric efficiency also depends upon valve overlap and speed of the engine, as overlap and speed are kept constant and hence changes in volumetric efficiency are noticed to be less.

Volumetric efficiency increased with increase in injector opening pressure due to better spraying characteristics of fuel and even at higher pressures leads to increase in efficiency also due to reduction of residual fraction of fuel with increase in injector opening pressure.

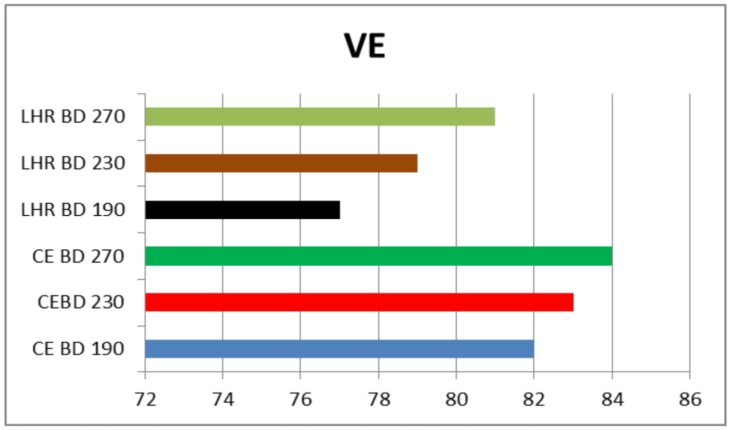


Fig.9 variation of Volumetric Efficiency for Biodiesel operation

Figure 10 represents the bar chart drawn for the variation of smoke levels in Hartridge Smoke Units (HSU) for biodiesel operation, at various injection pressures and 27^0bTDC injection timing. LHR engine with biodiesel operation reduced smoke at full load by 14%at 27^0bTDC in comparison to CE because of efficient combustion and less amount of fuel accumulated on the hot combustion chamber walls of the engine with LHR at different operating conditions of bio diesel to CE. Similar trends were observed by earlier researchers [7].

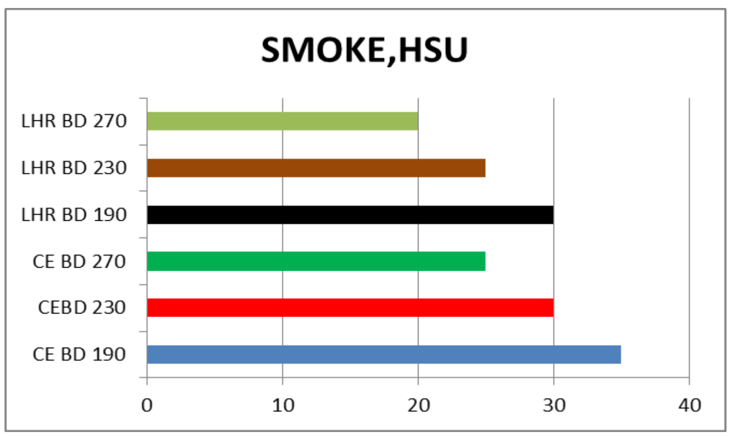


Fig.10 variation of Smoke Levels for Biodiesel operation

Smoke levels reduced with rise in injection pressures due to improvement in fuel operating characteristics which caused shorter ignition delay leading to better mixing of fuel and air resulting in faster combustion.

Fig 11 represents the bar chart drawn for the variations of NO_x levels with biodiesel operation for different injection pressures. Temp and availability of oxygen are two favorable conditions for NOx to develop. At peak loads NOx increased with test fuels at recommended injection timing due to higher peak temperatures as larger regions of gas burned at close to stoichiometric ratios.

LHR with biodiesel increased NOx by 55%in comparison to CE due to improved hear release rates of waste oil in hot environment provided by LHR. NOx levels reduced with rise in pressure due to decrease of gas temp with improved air fuel ratios.

Table-3 shows the values of volumetric efficiency, smoke and NO_x levels at different injection pressures for biodiesel

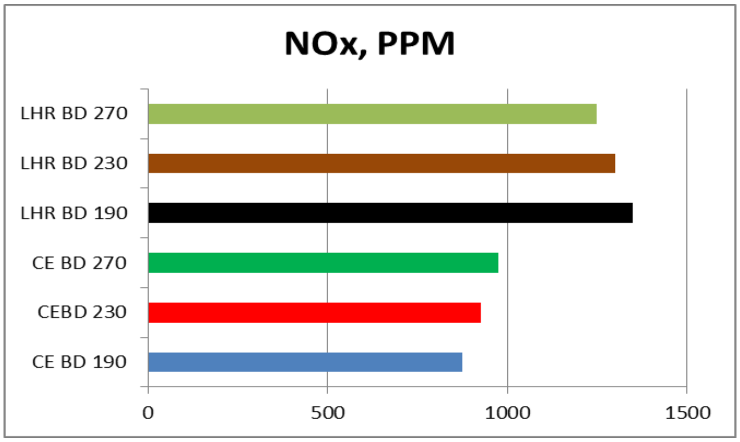


Fig.11. variation of NO_x Levels for Biodiesel operation

TABLE-3

	Volumetric Efficiency (%)			Smoke(HSU)			NO_X(PPM)		
	190bar	230bar	270bar	190bar	230bar	270bar	190bar	230bar	270bar
CE-Biodiesel	82	83	84	35	30	25	875	925	975
LHR – Biodiesel	77	79	81	30	25	20	1350	1300	1250

IV.CONCLUSIONS

LHR engine improved its performance when compared with CE in terms of performance parameters, smoke levels and combustion characteristics; however it increased drastically NOx levels with test fuels in comparison with CE. Therefore the methodology for reducing of NOx has to be established. This can be accomplished by inducting methyl alcohol or ethyl alcohol with injected biodiesel. However, this method will produce higher levels of formaldehyde and acetaldehyde emissions. Hence reduction can be achieved by means of selective catalytic reduction technique using lanthanum ion exchanged zeolite(catalyst-A) and urea infused lanthanum ion exchanged zeolite(catalyst-B) [8].

REFERENCES

[1] Venkatramn, Devaradjane G. Experimental investigation of performance and emission characteristics of diesel-pongamia oil, methyl esters diesel blends fueled DI engine at Optimum engine operating parameters. International Journal of Green Energy and Env. 2010;1:7-12

[2] Rasim B.Abdulvahab. C Performance and emission study of waste anchovy fish biodiesel in a diesel engine. Fuel Processing Technology. 2011;92:1187-1194

[3] Jaichandar S, Annamalai K. The status of biodiesel as an alternative fuel for diesel engine- an overview. Journal of Sustainable Energy & Environment, 2011; 71-75

[4] Ridvan Arslan. Emission characteristics of a diesel engine using waste cooking oil as a bio-diesel fuel. African Journal of Bio-Technology. 2011;10(9):3790-3794

[5] . Rama Mohan, K., "Performance evaluation of air gap insulated diesel engine with pure diesel", PhD Thesis, Kakatiya University, 1995.

[6]. Janardhan, N., Murali Krishna, M.V.S., Ushasri, P. and Murthy, P.V.K. "Performance of a low heat rejection diesel engine with jatropha". International Journal of Engineering Inventions, ISSN: 2278-7461, 1(2), 2012, pp: 23-35.

[7]. Krishna Murthy. P.V. Studies on biodiesel with low heat rejection diesel engine, PhD Thesis, J.N.T. University, Hyderabad, 2010

[8] Janardhan, N., Ushasri, P., Murali Krishna, M.V.S. and Murthy, P.V.K. 'Performance of biodiesel in low heat rejection diesel engine with catalytic converter'. *Int J Engineering and Advanced Technology ,* 2(2*),* 2012, pp: 97-109.

[9] Murali Krishna, M.V.S. Investigations on low heat rejection diesel engine with alternate fuels. PhD Thesis, (2004), J.N.T. University, Hyderabad.