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Research Article

Experimental Investigations on Exhaust Emissions with Low Heat Rejection Diesel Engine with Crude Vegetable Oil with Magnetic Induction

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Abstract

In the scenario of fast depletion of fossil fuels and increase of pollution levels the search for alternative fuels has become pertinent. Particulate emissions and oxides of nitrogen are exhaust emissions from diesel engine cause health hazards once they are inhaled in. They also cause environmental impact. Hence control of these pollutants is an immediate task and urgent. Crude vegetable oils are important substitutes for diesel fuel, as they are renewable, and have comparable properties with diesel fuel. However, drawbacks associated with crude vegetable oil of high viscosity and low volatility which cause combustion problems, call for low heat rejection (LHR) engine with its significant characteristics of maximum heat release and ability to handle the low calorific value fuel. LHR engine consisted of ceramic coated cylinder head. A hydrocarbon fuel was polarized by exposure to external force such as magnetism. Exhaust emissions of particulate emissions and oxides of nitrogen (NO_x) were determined at full load operation with conventional engine (CE) and LHR engine with and without magnetic induction with vegetable oil operation. LHR engine with crude vegetable oil operation with magnetic induction improved exhaust emissions when compared with CE with vegetable oil operation.

Keywords: *Alternative fuels, Vegetable oil, Low heat rejection, Exhaust emissions*

1. Introduction

Fossil fuels are limited resources; hence, search for renewable fuels is becoming more and more prominent for ensuring energy security and environmental protection. It has been found that the vegetable oils are promising substitute for diesel fuel, because of their properties are comparable to those of diesel fuel. They are renewable and can be easily produced. When Rudolph Diesel, first invented the diesel engine, about a century ago, he demonstrated the principle by employing peanut oil. He hinted that vegetable oil would be the future fuel in diesel engine [Acharya, 2009]. Several researchers experimented the use of vegetable oils as fuel on conventional engines (CE) and reported that the performance was poor, citing the problems of high viscosity, low volatility and their polyunsaturated character. It caused the problems of piston ring sticking, injector and combustion chamber deposits, fuel system deposits, reduced power, reduced fuel economy and increased exhaust emissions [Venkanna *et al*, 2009; Misra *et al*, 2010; No.Soo-Young, 2011; Avinash Kumar *et al*, 2013].

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The drawbacks associated with biodiesel (high viscosity and low volatility) call for hot combustion chamber, provided by low heat rejection (LHR) combustion chamber. The concept of the LHR engine is reduce heat loss to the coolant with provision of thermal resistance in the path of heat flow to the coolant. Three approaches that are being pursued to decrease heat rejection are (1) Coating with low thermal conductivity materials on crown of the piston, inner portion of the liner and cylinder head (LHR–1 engine), (2) air gap insulation where air gap is provided in the piston and other components with low-thermal conductivity materials like superni (an alloy of nickel),cast iron and mild steel (LHR–2 engine) and (3).LHR –3 engine contains air gap insulation and ceramic coated components.

Experiments were conducted on LHR-1 engine with vegetable oil. [Murali Krishna *et al,* 2012; Ratna Reddy *et al,* 2012; Kesava Reddy *et al,* 2012;]. They reported from their investigations, that LHR-1 engine at an optimum injection timing of 31° bTDC with vegetable oil operation at full load operation–decreased particulate emissions by 25–30% and increased NO_x levels, by 30–35% when compared with neat diesel operation on CE at 27° bTDC.

Installation of magnets at the fuel circuit is an old art. Investigations were carried out on diesel engine and petrol engine on the effect of electromagnetic flux density on the ionization and the combustion of fuel [Engr Okoronkwo *et al*, 2010].

Number of experiments in which influence of magnetic field with 1000 Gauss to 9000 Gauss intensity on working of IC engine and exhaust emission was studied for analysis. They reported that a considerable reduction in the hydrocarbon constituent and particulate matter of the exhaust. Experiments were conducted on two stroke gasoline engine with providing magnets of different intensities (2000,4000, 6000 and 9000 Gauss) [Shweta Jain *et al*. 2012]. The overall performance and exhaust emission tests showed a good result, where the rate of reduction in gasoline consumption ranged between (-1) %, and the higher the value of a reduction in the rate of 1% was obtained using field intensity 6000 Gauss as well as the intensity 9000 Gauss. It was found that the percentages of exhaust gas components (CO, HC) were decreased by 30%, 40% respectively, but CO2 percentage increased up to 10%.

Investigations were carried out on the study of magnetic fuel ionization method in four stroke diesel engines [Ali S Farisa *et al*.2012]. The results yielded from the experiments showed that thermal efficiency increased by 2% and emissions reduced to 5%.

Experimental work was carried out with magnetic fuel conditioner in internal combustion engine [P.V.Kumar *et al*. 2014]. A permanent magnet was mounted in path of fuel lines. Mounting magnets in fuel line enhance fuel properties by aligning & orienting hydrocarbon molecules, better atomization of fuel (Proper mixing of air with fuel) etc. Use of such fuel conditioners improves mileage & better emission of vehicle. Finally this article also reviewed about new emerging technology i.e. fuel conditioners, developments done across the globe.

A study of the existing literature on LHR engine thus reveals inconclusive results. Little literature is available on comparative studies on exhaust emissions with LHR-1 engine with magnetic induction. The present work attempts to make comparative studies with two versions of engine i.e. the conventional engine (CE)and the one with thermally insulated combustion chamber, LHR–1, (ceramic coated cylinder head); with crude cottonseed oil with and without magnetic induction. Results were compared with CE and also diesel working on similar operating conditions.

2. Materials and Methods

2.1. Fabrication of LHR-1 engine

Partially stabilized zirconium (PSZ) of thickness 500 microns was coated on inside portion of cylinder head by means of plasma coating technique. Fig. 1 shows photographic view of LHR-1 engine with ceramic coated combustion chamber.

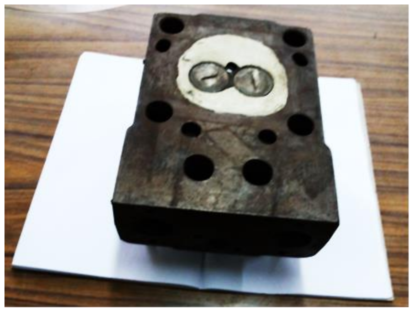
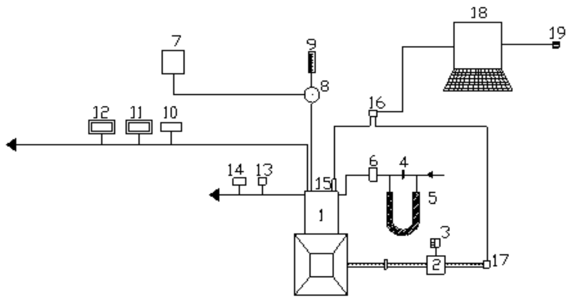


Fig.1 Photographic view of ceramic coated cylinder head

2.2 Experimental set-up

As mentioned earlier, this experiment uses two cylinder heads. The experimental set up used for investigations on engine with insulated combustion chambers with crude cotton seed oil is shown in Fig.2.



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

Fig.2 Schematic Diagram of Experimental Set-up

The specifications of the experimental engine are given in Table1. The engine is connected to an electrical dynamometer (Kirloskar make) for measuring its Brake Power (BP).Dynamometer is loaded by loading rheostat. The combustion chamber consists of a direct injection type with no special arrangement for swirling motion of air. The fuel is measured by Burette method while air consumption of engine is measured by Air box method. The naturally aspirated engine is provided with water cooling system. Engine oil is provided with a pressure feed system. However, there is no measurement of temperature of lubricating oil. The Exhaust Gas Temperature and water flow outlet temperature are measured by means of thermocouples made of iron and iron-constantan attached to the temperature indicator. Fuel injection pressures can be varied at 190, 270 bar by using nozzle testing device. The maximum injector opening pressure is restricted to 270 bar due to practical difficulties involved. The particulate emissions were measured using AVL

Smokemeter at full load of the engine, while NOx emissions were determined with Netel Chromatograph NOx analyzer at full load operation of the engine. The operation principle and accuracy of instrumentation were given in Table.2

Table1 Specifications of Engine

Description	Specification
Engine make and model	Kirloskar (India) AV1
Maximum power output at a speed of 1500 rpm	3.68 kW
Number of cylinders ×cylinder position× stroke	One × Vertical position × four-stroke
Bore × stroke	80 mm × 110 mm
Method of cooling	Water cooled
Rated speed (constant)	1500 rpm
Fuel injection system	In-line and direct injection
Compression ratio	16:1
BMEP @ 1500 rpm	5.31 bar
Manufacturer's recommended injection timing and pressure	27^obTDC × 190 bar
Dynamometer	Electrical dynamometer
Number of holes of injector and size	Three × 0.25 mm
Type of combustion chamber	Direct injection type
Fuel injection nozzle	Make: MICO-BOSCH No- 0431-202-120/HB
Fuel injection pump	Make: BOSCH: NO- 8085587/1

Table 2 Specifications of analyzers

Name of the analyzer	AVL Smoke meter	Netel Chromatograph NOx r
Operating Principle	Light extinction	Chemiluminiscence
Measuring Range	0-100 HSU	0-5000 ppm
Precision	1 HSU	5ppm
Resolution	1 HSU	5ppm
Accuracy	±1 HSU	±5 ppm

2.3 Characteristics of Cotton seed oil

The source of cottonseed oil is cottonseed, which is a crop by- product. The cottonseed crop is a fast growing plant with long productive life span of 3-4 months, its ability to survive on drought and poor soils. The cotton (gossypium arboreum) belongs to the Malvaceae, or mallow, family. The seeds and fibbers are enclosed in a boll which at maturity opens up to expose the white fibbers. The seed contains oil-bearing kernel surrounded by a hard black outer hull which produces fibbers and linters. Fibbers grow from and are attached to the cotton seeds, which are contained within a capsule called a boll that forms after the cotton plant flowers. As the plant matures, the bolls open to expose the fibbers and seeds. While propagation of the cotton plant is driven by demand for fibber to make cloth, the seeds of the cotton plant are also valuable as a food source. Oil extracted from the seeds is used for human consumption and the residual meal is fed to live stock. It contains high levels of saturated fats and tends to have high levels of pesticide residue as well, hence it was initially not considered healthy for human consumption. These days, however, after proper treatment, is being used as a cooking oil.

2.3.1. General description

Odourless, dirty brown coloured liquid. Less dense than water and insoluble in water. Hence floats on water. Freezing point 32°F. Contains principally the glycerides of palmitic, oleic and linoleic acids. It is basically a triglyceride ester with a number of branched chains of 8-18 carbon atoms. Its chemical Formula is $C_{55}H_{100}O_6$, Molecular Weight is 857.38. Table.2 shows the Physio Chemical properties of diesel and cottonseed oil as per IICT :

Table 2 Properties of Diesel and Cotton seed oil

Property	Diesel	Cottonseed
Calorific Value	44,800 kJ/kg	39,648 kJ/kg
Fire Point	68^o C	322^o C
Flash point	52-95 ^{o} C	316 ^{o} C
Viscosity	0.278 poise	2.52 poise
Density	0.916 kg/m^3	0.832 kg/m^3
Cetane number	50	41.8

2.4 Provision of magnetic induction

2.4.1 Specifications of Magnet

The permanent magnet has certain specifications like shape, size, gauss value, curie temperature.

The shape of magnet is rectangular. The number of magnets provided is four. The magnetic intensity varied from 7000 - 9000 gauss. The dimensions of the magnet are 50 mm× 25mm×12.5 mm

Fig 3 shows the installation of the magnets in fuel circuit.

Fig.3 Installation of Magnetizer Set Up on the fuel line

The magnetizer is installed after the pneumatic governor and before the injector on inlet pipe or housing for maximum alignment and maximum effect. The magnets are placed in pairs (2 pairs), and are placed on the fuel pipe through a special arrangement fabricated with mild steel material. This enables the easy removal of the magnets from the fuel line.

2.5 Operating Conditions

Different configurations of the combustion chamber used in the experiment are conventional engine and LHR-1 engine. Various test fuels used in experiment are crude vegetable oil (cotton seed oil) and diesel. Different operating conditions were with magnet induction and without magnetic induction.

3. Results and Discussions

Exhaust Emissions. The various exhaust emissions determined were particulate emissions and oxides of nitrogen.

Fig. 4 presents bar charts showing the variation of particulate emissions at full load in Hartridge Smoke Unit (HSU) with different versions of the engine with test fuels with and without magnetic induction.

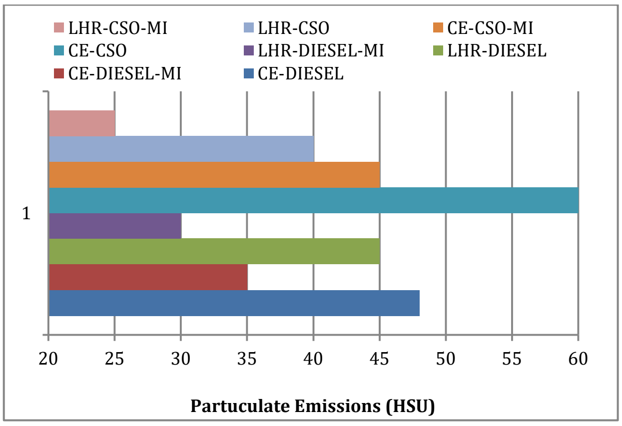


Fig.4 Bar chart showing the variation of particulate emissions at full load in Hartridge Smoke Unit (HSU) with different versions of the engine with test fuels with and without magnetic induction

Vegetable oil with CE showed drastic increase of particulate emissions at full load without magnetic induction. CE with vegetable oil without magnetic induction increased particulate emissions at full load by 25% when compared with CE with neat diesel operation. Presence of fatty acids, high value of C/H (C= Number of carbon atoms H= Number of hydrogen atoms in fuel composition) and high density of vegetable oil might have increased particulate emissions with CE with vegetable oil operation. LHR version of the engine reduced particulate emissions with test fuels with and without magnetic induction. Without magnetic induction, LHR-1 engine with vegetable oil operation decreased particulate emission at full load by 33% in comparison with CE with vegetable oil operation..Improved combustion with high heat release rate of LHR engine might have reduced particulate emissions at full load in comparison with CE. Magnetic induction with different versions of the engine with different test fuels reduced particulate emissions at full load. With magnetic induction, CE with vegetable oil decreased particulate emissions by 25% when compared with CE with vegetable oil operation. Improved combustion with proper alignment of fuel particles might have reduced particulate emissions at full load. LHR-1 engine with vegetable oil operation with magnetic induction showed lower particulate emission at full load in comparison with other versions of the engine. This showed that LHR-1 engine with vegetable oil operation with magnetic induction showed improved performance in comparison with other versions of the engine. High heat release rate and alignment of fuel particles in streamline might have improved the pollution levels with magnetic induction with LHR version of the engine.

Fig.5 presents bar charts showing the variation of oxides of nitrogen (NO_x) with different versions of the engine with test fuels with and without magnetic induction.

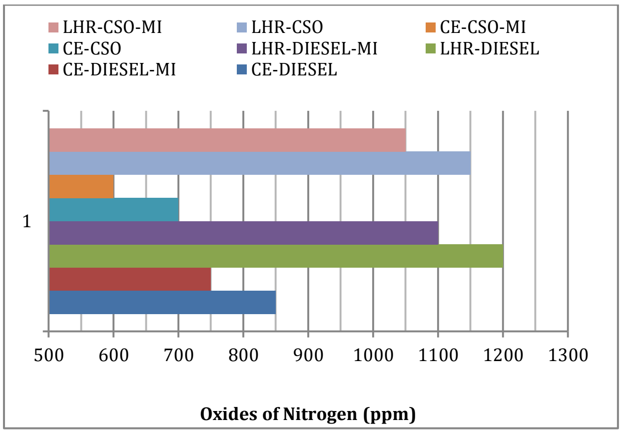


Fig.5 Bar chart showing the variation of oxides of nitrogen at full load with different versions of the engine with test fuels with and without magnetic induction

Cotton Seed oil with CE without magnetic induction showed a reduction of NO_x emissions in comparison with CE with diesel. CE with vegetable oil without magnetic induction decreased NOx emissions by 18% when compared with neat diesel operation on CE. Lower calorific value and higher viscosity of cottonseed oil might have deteriorated the performance of the engine causing reduction of NO_x levels. With magnetic induction with different versions of the engine, with test fuels showed decrease of NO_x levels in comparison with without magnetic induction. Alignment of fluid flow lines under the action of magnets, which improved combustion effectively causing reduction of combustion temperatures with improved oxygen-fuel ratios indicating lower NO_x levels at full load. With and without magnetic induction, with cottonseed oil, LHR-1 engine increased NOx emissions at full load in comparison with CE. Without magnet induction, LHR-1 engine increased NOx emissions by 65% when compared with CE. Faster rate of evaporation of fuel in the hot environment provided in the combustion chamber of LHR engine might have improved the combustion temperatures causing higher NO_x levels.

Conclusions

- Without magnetic induction, particulate emission at full load were observed to be the lower with vegetable oil operation on LHR engine in comparison with CE.
- Particulate emissions decreased with magnetic induction with both versions of the engine in comparison with without magnetic induction.
- With and without magnetic induction, nitrogen oxide levels at full load were observed to be the higher with test fuels with LHR engine in comparison with CE.
- Nitrogen oxide levels decreased with magnetic induction with both versions of the engine with test fuels in comparison with without magnetic induction.

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References

Acharya, S.K., Swain , R.K. and Mohanti, M.K. (2009).The use of rice bran oil as a fuel for a small horse-power diesel engine. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 33(1), 80-88.

Venkanna, B., Venkataramana Reddy, C., Swati, B. and Wadawadagi. (2009). Performance, emission and combustion characteristics of direct injection diesel engine running on rice bran oil / diesel fuel blend. International Journal of Chemical and Biological Engineering, 2(3), 131-137.

Misra, R.D. and Murthy, M.S. (2010).Straight vegetable oils usage in a compression ignition engine—A review. Renewable and Sustainable Energy Reviews, 14 (2), 3005–3013.

No. Soo-Young (2011). Inedible vegetable oils and their derivatives for alternative diesel fuels in CI engines: A review. Renew Sustain Energy Rev, 15 (2), 131–149.

Avinash Kumar Agarwal and Atul Dhar, (2013). Experimental investigations of performance, emission and combustion characteristics of Karanja oil blends fuelled DICI engine, Renewable Energy, 52 (2), 283–291.

Murali Krishna, M.V.S., Chowdary, R.P., Kishen Kumar Reddy, T. and Murthy, P.V.K. (2012). Performance evaluation of waste fried vegetable oil in la low grade low heat rejection diesel engine, *Int Res Mech Eng Technol* 2(2), 35-43.

Ratna Reddy, T., Murali Krishna, M.V.S., Kesava Reddy, Ch. and Murthy, P.V.K. (2012).Comparative performance of ceramic coated diesel engine with mohr oil in crude and biodiesel form. *Int J Eng Advanced Technol 2(3), 588-596.*

Kesava Reddy, Ch., Murali Krishna, M.V.S., Murthy, P.V.K. and Ratna Reddy, T. (2012). Performance evaluation of a low grade low heat rejection diesel engine with crude Pongamia oil, *Int Scholarly Res Network Renew Energy, Article ID 489605, 1-10.*

Engr Okoronkwo *et al. (2010).* The Effect of Electromagnetic Flux Density on the Ionization and Combustion of Fuel (An Economy Design Project), *American Journal of Scientific and Industrial Research*, 2(3), 528-531..

Shweta Jain *et al. (2012).* Experimental investigation of Magnetic Fuel Conditioner (MFC) in I.C. engine, *IOSR Journal of Engineering,* 2 (3),27-31.

Ali S Farisa *et al. (2012).* Effects of Magnetic Field on Fuel Consumption and Exhaust Emissions in Two-Stroke Engine, *Science Direct Energy Proceedings,* 18 (2), 327-338.

P.V.Kumar *et al*. (2014). Experimental study of a novel Magnetic Fuel ionization method in four stroke diesel engines, IJMERR, 3(1), 10-15