Investigations on exhaust emissions of insulated diesel engine with plastic oil

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ABSTRACT

Background of the problem: In the context depletion of fossil fuels, ever increases of fuel prices in International market causing economic burden on government of India and ever increases of pollution levels with fossil fuels, the search for alternative fuels has become pertinent. Alcohols and vegetables oils are important substitutes for diesel fuel as they renewable in nature. However, the drawbacks of vegetables oils (high viscosity and low volatility) and alcohols (low energy content and cetane number) call for semi-adiabatic diesel engine (SADE).The high energy content of plastic oil with supercharging can be taken together in order to have minimum pollution levels. The exhaust emissions of diesel engine cause severe health hazards once they are inhaled in. They also cause environmental disorders like Green-House effect, acid raining, and Global warming. Hence these pollutants are to be controlled at any cost.

Aim: Investigations were carried out to determine exhaust emissions of particulate matter, carbon monoxide (CO), un-burnt hydrocarbons (UBHC) and nitrogen oxide levels (NO_x) with

plastic oil blended with 15% diethyl ether (DEE) with supercharging at 0.8 bar of the conventional engine (CE) and semi adiabatic diesel engine (SADE)

Design Variables: Configuration of the engine, test fuels of diesel and plastic oil, with and without supercharging

Methodology: The experimental engine was single cylinder, four-stroke, water cooled, 3.68 k W at the rated speed of 1500 rpm engine with ceramic coated cylinder head (partially stabilized zirconium of thickness 500 µm coated over inside portion of cylinder head). Particulate matter was measured with AVL Smoke meter, while CO, UBHC and NO_x were determined by multi gas analyzer at full load. The engine was fuelled with plastic oil blended with 15% DEE by volume, to improve Cetane number (quality of combustion) and reduce viscosity of fuel. The engine was provided with supercharging at a pressure of 0.8 bar.

Brief Results: SADE with plastic oil considerably reduced pollutants with supercharging.

Keywords: Alternative fuels; Plastic oil; SADE; Exhaust emissions.

1.INTRODUCTION

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 causing the problems of piston ring sticking, injector and combustion chamber deposits, fuel system deposits, reduced power, reduced fuel economy and increased exhaust emissions .[1-4]. Plastic oil extracted from plastic is used as alternative fuel for diesel engine.[5-8]. Plastic oil deteriorated the performance of the conventional engine, though its calorific value is comparable to diesel fuel, due to presence of high carbon. The concept of semi adiabatic diesel engine (SADE) is to reduce heat loss to the coolant thus increasing thermal efficiency of the engine. There are two types of the SADE. Ceramic coated diesel engine and air gap insulated engines. Ceramic, partially stabilized zirconium (PSZ) of thickness 500µm was applied on the inner side of the cylinder head to reduce heat loss to the coolant. [9-11]. The performance of the SADE with ceramic coating with diesel operation improved marginally in comparison with neat diesel operation on conventional engine. The performance of the SADE with ceramic coating with vegetable oil operation improved marginally in comparison with neat diesel operation on conventional engine.[12-14]. Alcohols were used as blends in conventional diesel engine. [15-18]. They reported marginal improvement in the performance of the engine with blended alcohols. Alcohols were carbureted and used in SADE with vegetable oil. [19-21]. Change of injection timing was adopted to improve the performance of the engine. [22-24]. Little reports were available on exhaust emissions with SADE with plastic oil with and without supercharging. Hence the authors made an attempt to work in this direction.

2.MATERIALS AND METHODS

2.1 Fabrication Of Insulated Cylinder Head

Partially stabilized zirconium (PSZ) of thickness 500 microns is coated on inside portion of cylinder head by plasma spray technique. Fig.1 represents the photographic view of the ceramic coated cylinder head. At 500^0 C, thermal conductivity of PSZ is 2.2 W/m-K.

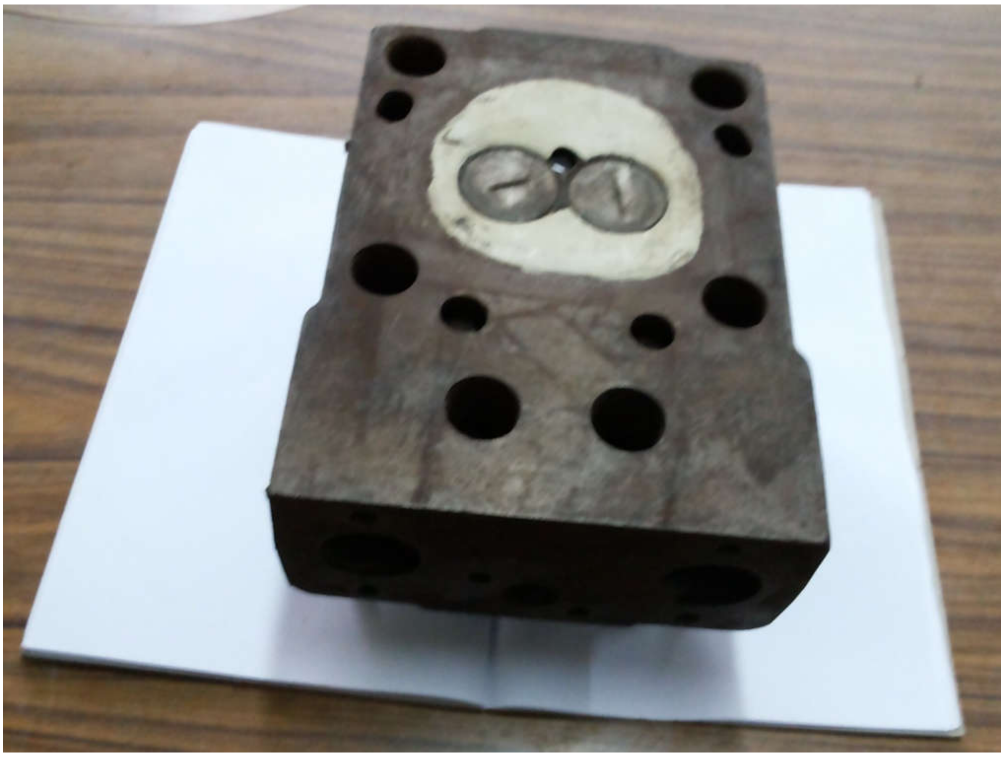


Fig.1. Photographic view of ceramic coated cylinder head

2.2.Preparation of Plastic Oil

Thermal cracking or pyrolysis involves the degradation or cracking of the polymeric materials by heating them to a very high temperature. The heating should be carried out in the absence of oxygen to make sure that no oxidation of the polymer takes place. The temperature ranges between 350 and 900°C. The products formed include a carbonized char (solid residues) and a volatile fraction. A portion of the volatile fraction can be condensed to give paraffins, isoparaffins, olefins, naphthenes, and aromatics, while the remaining is a non-condensable high calorific value gas. Table.1 shows the properties of waste plastic oil. The plastic oil was blended with diethyl ether by 15% as it was found to be optimum by earlier researchers.

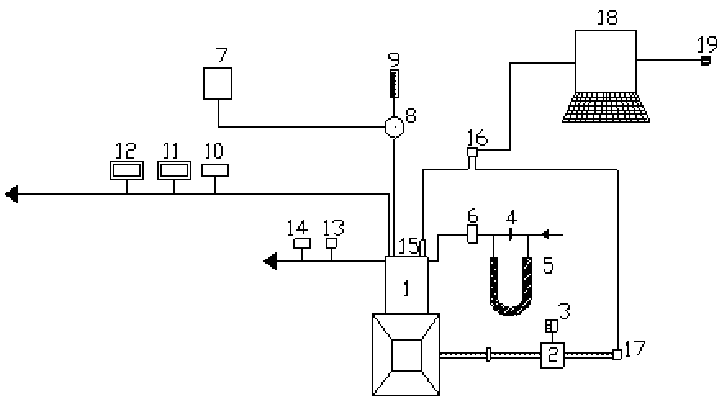
Table.1
Properties of Waste Plastic oil (WPO)

Property	Test Method	Diesel	WPO
Density (kg/m^3) at 15 ° C.	ASTM D1298	834	823
Kinematic viscosity at 40°C. (cSt)	ASTM D 445	3.44	3.11
Flash Point (° C))	ASTM D 93	66	54
Cetane Number	ASTM D976	56	46
Gross Calorific value (MJ/kg)	ASTM D240	45.5	45.2

2.4 Plastic oil operation

The exhaust emissions of the conventional engine drastically increased with plastic oil as contained high carbon content, as reported by many researchers. Hence work in that direction was left over. Instead, the authors used supercharging technique and crude plastic oil was injected in conventional manner.

The schematic diagram of the experimental setup used for the investigations with plastic oil operation is shown in Fig.2. The specifications of the engine are shown in Table 2.



1.Engine, 2.Electical Dynamometer, 3.Load Box, 4.Orifice meter, 5.U-tube water manometer, 6.Air box, 7.Diesel tank, 8 Three-way valve, 9.Burette, 10. Exhaust gas temperature indicator, 11.AVL Smoke meter, 12.Multi Gas Analyzer, 13.Outlet jacket water temperature indicator, 14. Outlet-jacket water flow meter, 15.Piezo-electric pressure transducer, 16.Console, 17.TDC encoder, 18.Personal Computer and 19.Printer.

Fig.2. Schematic diagram of the experimental setup for diesel operation

The engine was provided with supercharger of capacity 1.0 HP and 1500 rpm.

The naturally aspirated engine is provided with water-cooling system in which outlet temperature of water was maintained at 80^0 C by adjusting the water flow rate. .

Table.2.

Specifications Of The Test 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
Aspiration	Natural
BMEP @ 1500 rpm	5.31 bar
Manufacturer's recommended injection timing and pressure	27^0 bTDC × 190 bar
Dynamometer	Electrical dynamometer (Kirlosker make)
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

3.RESULTS AND DISCUSSION

Fig.3 shows variation of particulate matter in Hartridge Smoke Unit (HSU) with conventional engine and LHR engine consisted of ceramic coating on inside portion of cylinder head of thickness 0.5mm with plastic oil with and without supercharging (SC) at an optimum pressure of 0.8 bar.

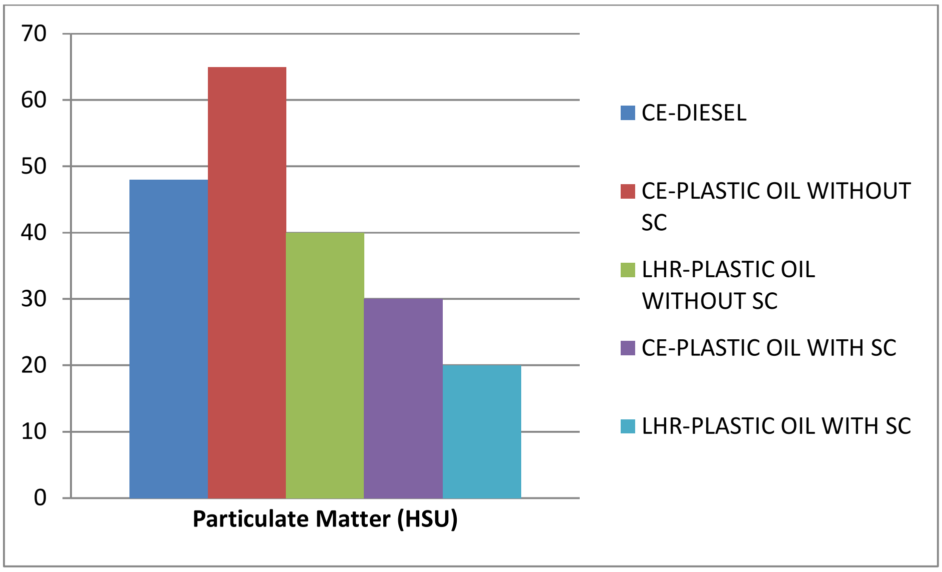


Fig.3. Variation of particulate matter at full load

Conventional Engine (CE) with plastic oil without supercharging showed drastic increase of particulate matter. This is due to high viscosity of plastic oil causing poor combustion. This is also due to high density (0.92 gm/cc) of plastic oil as particulate emissions are related to the density of plastic oil. High C/H (C=Number of carbon atoms, H= Number of hydrogen atoms in molecular composition of plastic oil) $(C2H4)_n$ increased particulate matter. However, LHR engine which contained ceramic coated cylinder head reduced particulate matter with plastic oil without supercharging. This is due to improved combustion with LHR engine causing reduction of particulate matter. CE with supercharging drastically reduced particulate matter with the supply of additional oxygen causing improved combustion. LHR engine further reduced particulate matter with supercharging with plastic oil due to high heat release rate and faster rate of combustion with the supply of additional oxygen with supercharging. LHR engine with plastic oil with supercharging reduced 50% of particulate matter in comparison with neat diesel operation on conventional engine

Fig.4 shows variation of un-burnt hydro carbons (UBHC) with conventional engine and LHR engine consisted of ceramic coating on inside portion of cylinder head of thickness 0.5mm with plastic oil with and without supercharging (SC) at an optimum pressure of 0.8 bar. UBHC levels drastically increased with CE without supercharging with plastic oil. This is due to incomplete combustion with inadequate supply of necessary combustion of plastic oil. This is due to accumulation of fuel in crevice volume of piston rings, gap between piston and cylinder liner, and valves located in cylinder head, which will not participate combustion and also they are subjected to low temperatures. LHR engine without supercharging with plastic oil reduced UBHC emissions in comparison with UBHC emissions with neat diesel operation due to faster rate of combustion of fuel. CE with supercharging drastically reduced UBHC emissions with plastic oil due to additional supply of oxygen causing improved combustion. LHR engine further reduced UBHC emissions with supercharging as the fuel was burnt in the hot environment created by LHR engine. LHR engine with supercharging with plastic oil reduced 66% of UBHC in comparison with neat diesel operation on conventional engine.

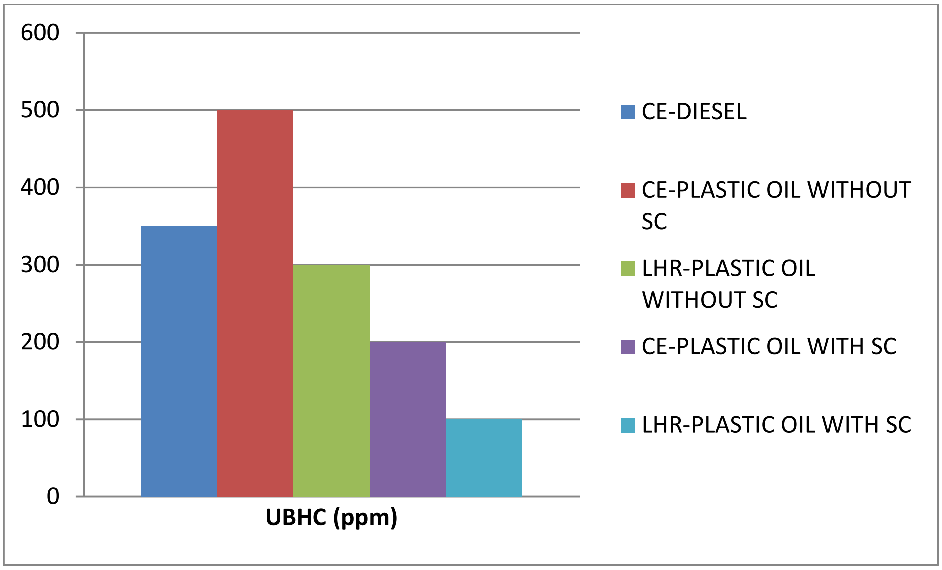


Fig.4. Variation of UBHC at full load

Fig.5 shows variation of carbon monoxide (CO) with conventional engine and LHR engine consisted of ceramic coating on inside portion of cylinder head of thickness 0.5mm with plastic oil with and without supercharging (SC) at an optimum pressure of 0.8 bar. CO emissions followed similar trends of UBHC with both versions of the engine with and without supercharging. CO emissions drastically increased with CE without supercharging with plastic oil. This is due to incomplete combustion of the fuel with high viscosity, low volatility and high duration of combustion reaching diffusion combustion. LHR engine with plastic oil reduced CO emissions in comparison with neat diesel operation on CE. This is due to improved combustion with faster rate of combustion and high heat release rate of LHR engine. CE with supercharging drastically reduced CO levels in comparison with neat diesel operation on CE. LHR engine with supercharging considerably reduced CO levels due to improved oxygen-fuel ratios. LHR engine reduced CO levels by 75%C with supercharging in comparison with CE with diesel operation.

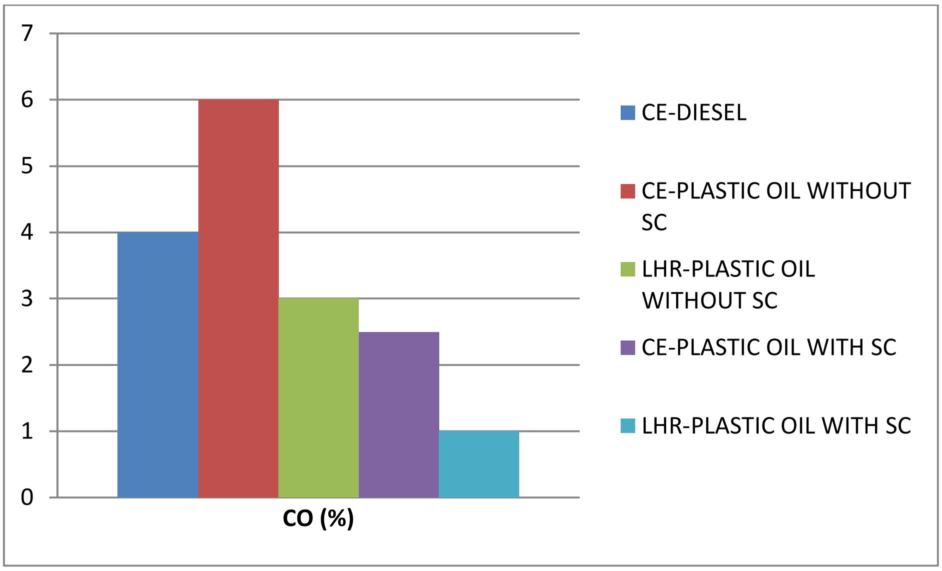


Fig.5 Variation of CO levels at full load

Fig.6 shows variation of nitrogen oxide (NO_x) levels with conventional engine and LHR engine consisted of ceramic coating on inside portion of cylinder head of thickness 0.5mm with plastic oil with and without supercharging (SC) at an optimum pressure of 0.8 bar. Temperature and availability of oxygen are the main sources of NO_x levels. CE with plastic oil without supercharging (SC) marginally increased NO_x levels in comparison with diesel operation on CE. This is due to poor combustion with plastic oil increased deposits which in turn increased combustion temperatures causing marginally higher NO_x levels in CE with plastic oil without supercharging. LHR engine drastically increased NO_x levels without supercharging due to increase of combustion temperatures with increased heat release rate of LHR engine. Supercharging reduced NO_x levels with both versions of the engine due to reduction of gas temperatures with additional supply of oxygen with supercharging. LHR engine with supercharging reduced NO_x levels by 25% in comparison with diesel operation on CE.

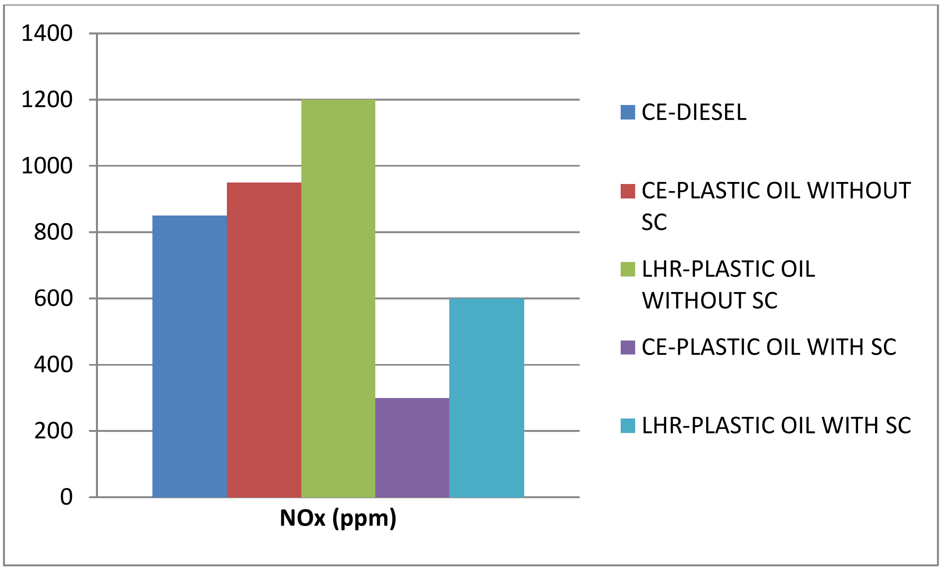


Fig.6 Variation of NO_x levels at full load

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