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Studies on Direct Injection Diesel Engine with Air Gap Insulated Low Heat Rejection Combustion Chamber with Emulsified fuel of Cotton seed oil and Ethanol

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Nomendature

ρ_a density of air, kg/m^3
ρ_d density of fuel, gm/cc
η_d efficiency of dynamometer, 0.85
a area of the orifice flow, m^2
BP brake power of the engine, kW
C number of carbon atoms in fuel composition
C_d coefficient of discharge, 0.65
Cp specific heat of water in kJ/kg K
D bore of the cylinder, 80 mm
D diameter of the orifice flow meter, 20 mm
DF diesel fuel
H number of hydrogen atoms in fuel
HSU Hartridge smoke unit
I ammeter reading, ampere
H difference of water level in U-tube water manometer in cm of water column
IT injection timing, degree bTDC
K number of cylinders, 01
L stroke of the engine, 110 mm
m_a mass of air inducted in engine, kg/h
m_f mass of fuel, kg/h
m_w mass flow rate of coolant (water), kg/s
n power cycles per minute, N/2,
N speed of the engine, 1500 rpm
P_a atmosphere pressure in mm of mercury
R gas constant for air, 287 J/kg K
t time taken for collecting 10 cc of fuel, second
T_a room temperature, degree centigrade
T_I inlet temperature of water, degree centigrade
T_o outlet temperature of water, degree centigrade
V voltmeter reading, volt
V_s stroke volume, m^3

Abstract: *Vegetable oils and alcohols (ethanol and methanol), which are renewable in nature are important substitutes for diesel fuel in diesel engine, as their properties are comparable to diesel fuel. However, the disadvantages associated with vegetable oils (high viscosity and low volatility) and alcohols (low cetane number) call for engine with low heat rejection (LHR) combustion chamber, with significant characteristics of higher operating temperature, maximum heat release, higher brake thermal efficiency and ability to handle the lower calorific value fuel. Investigations were carried out to evaluate the performance of diesel engine with LHR combustion chamber consisting of air gap insulated piston and air gap insulated liner with emulsified cotton seed oil with ethanol with varied injector opening pressure. Performance parameters [brake thermal efficiency, exhaust gas temperature, coolant load and volumetric efficiency] were determined at various values of brake mean effective pressure (BMEP) of the engine and compared with conventional engine with diesel operation. Cotton seed oil showed deteriorated performance with conventional engine (CE), while LHR combustion chamber improved the performance in comparison with pure diesel operation at similar operating conditions. Emulsified cotton seed oil improved performance further with conventional engine and engine with LHR combustion chamber. Engine with LHR combustion chamber with 40% emulsified cotton seed oil increased peak BTE by 5%, at full load operation – decreased brake specific energy consumption by 2%, decreased exhaust gas temperature by 25%, decreased coolant load by 17%, increased volumetric efficiency by 5% and decreased smoke levels by 37% in comparison with pure cotton seed oil operation at similar operating conditions.*

Keywords*: Vegetable oil; LHR combustion chamber; Fuel performance and smoke levels.*

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1. INTRODUCTION

The resources of petroleum as fuel are dwindling day by day and increasing demand of fuels, as well as increasingly stringent regulations, pose a challenge to science and technology [1].

Vegetable oils which are renewable in nature have properties comparable to diesel fuel. Rudolph Diesel, the inventor of the diesel engine that bears his name, experimented with fuels ranging from powdered coal to peanut oil and hinted that vegetable oil would be the future fuel. [2]. 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. [3–5]. Not only that, the common problems of crude vegetable oils in diesel engines are formation of carbon deposits, oil ring sticking, thickening and gelling of lubricating oil as a result of contamination by the vegetable oils Experiments were conducted on preheated vegetable oils [temperature at which viscosity of the vegetable oils were matched to that of diesel fuel] and it was reported that performance improved marginally with preheated vegetable oils [6–9]. Increased injector opening pressures may also result in efficient combustion in compression ignition engine [3–5].

Alcohols (ethanol and methanol) are important substitutes for diesel fuel in diesel engine. Alcohols have good volatility and low C/H ratio. However, they have low cetane number. Hence engine modification is necessary for use them as fuel in diesel engines. That too, most of the alcohol produced is diverted for Petro-chemical industries in India. There are many methods of inducting alcohols in diesel engines, out of which blending is simple technique [10–12]. However, the maximum amount of induction of alcohol in compression ignition engine is limited in blending technique.

However, the disadvantages associated with use of cotton seed oil of high viscosity and low volatility call for engine with LHR combustion chamber. The concept of LHR combustion chamber is to reduce coolant losses by providing thermal resistance in the path of heat flow to the coolant, there by gaining thermal efficiency. Several methods adopted for achieving LHR to the coolant are i) ceramic coated combustion chambers by providing low thermal conductivity material on cylinder head, crown surface of piston and inner portion of liner and ii) air gap insulated combustion chambers, where air gap is created in the piston and other components with low-thermal conductivity materials like superni, cast iron and mild steel.

Investigations were carried out by various researchers on engines with medium grade LHR combustion chamber (air gap insulated piston and air gap insulated liner) with vegetable oil operation. [13–15]. It was reported from their investigations that brake specific fuel consumption (BSFC) improved in the range 5–9% and pollution levels decreased with ceramic coated combustion chamber. [16].

Emulsified vegetable oil operation was carried out on ceramic coated combustion chamber [17]. It was reported from their investigations that pollution levels decreased by 25% and improved BSFC.

Little literature was available on studies of emulsified vegetable oil with ethanol with air gap insulated piston and air gap insulated liner combustion chamber. Hence it was attempted here to evaluate the performance of the engine with emulsified cotton seed oil at different injector opening pressure and compared with engine with conventional engine. Comparative studies were also made with diesel operation at similar operating conditions.

2. MATERIAL AND METHOD

2.1 Manufacturing of Emulsified Vegetable Oil

Cottonseed oil is obtained as a byproduct of cotton production. Cottonseed oil is a cooking oil extracted from the seeds of cotton plant of various species, mainly gossypium hirsutum and gossypium herbaceum. Cotton seed oil was blended with ethanol with emulsified agent of soap solution of 2% by volume and emulsified with mechanical stirrer, such that no phase separation should occur among the solvents. The purpose of adding ethanol with cotton seed oil is to reduce viscosity and improve volatility. Table.1 shows physical-chemical properties of test fuels.

Table1: Physical-Chemical Properties of Test Fuels

Property	Units	Diesel	Cotton Seed oil (CSO)	Ethanol
Carbon chain	--	C_8-C_{28}	C_{16}-C_{24}	C_2H_5OH
Cetane Number		55	45	Less than 10
Density	gm/cc	0.84	0.92	0.72
Bulk modulus @ 20Mpa	Mpa	1475	1850	---
Kinematic viscosity @ 40^{o}C	cSt	2.25	3.5	--
Sulfur	%	0.25	0.1	--
Oxygen	%	0.3	10	32
Air fuel ratio (stochiometric)	--	14.86	12.5	9.6
Low calorific value	kJ/kg	42 000	41200	26700
Flash point (Open cup)	^{o}C	66	270	--
Molecular weight	--	226	261	44
Colour	--	Light yellow	Dark orange	Colorless

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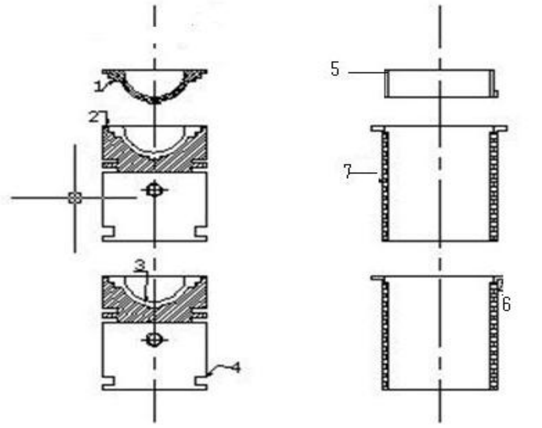
2.2 Fabrication Of Engine with LHR Combustion Chamber

Figure.1 shows the details of insulated piston and insulated liner employed in the experiment.



1. Crown with threads
2. Gasket
3. Air gap
4. Body

5. Insert with threads
6. Air gap
7. Liner

Insulated piston *Insulated liner*

Figure 1: Assembly details of air gap insulated piston and air gap insulated liner

The engine with LHR combustion chamber contains a two–part piston the top crown made of low thermal conductivity material, superni–90 was screwed to aluminum body of the piston, providing a 3mm air gap in between the crown and the body of the piston. The optimum thickness of air gap in the air gap piston is found to be 3 mm for improved performance of the engine with superni inserts with diesel as fuel. A superni–90 insert was screwed to the top portion of the liner in such a manner that an air gap of 3mm is maintained between the insert and the liner body. The properties and composition of superni–90 material are shown in Table-2 and Table-3

.

Table-2 Properties of superni-90 material

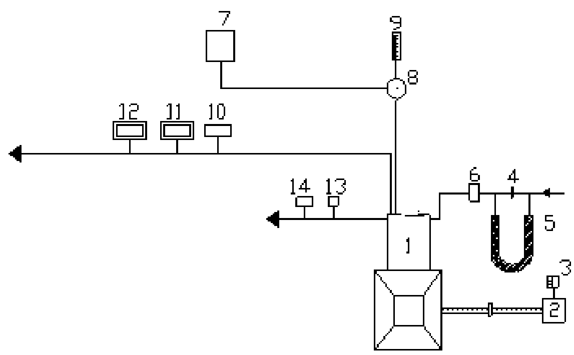
Thermal conductivity at 500^0 C	21 W/m–K
Melting Point	1400^0 C
Young's modulus at 500^0C	1328 N/m^2
Mean coefficient of Thermal expansion	14.1×10^{-6}
Electrical resistivity at room temp	1ohm m^2 /m

Table-3 Composition of superni-90 material

Cobalt -- 2.0 %, Chromium---2.93 %, Aluminum-- 1.5 %, Titanium – 2.5 %,Carbon—0.07%, Iron – 1 % and Nickel – Balance.

2.3 Description of the Experimental Set–Up

Schematic diagram of experimental set–up used for the investigations on compression ignition diesel engine and LHR combustion chamber with test fuels is shown in Fig. 2. The specifications of the experimental engine are shown in Table.4. The combustion chamber consisted of a direct injection type with no special arrangement for swirling motion of air. The engine was connected to an electric dynamometer for measuring its brake power with output signals of current and voltage. The accuracy obtained with loading of dynamometer is ±1%. The fuel consumption was registered with the aid of fuel measuring device (Burette and stop watch) and then mass flow rate of fuel was determined by knowing the density of the fuel. Density of fuel was determined by hydrometer. Percentage error obtained with measurement of fuel flow rate assuming laminar film in the burette was within the limit. The accuracy of determination of brake thermal efficiency obtained is ±2%. The speed of the engine was measured with digital tachometer with accuracy ±1%. Air–consumption of the engine was measured by an air–box method (Air–box was provided with an orifice flow meter and U–tube water manometer). Air–box was provided with damper to damp out oscillations. The naturally aspirated engine was provided with water–cooling system in which inlet temperature of water was maintained at 80 ^{o}C by adjusting the water flow rate. Engine oil was provided with a pressure feed system. No temperature control was incorporated, for measuring the lube oil temperature. Injector opening pressure was changed using nozzle testing device from 190 bar to 270 bar (in steps of 40 bar) using nozzle testing device. The maximum injector opening pressure was restricted to 270 bar due to practical difficulties involved. Exhaust gas temperature, coolant outlet temperature was measured with thermocouples made of iron and iron–constantan connected to analogue temperature indicators. The accuracy with these temperature indicators are ±1%. Partially stabilized zirconium of thickness 0.5 mm was coated on inside portion of cylinder head by plasma spray technique.



1.Engine, 2.Electical Dynamo meter, 3.Load Box, 4.Orifice meter, 5.U-tube water manometer, 6.Air box, 7.Fuel tank, 8, Three-way valve, 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.

Figure 2: Schematic diagram of experimental set–up

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Table.4. 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
BMEP @ 1500 rpm	5.31 bar
Manufacturer's recommended injection timing and pressure	27^{o}bTDC × 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

2.4 Operating conditions

Various test fuels used in experiment were pure diesel, pure cotton seed oil, and emulsified cotton seed oil with ethanol. Different combustion chambers used in the experiment were conventional engine and engine with LHR combustion chamber with air gap insulated piston and air gap insulated liner. Different operating conditions of the cotton seed oil were normal temperature and preheated temperature. Different injector opening injector opening pressures attempted in this experiment were 190 bar, 230 bar and 270 bar.

2.4 Definitions of used values:

$$m_f = \frac{10 \times \rho_d \times 3600}{t \times 1000} \quad \text{--(1)}$$

$$BP = \frac{V \times I}{\eta_d \times 1000} \quad (2)$$

$$BTE = \frac{BP \times 3600}{m_f \times CV} \quad (3)$$

$$BSEC = \frac{1}{BTE} \quad \text{----(4)}$$

$$BP = \frac{BMEP \times 10^5 \times L \times A \times n \times k}{60000} \quad \text{---(5)}$$

$$CL = m_w \times c_p \times (T_o - T_i) \quad (7)$$

$$m_a = C_d \times a \times \sqrt{2 \times 10 \times g \times h \times \rho_a} \times 3600 \quad (6)$$

$$a = \frac{\pi \times d^2}{4} \quad (7)$$

$$\eta_v = \frac{m_a \times 1}{60 \times \rho_a \times N \times V_s} \quad (8)$$

$$\rho_a = \frac{P_a \times 10^5}{750 \times R \times T_a} \quad (9)$$

3. RESULTS AND DICUSSION

3.1 Performance Parameters

Data of pure diesel was taken from reference [4]. Curves in Fig.3, indicate brake thermal efficiency increased up to 80% of the full load and beyond that load it decreased in conventional engine with test fuels. This was due to increase of fuel conversion up to 80% of full load. Beyond 80% of peak load, air fuel ratios got reduced as oxygen was completely used up. Conventional engine operated with crude cotton seed oil (CSO) showed deteriorated performance at all loads when compared with the pure diesel operation on conventional engine at 27^{o} bTDC. This was due to higher viscosity and accumulation of carbon on nozzle tip with cotton seed oil. In addition, less air entrainment by the fuel spay suggested that the fuel spray penetration might increase and resulted in more fuel reaching the combustion chamber walls. Furthermore droplet mean diameters (expressed as Sauter mean) were larger for cotton seed oil leading to reduce the rate of heat release as compared with diesel fuel. This also, contributed the higher ignition (chemical) delay of the cotton seed oil due to lower cetane number. According to the qualitative image of the combustion under the crude cotton seed oil operation with CE, the lower BTE was attributed to the relatively retarded and lower heat release rates. Curves from same figure indicate that LHR version of combustion chamber with cotton seed oil operation at recommended injection timing showed improvement in the performance for the entire load range compared with conventional engine with pure diesel.

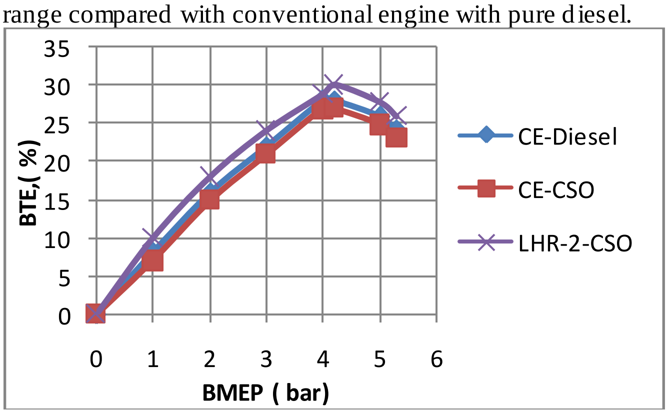

Figure 3: Variation of brake thermal efficiency with brake mean effective pressure (BMEP) with cotton seed oil operation in conventional engine and engine with LHR–2 combustion chamber at an injection timing of 27^{o}bTDC and injector opening pressure of 190 bar.

High cylinder temperatures helped in improved evaporation and faster combustion of the fuel injected into the combustion chamber. Reduction of ignition delay of the crude cotton seed oil in the hot environment of the LHR–2 combustion chamber improved heat release rates and efficient energy utilization. Curves in Fig.4 indicate that BTE increased at all loads with 20% ethanol in emulsified cotton seed oil and with the increase of ethanol content in emulsified cotton seed oil beyond 20%, it decreased at all loads in the conventional engine when compared to the standard diesel engine.

The reason for improving the efficiency with the 20% emulsified cotton seed oil was because of improved homogeneity of the mixture with the presence of ethanol, decreased dissociated losses, specific heat losses and cooling losses due to lower combustion temperatures. This was also due to high heat of evaporation of ethanol, which caused the reduction the gas temperatures resulting in a lower ratio of specific heats leading to more efficient conversion of heat into work. Emulsifying with ethanol with cotton seed oil resulted in more moles of working gas, which caused high pressures in the cylinder. The observed increased in the ignition delay period would allow more time for fuel to vaporize before ignition started. This means higher burning rates resulted more heat release rate at constant volume, which was a more efficient conversion process of heat into work. When ethanol content was more than 20% in emulsified cotton seed oil, performance deteriorated with increase of ignition delay and reduction of combustion temperatures.

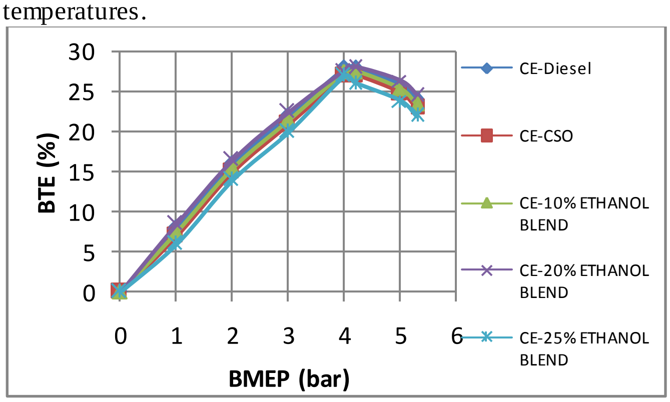

Figure 4: Variation of BTE with BMEP with different percentages of ethanol in emulsified cotton seed oil in the conventional engine at the recommended injection timing and pressure

Curves in Fig.5 indicate engine with LHR–2 combustion chamber showed an improvement in the performance with the emulsified cotton seed oil at all loads when compared to the standard diesel engine. This was due to recovery of heat from the hot insulated components of engine with LHR–2 combustion chamber due to high latent heat of evaporation of the ethanol, which lead to increase in thermal efficiency.

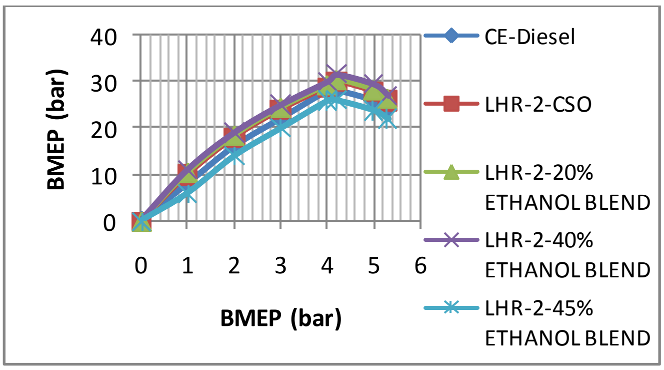

Figure 5: Variation of BTE with BMEP

Fig 5 shows the Variation of BTE with BMEP with different percentages of ethanol in emulsified cotton seed oil in the engine with LHR–2 combustion chamber at the recommended injection timing and pressure

The maximum content of ethanol was 40% in emulsified cotton seed oil in the engine with LHR combustion chamber, which showed improvement in the performance at all loads when compared to standard diesel engine. However when ethanol content in emulsified cotton seed oil was increased more than 40% in the engine with LHR-2 combustion chamber, brake thermal efficiency deteriorated at all loads when compared to the standard diesel engine.

From Table5, it is noticed that peak brake thermal efficiency increased with increase in injector opening pressure in both versions of the combustion chamber at different operating conditions of the test fuel. The improvement in brake thermal efficiency at higher injector opening pressure was due to improved fuel spray characteristics. Preheated vegetable oil showed marginally higher BTE than normal vegetable oil. This was due to improvement in spray characteristics with improved air fuel ratios.

Engine with LHR–2 combustion chamber with 40% emulsified cotton seed oil gave marginally higher thermal efficiency than conventional engine with 20% emulsified cotton seed oil due to higher amount of ethanol substitution, which improved evaporation characteristics from hot insulated components of the engine with LHR–2 combustion chamber.

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Table.5: Data of Peak BTE

Test Fuel	Peak BTE (%)											
	Conventional Engine (CE)						Engine with LHR-2 combustion chamber					
	Injector opening pressure (Bar)						Injector opening pressure (Bar)					
	190		230		270		190		230		270	
	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT
Diesel	28	--	29	---	30	--	29	--	30	--	30.5	--
CSO	27	28	28	29	29	30	30	30.5	30.5	31	31	31.5
20% Emulsified cotton seed oil	28	--	29	--	30	--	30.5	--	31	--	31.5	--
40% Emulsified cotton seed oil	-	--	--	--	--	--	31.5	--	32	--	32.5	-

Brake specific fuel consumption (BSFC), is not used to compare the two different fuels, because their calorific value, density, chemical and physical parameters are different. Brake specific energy consumption (BSEC) defined as energy consumed by the engine in producing 1 kW brake power. Lesser is the value of BSEC, the better is the performance of the engine.

From Table.6, it is noticed that BSEC was lower with preheated vegetable oil than normal vegetable oil. Bulk modulus and hence compressibility of the fuel also changes with preheating. That shows lower energy substitution and effective energy utilization of vegetable oil, which could replace 100% diesel fuel. BSEC was higher with vegetable oil with conventional engine due to due to higher viscosity, poor volatility and reduction in heating value of crude vegetable oil because of its poor atomization and combustion characteristics.

BSEC at full load operation decreased with 20% emulsified cotton seed oil with conventional engine when compared with standard diesel engine. This was due to improved combustion with reduction of viscosity of the crude vegetable oil by blending with ethanol. Engine with LHR–2 combustion chamber with 40% emulsified cotton seed oil gave marginally lower BSEC at full load operation when compared with conventional engine with 20% emulsified cotton seed oil. This was due to substitution of higher amount of ethanol, which improved combustion with reduction of losses during combustion.

Table.6: Data of Brake specific energy consumption (BSEC) at full load operation

Test Fuel	Brake Specific Energy Consumption (kW.h) at full load operation											
	Conventional Engine (CE)						Engine with LHR-2 combustion chamber					
	Injector opening pressure (Bar)						Injector opening pressure (Bar)					
	190		230		270		190		230		270	
	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT
Diesel	4		3.96		3.92		4.2		4.1		4.0	
CSO	4.2	4.0	4.0	3.94	3.94	3.92	3.88	3.86	3.86	3.82	3.82	3.78
20% Emulsified cotton seed oil	3.96	--	3.92	--	3.88	--	3.84	--	3.80	--	3.76	--
40% Emulsified cotton seed oil	--	--	--	--	--	--	3.80	--	3.76	--	3.72	--

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From Fig.6, it is observed that conventional engine with crude vegetable oil operation recorded drastically higher value of EGT at all loads compared with CE with pure diesel operation. Though calorific value (or heat of combustion) of fossil diesel is more than that of crude vegetable oil, its density is less in comparison with vegetable oil. Therefore lesser the heat is released in the combustion chamber leading to generate lower temperature with diesel operation on conventional engine. Also, there is an advanced combustion of crude vegetable oil due to its higher bulk modulus. However its cetane number is less when compared to fossil diesel. Hence there is no effect of bulk modulus on injection timing (advance or retardation) and heat release. Vegetable oil operation on conventional engine exhausted more amount of heat in comparison with pure diesel operation on CE. Lower heat release rates and retarded heat release associated with high specific energy consumption caused increase in exhaust gas temperature in conventional engine. Ignition delay in the conventional engine with different operating conditions of vegetable oil increased the duration of the burning phase. At recommended injection timing, with vegetable oil operation, engine with LHR–2 combustion chamber recorded lower value of exhaust gas temperature when compared with conventional engine. This was due to reduction of ignition delay in the hot environment with the provision of the insulation in the engine with LHR–2 combustion chamber, which caused the gases expanded in the cylinder giving higher work output and lower heat rejection. This showed that the performance improved with engine with LHR–2 combustion chamber over CE with vegetable oil operation.

EGT decreased with increase of injector opening pressure with both versions of the combustion chamber with test fuels which confirmed that performance increased with increase of injector opening pressure. This was due to improved spray characteristics of the fuel with improved air fuel ratios.

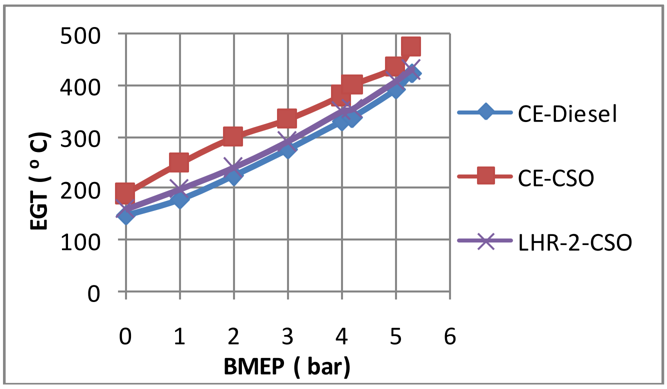

Figure 6: Variation of exhaust gas temperature (EGT) with brake mean effective pressure (BMEP) with vegetable oil operation in conventional engine and engine with LHR–2 combustion chamber at an injection timing of 27^{o} bTDC and injector opening pressure of 190 bar.

From Table.7, it is noticed that the exhaust gas temperatures of preheated vegetable oil were higher than that of normal vegetable oil, which indicates the increase of diffused combustion due to high rate of evaporation and improved mixing between fuel and air. Therefore, as the fuel temperature increased, the ignition delay decreased and the main combustion phase (that is, diffusion controlled combustion) increased, which in turn raised the temperature of exhaust gases.

.

Table 7: Data of Exhaust gas temperature at full load operation

Test Fuel	Exhaust Gas Temperature at peak load operation (degree Centigrade)											
	Conventional Engine (CE)						Engine with LHR-2 combustion chamber					
	Injector opening pressure (Bar)						Injector opening pressure (Bar)					
	190		230		270		190		230		270	
	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT
DF	425	--	410	---	395	--	475		450		425	
CSO	475	500	440	475	410	435	430	400	400	380	380	360
20% Emulsified cotton seed oil	400	--	375	--	350	--	360		340		320	
40% Emulsified cotton seed oil							320	--	300	--	280	--

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EGT at full load operation decreased marginally with 20% ethanol blend with conventional engine when compared with standard diesel engine. This was due to high latent heat of ethanol which absorbs temperatures in combustion zone. Engine with LHR–2 combustion chamber with 40% emulsified cotton seed oil gave marginally lower EGT at full load operation when compared with conventional engine with 20% emulsified cotton seed oil. This was due to substitution of higher amount of ethanol, which caused reduction of EGT due to its high latent heat. This was also because of increased thermal efficiency and decreased rejection losses with the engine with LHR–2 combustion chamber when compared with standard diesel operation.

It can be observed from Fig.7, that volumetric efficiency decreased with an increase of brake mean effective pressure in both versions of the combustion chamber with vegetable oil operation. This was due to increase of gas temperature with the load. At the recommended injection timing, volumetric efficiency in the both versions of the combustion chamber with vegetable oil operation decreased at all loads when compared with conventional engine with pure diesel operation. Volumetric efficiency mainly depends on speed of the engine, valve area, valve lift, timing of the opening or closing of valves and residual gas fraction rather than on load variation. Hence with vegetable oil operation with conventional engine, volumetric efficiency decreased in comparison with pure diesel operation on conventional engine, as residual gas fraction increased**.** This was due to increase of deposits with vegetable oil operation with conventional engine. This was also due to increase of exhaust gas temperatures with conventional engine with vegetable oil operation which in turn increased combustion chamber wall temperature.

The reduction of volumetric efficiency with engine with LHR–2 combustion chamber was due increase of temperature of incoming charge in the hot environment created with the provision of insulation, causing reduction in the density and hence the quantity of air with engine with LHR–2 combustion chamber.

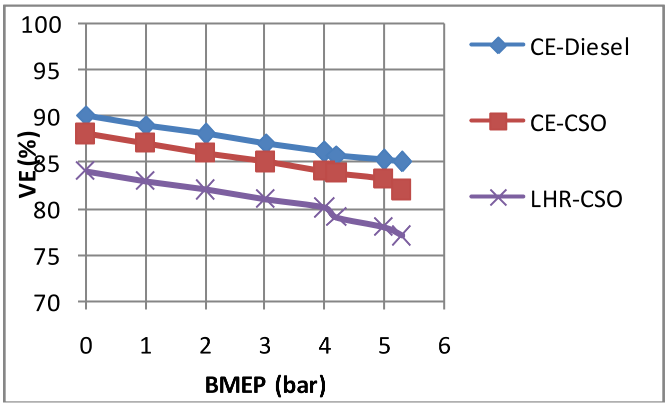

Figure 7: Variation of volumetric efficiency with brake mean effective pressure (BMEP) with vegetable oil operation in conventional engine and engine with LHR–2 combustion chamber at an injection timing of 27^{o} bTDC and injector opening pressure of 190 bar.

From Table.8, it is observed that volumetric efficiency increased with increase of injector opening pressure in both versions of the combustion chamber with vegetable oil. This was also due to improved fuel spray characteristics and evaporation at higher injector opening pressures leading to marginal increase of volumetric efficiency.

Table.8: Data of Volumetric efficiency at full load operation

Test Fuel	Volumetric Efficiency (%) at full load operation											
	Conventional Engine (CE)						Engine with LHR–2 combustion chamber					
	Injector opening pressure (Bar)						Injector opening pressure (Bar)					
	190		230		270		190		230		270	
	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT
DF	85	--	86	--	87	--	79	--	80	--	81	--
CSO	82	81	83	82	84	83	77	78	78	79	79	81
CSO+20% ethanol emulsion	86	--	87	--	88	--	78	--	79	--	80	--
CSO+40% ethanol emulsion	--	--	--	--	--		81	--	82	--	83	--

This was also due to the reduction of residual fraction of the fuel, with the increase of injector opening pressure. Increase of volumetric efficiency depends on combustion chamber wall temperature, which in turn depends on exhaust gas temperatures. With increase of injector opening pressure, exhaust gas temperatures decreased and hence volumetric efficiency increased.

Preheating of the crude vegetable oil marginally decreased volumetric efficiency, when compared with the normal temperature of crude vegetable oil, because of reduction of bulk modulus, density of the fuel and increase of exhaust gas temperatures.

Volumetric efficiency at full load operation increased marginally with 20% emulsified cotton seed oil with conventional engine when compared with standard diesel engine. This was due to high latent heat of ethanol which absorbs temperatures in combustion zone, with which density of charge increased leading to increase of volumetric efficiency. This was also because of decrease of combustion chamber wall temperatures.

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Engine with LHR–2 combustion chamber with 40% emulsified cotton seed oil gave lower volumetric efficiency at full load operation when compared with conventional engine with 20% emulsified cotton seed oil. This was due to increase of temperatures with hot insulated components of the engine with which density of the air decreased. However, volumetric efficiency of the engine with LHR–2 combustion chamber with 40% emulsified cotton seed oil was marginally higher than engine with same configuration of the engine with 20% emulsified cotton seed oil. This was more temperature drop with 40% emulsified cotton seed oil than 20% emulsified cotton seed oil.

Curves in Fig.8 indicate that coolant load increased with BMEP for test fuels with both versions of the combustion chamber. This was due to increase of gas temperatures. Cooling load was higher with vegetable oil operation with conventional engine.

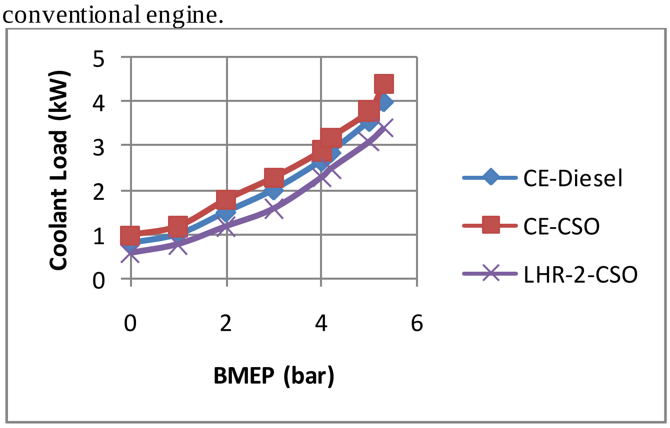

Figure 8: Variation of coolant load with brake

Fig 8 shows Variation of coolant load with brake mean effective pressure (BMEP) with vegetable oil operation in conventional engine and engine with LHR–2 combustion chamber at an injection timing of 27^{o}bTDC and injector opening pressure of 190 bar.

This was due to un–burnt fuel concentration at combustion chamber walls. Coolant load decreased with engine with LHR–2 combustion chamber with vegetable oil operation.

This was due to not only insulation provided with LHR–2 combustion chamber, but also due to improved combustion with the provision of insulation. This was also because of improved air fuel ratio with which gas temperatures decreased.

It is observed from Table.9, coolant load increased marginally in the conventional engine while it decreased in the engine with LHR–2 combustion chamber with increasing of the injector opening pressure with vegetable oil. This was due to the fact with increase of injector opening pressure with conventional engine, increased nominal fuel spray velocity resulting in better fuel-air mixing with which gas temperatures increased. The reduction of coolant load in the engine with LHR–2 combustion chamber was not only due to the provision of the insulation but also it was due to better fuel spray characteristics and increase of air-fuel ratios causing decrease of gas temperatures and hence the coolant load. Coolant load decreased marginally with preheating of vegetable oil. This was due to improved air fuel ratios with improved spray characteristics.

Table.9: Data of Coolant load at full load operation

Test Fuel	Data of Coolant Load (kW) at peak load operation.											
	Conventional Engine (CE)						Engine with LHR–2 combustion chamber					
	Injector opening pressure (Bar)						Injector opening pressure (Bar)					
	190		230		270		190		230		270	
	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT
DF	4.0	---	3.8	--	3.6	---	4.5	---	4.2	--	3.8	---
CSO	4.4	4.2	4.0	3.8	3.8	3.6	3.4	3.2	3.2	3.0	3.0	2.8
CSO+20% ethanol emulsion	3.8	--	3.6	--	3.4	--	3.2	--	3.0	--	2.8	--
CSO+40% ethanol emulsion	--	--	--	--	--	--	2.8	--	2.6	--	2.4	--

Coolant load at full load operation decreased marginally with 20% emulsified cotton seed oil with conventional engine when compared with standard diesel engine. This was due to high latent heat of ethanol which absorbs temperatures in combustion zone.

Engine with LHR–2 combustion chamber with 40% emulsified cotton seed oil gave lower coolant load at full load operation when compared with conventional engine with 20% ethanol blend. This was due to provision of insulation in the path of coolant. This was also due to improved combustion with increase of air fuel ratios. Coolant load of the engine with LHR-2 combustion chamber with 40% emulsified cotton seed oil marginally lower with the engine with same configuration of the engine with 20% emulsified cotton seed oil. This was more temperature drop with 40% emulsified cotton seed oil than 20% emulsified cotton seed oil.

3.2 Pollution Levels

Curves in Fig.9 indicates that drastic increase of smoke levels at all loads with CE fuelled with vegetable oil was observed when compared with pure diesel operation on CE. This was due to the higher value of ratio of C/H vegetable oil [$C_{18}H_{32}O_2$], 0.56 when compared with pure diesel (0.45). The increase of smoke levels was also due to decrease of air–fuel ratios and volumetric efficiency. Smoke levels were related

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to the density of the fuel. Smoke levels were higher with vegetable oil due to its high density.

However, smoke levels were comparable with engine with LHR–2 combustion chamber with vegetable oil operation, due to efficient combustion and less amount of fuel accumulation on the hot LHR combustion chamber walls of the engine at different operating conditions of the vegetable oil.

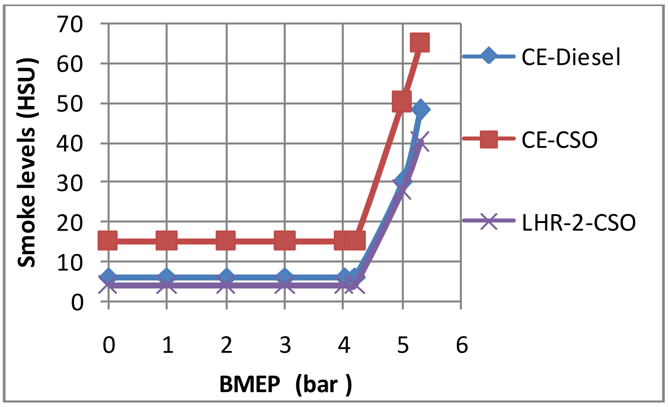

Figure 9: Variation of smoke levels in Hartridge Smoke Unit (HSU) with brake mean effective pressure (BMEP) with vegetable oil operation in conventional engine and engine with LHR–2 combustion chamber at an injection timing of 27^o bTDC and injector opening pressure of 190 bar.

Data from Table.10 shows that smoke levels decreased with increase of injector opening pressure in both versions of the combustion chamber, with different operating conditions of the vegetable oil. This was due to improvement in the fuel spray characteristics with higher injector opening pressures, causing lower smoke levels. Preheating of the vegetable oils decreased smoke levels in both versions of the engine, when compared with normal temperature of the vegetable oil. This was due to i) the reduction of density of the vegetable oil, as density was directly related to smoke levels, ii) the reduction of the diffusion combustion proportion in conventional engine with the preheated vegetable oil, iii) reduction of the viscosity of the vegetable oil, with which the fuel spray does not impinge on the combustion chamber walls of lower temperatures rather than it was directed into the combustion chamber.

Table.10: Data of Smoke levels at full load operation

Test Fuel	Smoke levels (Hartridge Smoke Unit, HSU) at full load operation											
	CE						Engine with LHR–2 combustion chamber					
	Injector opening pressure (Bar)						Injector opening pressure (Bar)					
	190		230		270		190		230		270	
	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT
Diesel fuel	48	--	38	--	34	--	55	--	55	--	45	--
CSO	65	60	60	55	55	50	40	35	40	30	30	25
CSO+20% ethanol emulsion	50	--	45	--	40	--	35	--	35	--	25	--
CSO+40% ethanol emulsion	--	--	--	--	--	--	25	--	25	--	15	--

Conventional engine with 20% ethanol blend decreased smoke levels when compared with standard diesel operation. The combustion of injected fuel in case of pure diesel operation was predominantly one of oxidation of products of destructive decomposition. In this case, there were greater chances of fuel cracking and forming carbon particles. On the other hand, the combustion of ethanol was predominantly a process of hydroxylation and the chances of fuel cracking were negligible. Ethanol does not contain carbon–carbon bonds and therefore cannot form any un–oxidized carbon particles or precursor to soot particles. One of the promising factor for reducing smoke levels with the ethanol blended vegetable oil was it contains oxygen in its composition which helps to reduce smoke levels.

Smoke levels increased linearly with the increase of carbon to hydrogen atoms (C/H) ratio provided the equivalence ratio was not altered. This was because higher C/H lead to more concentration of carbon dioxide, which would be further, reduced to carbon. Lower C/H will produce more water vapor, which has more affinity towards oxygen leading to reduce smoke levels. Consequently, induction of alcohol reduced the quantity of carbon particles in the exhaust gases as the values of C/H for pure diesel, pure vegetable oil and ethanol are 0.45, 0.6 and 0.33. Lower smoke levels were observed in both versions of the engine with emulsified cotton seed oil when compared to the pure diesel operation on conventional engine.

The engine with LHR–2 combustion chamber with 40% emulsified cotton seed oil gave lower smoke levels when compared to the conventional engine with 20% emulsified cotton seed oil. This was due to higher amount of ethanol content with engine with LHR–2 combustion chamber. For same amount of emulsified cotton seed oil (20% ethanol) engine with LHR–2 combustion chamber gave marginally

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lower smoke levels than conventional engine. This showed that combustion improved with insulated engine.

4. SUMMARY

Engine with LHR combustion chamber with 40% emulsified cotton seed oil increased peak BTE by 12%, at full load operation–decreased brake specific energy consumption by 4%, exhaust gas temperature decreased by 20%, decreased volumetric efficiency by 6%, decreased coolant load by 26% and decreased smoke levels by 50% in comparison with conventional engine with 20% emulsified cotton seed oil.

Conventional engine with cotton seed oil at normal temperature decreased peak BTE by 3%, at full load operation–increased brake specific energy consumption by 5%, increased exhaust gas temperature by 12%, decreased volumetric efficiency by 4%, increased coolant load by 19% and increased smoke levels by 35% in comparison with conventional engine with pure diesel operation.

Performance parameters and pollution levels improved with an increase of injector opening pressure with engine with test fuels with both versions of the combustion chamber.

With preheating of cotton seed oil- Peak brake thermal efficiency increased, at full load operation–brake specific energy consumption decreased, exhaust gas temperature increased, volumetric efficiency decreased, coolant load decreased smoke levels in comparison normal temperature of the cotton seed oil.

4.1 Research Findings

Comparative studies on performance parameters and pollution levels with direct injection diesel engine with air gap insulated piston and air gap insulated liner combustion chamber and engine with conventional combustion chamber were made at varied injector opening pressure with emulsified cotton seed oil. Experimental results were compared with pure diesel operation at similar operating conditions.

4.2 Future Scope of Work

Hence further work on the effect of injection timing on performance parameters, exhaust emissions and combustion characteristics with air gap insulated LHR combustion chamber with emulsified cotton seed oil operation is necessary.

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REFERENCES

[1] **Matthias Lamping, Thomas Körfer, Thorsten Schnorbus, Stefan Pischinger, Yunji Chen (2008). Tomorrows diesel fuel diversity – challenges and solutions, SAE 2008–01–1731**

[2] **Murali Krishna MVS, Murthy, PVK, Pujari Pawan, P, Basavaraju. Potential of a medium grade low heat rejection diesel engine with crude tobacco seed oil, (IMECE-2013-62262). In: Proceedings of ASME 2013 mechanical engineering congress and exposition, (IMECE-2013-62262); 2013.**

[3] **Venkateswara Rao, N., Murali Krishna, M.V.S. and Murthy, P.V.K. (2013). comparative studies on exhaust emissions and combustion characteristics of tobacco seed oil in crude form and biodiesel form in direct injection diesel engine. International Journal of Mechanical and Production Engineering Research and Development, 3(4), 125–138.**

[4] **Venkateswara Rao, N., Murali Krishna, M.V.S. and Murthy, P.V.K. (2013). Comparative studies on performance of tobacco seed oil in crude form and biodiesel form in direct injection diesel engine International Journal of Automobile Engineering Research & Development, 3(4),57–72**

[5] **Srikanth, D., Murali Krishna, M.V.S., Ushasri, P. and Krishna Murthy, P.V. (2013). Performance evaluation of a diesel engine fuelled with cotton seed oil in crude form and biodiesel form. International Journal of Academic Research for Multidisciplinary 1(9), 329–349.**

[6] **Senthil Kumar, M., Kerihuel, A., Bellettre, J. and Tazerout, M. (2005). Experimental investigations on the use of preheated animal fat as fuel in a compression ignition engine. Renewable Energy, 30, 2314–2323.**

[7] **Agarwal, D., Agarwal, A.K. (2007).Performance and emissions characteristics of jatropha oil (preheated and blends) in a direct injection compression ignition engine. Int. J. Applied Thermal Engineering, 27, 2314–23.**

[8] **Canaker, M., Ozsezen, A.N. and Turkcan, A. (2009). Combustion analysis of preheated crude sunflower oil in an IDI diesel engine. Biomass & Bio-energy, 33, 760–770.**

[9] **Hanbey Hazar and Huseyin Aydin. (2010). Performance and emission evaluation of a CI engine fueled with preheated raw rapeseed oil (RRO)-diesel blends. Applied Energy, 87, 786–790.**

[10] **Lalit Kumar Daheriya and Nitin Shrivastava, Effect of performance and emissions on DI diesel engine using ethanol diesel blends- A Review, Int J Eng Res & Tech 1(6), 2012, 1-9.**

[11] **Wang, L.J., Song, R.J., Zou, H.B., Liu, S.H. and Zhou, L.B. Study on combustion characteristics of a methanol–diesel fuel compression ignition engine. Proc. of Institution of Mechanical Engineers, Part D: J. Automobile Engineering, 222, 2008, 619-627.**

[12] **Satish Kumar, Jae Hyun Cho, Jaedeuk Park and Il Moon. Advances in diesel–alcohol blends and their effects on the performance and emissions of diesel engines, Renew Sustain Energy Reviews, 22, 2013, 46-72.**

ISSN 2320-6802

INTERNATIONAL JOURNAL FOR ADVANCE RESEARCH IN ENGINEERING AND TECHNOLOGY

WINGS TO YOUR THOUGHTS…..
[13] **Janardhan, N., Murali Krishna, M.V.S., Ushasri, P. and Murthy, P.V.K. (2012). Potential of a medium low heat rejection diesel engine with crude jatropha oil. International Journal of Automotive Engineering and Technologies,1(2), 1-16.**

[14] **Murali Krishna, M.V.S., Durga Prasada Rao, N., Anjeneya Prasad, A. and Murthy, P.V.K. (2013). Improving of emissions and performance of rice brawn oil in medium grade low heat rejection diesel engine. International Journal of Renewable Energy Research, 3(1), 98-108.**

[15] **Srikanth, D., Murali Krishna, M.V.S., Ushasri, P., and Krishna Murthy, P.V. (2013). Comparative studies on medium grade low heat rejection diesel engine and conventional diesel engine with crude cotton seed oil, International Journal of Innovative Research in Science, Engineering and Technology, 2(10), 5809-5228**

[16] **M. Deepika Patali, D.Shravya, K. Sai Srinivas and M.V.S. Murali Krishna, Studies on Direct Injection Diesel Engine with Ceramic Coated Low Heat Rejection Combustion Chamber with Tyre Oil, IJARET, vol:2 issue IV April 2014, 2320-6802.**

[17] **K. Krishna Sai varun, A.S. Yaswanth and M.V.S. Murali Krishna. Studies on Direct Injection with Ceramic Coated Low Heat Rejection Combustion Chamber with Emulsified fuel of Cotton Seed oil and ethanol., vol:2 issue IV April 2014, 2320-6802.**

[18] **K. Krishna Sai varun, A.S. Yaswanth and M.V.S. Murali Krishna. Studies on Direct Injection with Ceramic Coated Low Heat Rejection Combustion Chamber with Emulsified fuel of Cotton Seed oil and ethanol., vol:2 issue IV April 2014, 2320-6802.**