IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 10, Issue 3 (Nov. - Dec. 2013), PP 44-54
www.iosrjournals.org

Comparative Performance of Crude Pongamia Oil in A Low Heat Rejection Diesel Engine

Chirra Kesava Reddy
Mechanical Engineering Department, Mahatma Gandhi Institute Of Technology, Gandipet, Hyderabad, Andhra Pradesh, India

Abstract: Aim: *Experiments were carried out to evaluate the performance of a low heat rejection (LHR) diesel engine with ceramic coated cylinder head [ceramic coating of thickness 500 microns was done on inside portion of cylinder head] with different operating conditions [normal temperature and pre-heated temperature] of crude Pongamia oil with varied injection pressure and injection timing.*
Study Design: *Performance parameters of brake thermal efficiency, exhaust gas temperature and volumetric efficiency were determined at various values of brake mean effective pressure (BMEP).*
Methodology: *Exhaust emissions of smoke and oxides of nitrogen (NOx) were noted at the various values of BMEP. Combustion characteristics at peak load operation of the engine were measured with TDC (top dead centre) encoder, pressure transducer, console and special pressure-crank angle software package.*
Brief Results: *Conventional engine (CE) showed deteriorated performance, while LHR engine showed improved performance with biodiesel operation at manufacturer's recommended injection timing of 27^{o}bTDC and pressure of 190 bar. The performance of both version of the engine was improved with advanced injection timing and at higher injection pressure when compared with CE with pure diesel operation. The optimum injection timing was 32^{o}bTDC for CE, while it was 29^{o}bTDC for LHR engine with CPO operation. Peak brake thermal efficiency increased by 7%, smoke levels timing, when compared with pure diesel operation on CE at manufacturer's recommended injection timing.*
Keywords: *Crude Pongamia Oil, LHR Engine, Pollution Levels, Exhaust Emissions, Combustion Characteristics.*

I. Introduction

In view of heavy consumption of diesel fuel involved in not only transport sector but also in agricultural sector and also fast depletion of fossil fuels, the search for alternate fuels has become pertinent apart from effective fuel utilization which has been the concern of the engine manufacturers, users and researchers involved in combustion & alternate fuel research.

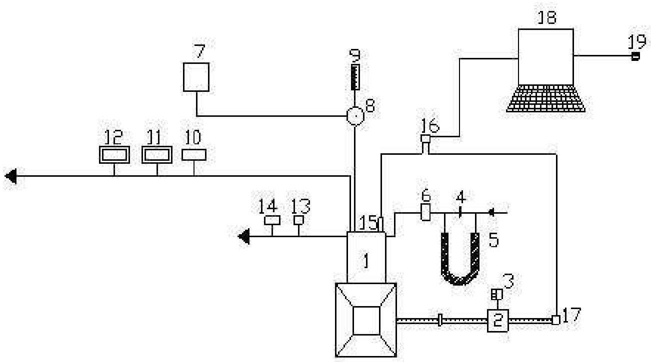
The idea of using vegetable oil as fuel has been around from the birth of diesel engine. Rudolph diesel, the inventor of the engine that bears his name, experimented with fuels ranging from powdered coal to peanut oil. Several researchers [1-4] experimented the use of vegetable oils as fuel on conventional engines and reported that the performance was poor, citing the problems of high viscosity, low volatility and their polyunsaturated character. The drawbacks of viscosity and poor volatility of vegetable oils call for LHR engine which provide hot combustion chamber for burning these fuels which got high duration of combustion.

It is well known fact that about 30% of the energy supplied is lost through the coolant and the 30% is wasted through friction and other losses, thus leaving only 30% of energy utilization for useful purposes. In view of the above, the major thrust in engine research during the last one or two decades has been on development of LHR engines. Several methods adopted for achieving LHR to the coolant are i) using ceramic coatings on piston, liner and cylinder head ii) creating air gap in the piston and other components with low-thermal conductivity materials like superni, cast iron and mild steel etc. Investigations were carried out [5] on LHR engine with varying degree of insulation such as ceramic coated engine, air gap insulated piston engine and air gap insulated liner engine with pure diesel operation and reported improvement in the performance of the engine with increase of degree of insulation of LHR version of the engine. Ceramic coatings provided adequate insulation and improved brake specific fuel consumption (BSFC) and decreased pollution levels with pure diesel operation which was reported by various researchers [6-11]. Experiments were also conducted on LHR engines with vegetable oils. Experiments were conducted [12] on pongamia oil in LHR engine, which consisted of ceramic-coated cylinder head and air gap cylinder liner and reported that performance improved and pollution levels of hydrocarbon and smoke decreased with LHR version of the engine with pongami oil when compared with CE with pure diesel operation. Ignition improvers to pongamiaoil further improved the performance and reduced the pollution levels. Three vegetable oils of neem oil, rice bran oil and karanja oil were tested [13] in LHR engine with ceramic coated cylinder head and reported that performance of vegetable oils improved with pre-heating. 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. These problems can be solved, if neat vegetable oils are chemically modified to bio-diesel [14]. Investigations were carried out on LHR engine with biodiesel. Experiments were conducted [15] on low heat rejection diesel engine with biodiesel with ceramic coated material MgO–ZrO2 on cylinder head, exhaust, and inlet valves while the piston surface was coated with ZrO2 with canola methyl and reported that increase in engine power and decrease in specific fuel consumption, as well as significant improvements in exhaust gas emissions and smoke density with LHR engine when compared with CE. Experiments were conducted [16] on LHR engine with ceramic coated piston crown, liner and inner surface of cylinder head with palm oil based bio-diesel and reported that LHR engine reduced smoke and marginally increased NOx emissions and thermal efficiency. Investigations were carried out [17] on low heat rejection diesel engine with fly ash coated (thickness-200 microns) cylinder head, cylinder liner, valves and piston crown with pongamia and rice brawn based bio-diesel and reported that LHR engine improved efficiency with these alternate fuels. Pongamia oil was tested [18] in LHR engine with ceramic coating of thickness 500 microns on inside portion of cylinder head and reported that performance improved with advanced injection timing.

The present paper attempted to evaluate the performance of LHR engine, which contained ceramic coated cylinder head with different operating conditions of CPO with varied engine parameters of injection pressure and timing and compared with CE with pure diesel operation at recommended injection timing and injection pressure.

II. Methodology

Experimental setup used for the investigations of LHR diesel engine with CPO is shown in Figure 1. CE had an aluminum alloy piston with a bore of 80 mm and a stroke of 110mm. The rated output of the engine was 3.68 kW at a speed of 1500 rpm. The compression ratio was 16:1 and manufacturer's recommended injection timing and injection pressures were 27^{o}bTDC and 190 bar respectively. The fuel injector had 3-holes of size 0.25-mm. The combustion chamber consisted of a direct injection type with no special arrangement for swirling motion of air. The engine was connected to electric dynamometer for measuring its brake power.



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, 15. Piezo-Electric Pressure Transducer, 16. Console, 17. TDC Encoder, 18. Pentium Personal Computer and 19. Printer

FIGURE 1: EXPERIMENTAL SET-UP

Burette method was used for finding fuel consumption of the engine. Air-consumption of the engine was measured by air-box method. The naturally aspirated engine was provided with water-cooling system in which inlet temperature of water is maintained at $60^{O}C$ 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.

Copper shims of suitable size were provided in between the pump body and the engine frame, to vary the injection timing and its effect on the performance of the engine was studied, along with the change of injection pressures from 190 bar to 270 bar (in steps of 40 bar) using nozzle testing device. The maximum injection pressure was restricted to 270 bar due to practical difficulties involved. Exhaust gas temperature (EGT) was measured with thermocouples made of iron and iron-Constantan. Partially stabilized zirconium

(PSZ) of thickness 500 microns was coated on inside portion of cylinder head.

Exhaust emissions of smoke and NO_X were recorded by AVL smoke meter and Netel Chromatograph NOx analyzer at various values of BMEP. Piezo electric transducer, fitted on the cylinder head to measure pressure in the combustion chamber was connected to a console, which in turn was connected to Pentium personal computer. TDC encoder provided at the extended shaft of the dynamometer was connected to the console to measure the crank angle of the engine.

A special P-□□ software package evaluated the combustion characteristics such as peak pressure (PP), time of occurrence of peak pressure (TOPP), maximum rate of pressure rise (MRPR) and time of occurrence of maximum rate of pressure rise (TOMRPR) from the signals of pressure and crank angle at the peak load operation of the engine. Pressure- crank angle diagram was obtained on the screen of the personal computer. The properties of the CPO and the diesel used in this work were presented in Table-1.

TABLE 1: PROPERTIES OF TEST FUELS

Test Fuel	Viscosity at 25 ^{o} C (centi-poise)	Density at 25 ^{o} C	Cetane number	Calorific value (kJ/kg)
Diesel	12.5	0.84	55	42000
Crude pongamia oil (CPO)	120	0.91	48	37100

III. Results And Discussions

Performance Parameters

Figure 2 indicates that CE with CPO showed the deterioration in the performance for entire load range when compared with the pure diesel operation on CE at recommended injection timing. Although carbon accumulations on the nozzle tip might play a partial role for the general trends observed, the difference of viscosity between the diesel and CPO provided a possible explanation for the deterioration in the performance of the engine with CPO operation. 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 vegetable oil leading to reduce the rate of heat release as compared with diesel fuel.

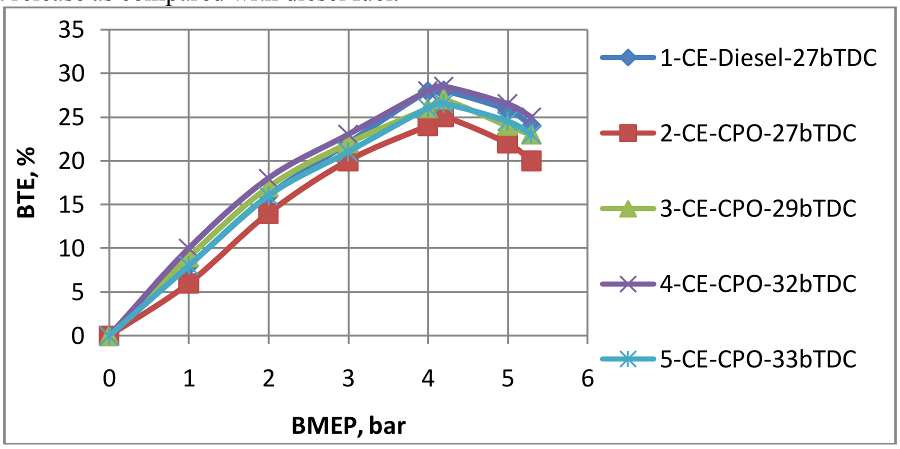


FIGURE 2: VARIATION OF BTE WITH BMEP IN CE WITH VARIOUS INJECTION TIMINGS

This also, contributed the higher ignition (chemical) delay of the vegetable oil due to lower cetane number. According to the qualitative image of the combustion under the CPO operation with CE, the lower BTE was attributed to the relatively retarded and lower heat release rates. BTE increased with the advancing of the injection timing in CE with the CPO at all loads, when compared with CE at the recommended injection timing and pressure. This was due to initiation of combustion at earlier period and efficient combustion with increase of air entrainment in fuel spray giving higher BTE. BTE increased at all loads when the injection timing was advanced to 32^{o}bTDC in the CE at the normal temperature of CPO. The increase of BTE at optimum injection timing over the recommended injection timing with CPO with CE could be attributed to its longer ignition delay and combustion duration. BTE increased at all loads when the injection timing is advanced to 32^{o}bTDC in CE, at the preheated temperature of CPO.

The performance improved further in CE with the preheated vegetable oil for entire load range when compared with normal vegetable oil. Preheating of the vegetable oil reduced the viscosity, which improved the spray characteristics of the oil and reduced the impingement of the fuel spray on combustion chamber walls, causing efficient combustion thus improving BTE.

Curves from Figure 3 denotes that LHR version of the engine showed the marginal improvement in the performance for entire load range compared with CE with pure diesel operation. High cylinder temperatures helped in better evaporation and faster combustion of the fuel injected into the combustion chamber. Reduction of ignition delay of the CPO in the hot environment of the LHR engine improved heat release rates and efficient energy utilization. Preheating of CPO improved performance further in LHR version of the engine.

The optimum injection timing was found to be 29°bTDC with LHR engine with normal CPO. Since the hot combustion chamber of LHR engine reduced ignition delay and combustion duration and hence the optimum injection timing was obtained earlier with LHR engine when compared with CE with the CPO operation.

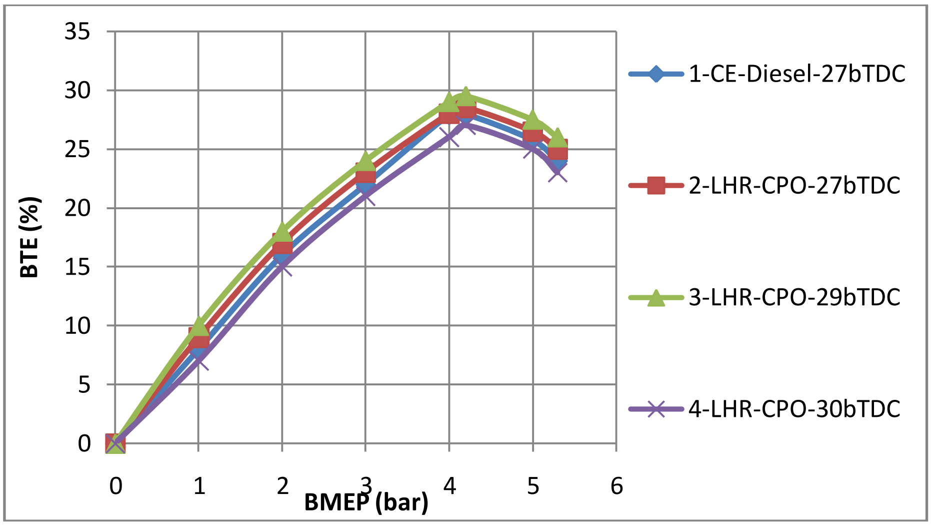


FIGURE 3: VARIATION OF BTE WITH BMEP IN LHR ENGINE WITH VARIOUS INJECTION TIMINGS

Figure 4 indicates that LHR engine at recommend and optimum injection timings showed higher BTE, when compared with CE with CPO operation.

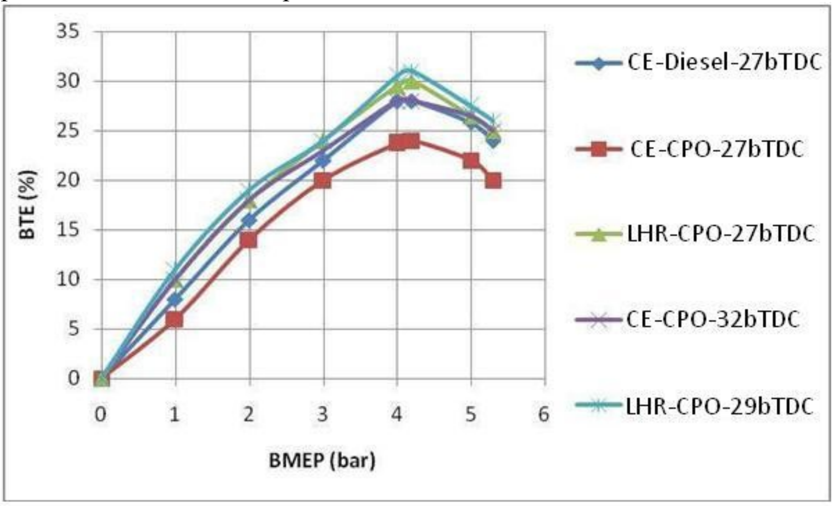


FIGURE 4: VARIATION OF BTE WITH BMEP IN BOTH VERSIONS OF THE ENGINE AT RECOMMEND AND OPTIMUM INJECTION TIMINGS

As mentioned earlier, hot combustion chamber was needed for CPO operation as it was high viscous and had higher combustion duration, which was provided by LHR engine.

Injection pressure was varied from 190 bars to 270 bars to improve the spray characteristics and atomization of the CPO and injection timing was advanced from 27 to 34°bTDC for CE and LHR engine. Table-2 shows that peak BTE increased with increase in injection pressure in both versions of the engine at different operating conditions of the CPO.

TABLE 2: DATA OF PEAK BTE

Injection Timing (°bTDC)	Test Fuel	Peak BTE (%)											
		Conventional Engine						LHR Engine					
		Injeciton Pressure (Bars)						Injection Pressure (Bars)					
		190		230		270		190		230		270	
		NT	PT	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT
27	DF	28	--	29	---	30	--	29	--	30	--	30.5	--
	CPO	24	25	25	26	26	27	30	31	31	32	32	33
29	DF	29	--	30	--	31		29	--	30	--	31	--
	CPO	25	26	26	27	27	28	31	32	32	33	33	34
30	DF	30	---	31	--	31	--	29	--	30	--	31	--
	CPO	26	27	27	28	28	29	27	28	28	29	29	30
31	DF	30	--	30	--	31	--	--	--	--	--	--	--
	CPO	27	28	28	29	27	28	--	--	--	---	--	--
32	DF	30		31		32							
	CPO	28	29	27	28	26	27	--	--	--	--	--	--
33	DF	31		31		30	---	--	--	--	--	--	-

DF-Diesel Fuel, NT-Normal or Room Temperature, PT-Preheat Temperature

The improvement in BTE at higher injection pressure was due to improved fuel spray characteristics. However, the optimum injection timing was not varied even at higher injection pressure with LHR engine, unlike the CE. Hence it was concluded that the optimum injection timing is 32^{O}bTDC at 190 bar, 31^{O}bTDC at 230 bar and 30^{O}bTDC at 270 bar for CE. The optimum injection timing for LHR engine was 29^{O}bTDC irrespective of injection pressure. Peak BTE was higher in LHR engine when compared with CE with different operating conditions of the CPO.

It could be observed from Figure 5, CE with CPO at the recommended injection timing recorded higher EGT at all loads compared with CE with pure diesel operation. Lower heat release rates and retarded heat release associated with high specific energy consumption caused increase in EGT in CE. Ignition delay in the CE with different operating conditions of CPO increased the duration of the burning phase.

LHR engine recorded lower value of EGT when compared with CE with CPO operation. This was due to reduction of ignition delay in the hot environment with the provision of the insulation in the LHR engine, which caused the gases expand in the cylinder giving higher work output and lower heat rejection. This showed that the performance improved with LHR engine over CE with CPO operation.

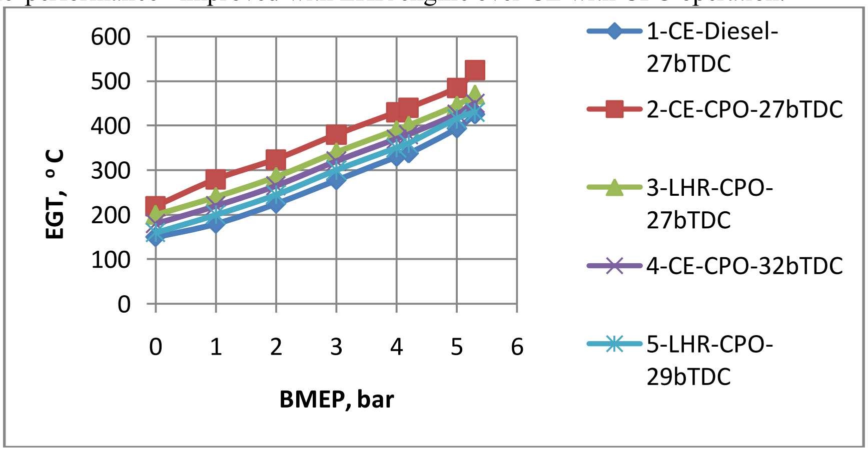


FIGURE 5: VARIATION OF EGT WITH BMEP IN BOTH VERSIONS OF THE ENGINE AT RECOMMEND AND OPTIMUM INJECTION TIMINGS

From Table 3, it is evident that EGT decreased with increase in injection pressure and injection timing with both versions of the engine, which confirmed that performance increased with injection pressure. Preheating of CPO decreased EGT in both versions of the engine.

TABLE 3: DATA OF EGT AT PEAK LOAD OPERATION

Injection Timing (°bTDC)	Test Fuel	EGT at the Peak Load (°C)											
		Conventional Engine						LHR Engine					
		Injeciton Pressure (Bars)						Injection Pressure (Bars)					
		190		230		270		190		230		270	
		NT	PT	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT
27	DF	425	--	410	---	395	--	460	---	450	--	440	--
	CPO	480	500	500	490	490	465	450	425	425	400	400	375
29	DF	415	--	405	--	400	--	440	--	430	--	420	--
	CPO	470	450	450	430	430	410	425	400	400	375	375	350
30	DF	410	---	400	--	385	---	460	---	450	--	440	375
	CPO	460	440	440	420	420	400	450	425	425	400	400	---
31	DF	400	---	390	--	375	---	450	---	445	---	440	---
	CPO	440	420	420	400	440	420						
32	DF	390		380		380							--
	CPO	420	400	440	420	460	440	---- ---	---	---	----	---	-
33	DF	375	---	375	---	400	--	--	--	--	---	--	--
	CPO	400	390	410	400	420	410	--	--	--	--	--	--

From Figure 6, it is noticed that the volumetric efficiency (VE) decreased with an increase of BMEP in both versions of the engine. This was due to increase of gas temperature with the load. At the recommended injection timing, VE in the both versions of the engine with CPO operation decreased at all loads when compared with CE with pure diesel operation. This 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 LHR engine. VE increased marginally in CE and LHR engine at optimized injection timings when compared with recommended injection timings with CPO. This was due to decrease of un-burnt fuel fraction in the cylinder leading to increase in VE in CE and reduction of gas temperatures with LHR Engine.

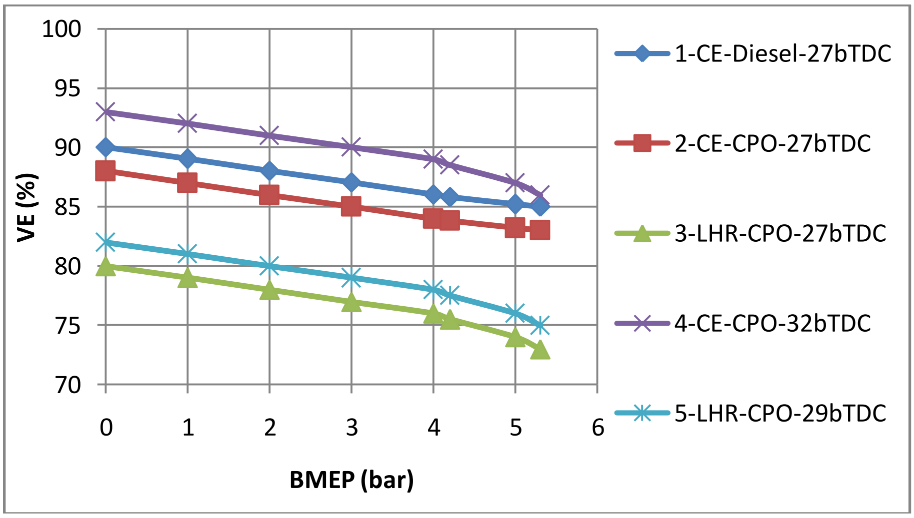


FIGURE 6: VARIATION OF VE WITH BMEP IN BOTH VERSIONS OF THE ENGINE AT RECOMMEND AND OPTIMUM INJECTION TIMINGS

This was due to better fuel spray characteristics and evaporation at higher injection pressures leading to marginal increase of VE. This was also due to the reduction of residual fraction of the fuel, with the increase of injection pressure. Preheating of the vegetable oil marginally improved VE in both versions of the engine, because of reduction of un-burnt fuel concentration with efficient combustion, when compared with the normal temperature of oil. From Table 4, it is observed that VE increased marginally with the advancing of the injection timing and with the increase of injection pressure in both versions of the engine.

TABLE 4: DATA OF VOLUMETRIC EFFICIENCY AT THE PEAK LOAD OPERATION

Injection Timing (°bTDC)	Test Fuel	Volumetric Efficiency (%)											
		Conventional Engine						LHR Engine					
		Injeciton Pressure (Bars)						Injection Pressure (Bars)					
		190		230		270		190		230		270	
		NT	PT	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT
27	DF	85	--	86	--	87	--	78	--	80	--	82	--
	CPO	83	84	84	85	85	86	75	76	76	77	77	78
29	DF							80		81		82	
	CPO	84	85	85	86	86	87	76	77	77	78	78	79

30	DF	86	--	87	--	88	---	77	--	79	--	80	--
	CPO	85	86	86	87	87	88	75	76	76	77	77	78
31	DF	87	--	88	--	89	--						
	CPO	86	87	87	88	86	87	-	--	--	--	--	-
32	DF	88	--	88	--	87	--	-	--	-	--	--	-
	CPO	87	88	86	87	85	86	--	--	--	--	--	--
33	DF	89	--	89	--	86	--	--	--	--	--	--	--

Exhaust Emissions

Figure 7 indicates that the value of smoke intensity increased from no load to full load in both versions of the engine. During the first part, the smoke level was more or less constant, as there was always excess air present. However, in the higher load range there was an abrupt rise in smoke levels due to less available oxygen, causing the decrease of air- fuel ratio, leading to incomplete combustion, producing more soot density. The variation of smoke levels with the brake power typically showed a U-shaped behavior due to the pre-dominance of hydrocarbons in their composition at light load and of carbon at high load Drastic increase of smoke levels was observed at the peak load operation in CE at different operating conditions of the CPO, compared with pure diesel operation on CE. This was due to the higher value of the ratio of C/H of CPO (0.83) when compared with pure diesel (0.45). (C= Number of carbon atoms and H = Number of hydrogen atoms in fuel composition). The increase of smoke levels was also due to decrease of air-fuel ratios and VE with CPO compared with pure diesel operation. Smoke levels were related to the density of the fuel. Since vegetable oil had higher density compared to diesel fuels, smoke levels are higher with vegetable oil.

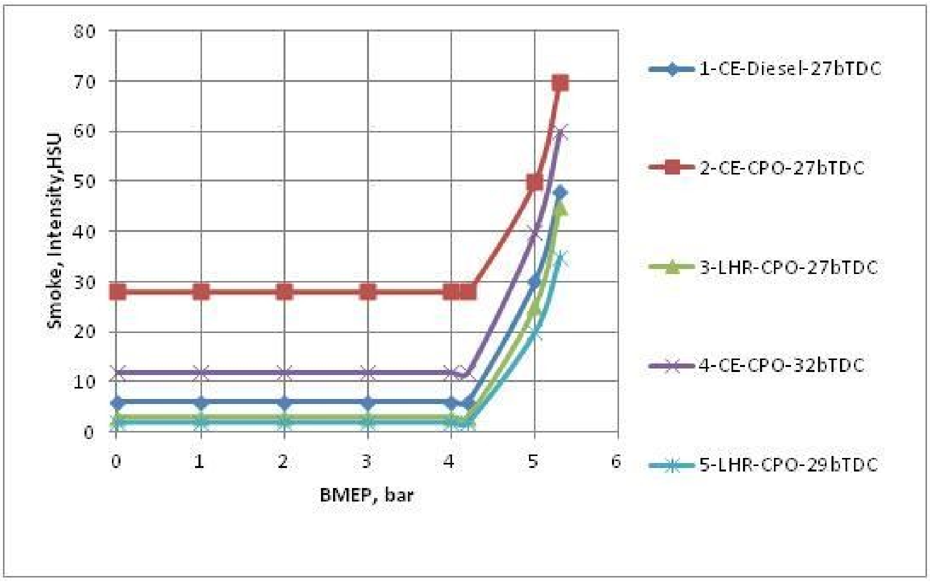


FIGURE 7: VARIATION OF SMOKE INTENSITY IN HARTRIDGE SMOKE UNIT (HSU) WITH BMEP IN BOTH VERSIONS OF THE ENGINE AT RECOMMEND AND OPTIMUM INJECTION TIMINGS

However, LHR engine marginally reduced smoke levels due to efficient combustion and less amount of fuel accumulation on the hot combustion chamber walls of the LHR engine at different operating conditions of the CPO compared with the CE. Density influences the fuel injection system. Decreasing the fuel density tends to increase spray dispersion and spray penetration. Preheating of the CPO reduced 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 proportional to smoke levels, ii) the reduction of the diffusion combustion proportion in CE with the preheated vegetable oil, iii) the 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 directs into the combustion chamber.

Table-5 shows that smoke levels decreased with increase of injection timings and with increase of injection pressure, in both versions of the engine, with different operating conditions of the vegetable oil. This was due to improvement in the fuel spray characteristics at higher injection pressures and increase of air entrainment, at the advanced injection timings, causing lower smoke levels.

TABLE 5: DATA OF SMOKE INTENSITY IN HARTRIDGE SMOKE UNIT AT PEAK LOAD OPERATION

Injection Timing (°bTDC)	Test Fuel	Smoke Intensity (HSU)											
		Conventional Engine						LHR Engine					
		Injeciton Pressure (Bars)						Injection Pressure (Bars)					
		190		230		270		190		230		270	
		NT	PT	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT
27	DF	48	--	38	--	34	--	55	--	50	--	45	--
	CPO	65	60	60	55	55	50	53	45	45	40	40	35
29	DF	40	--	36	--	34							
	CPO	60	55	55	50	50	45	47	40	40	35	35	30
30	DF	36	--	34	--	32	--	45	--	42	--	41	--
	CPO	55	50	50	45	45	40	57	50	50	45	45	40
31	DF	33	---	32	--	30	--	43	--	41	--	40	--
	CPO	50	45	45	40	50	45	--	--	--	--	--	--
32	DF	32	--	31	--	32	--	--	--	--	--	--	--
	CPO	45	40	50	45	55	50	--	--	--	--	---	-
33	DF	30	---	30	--	35	--	-	--	--	--	--	--

It is observed from the Figure 8, NOx levels were lower in CE while they were higher in LHR engine at different operating conditions of the vegetable oil at the peak load when compared with diesel operation.

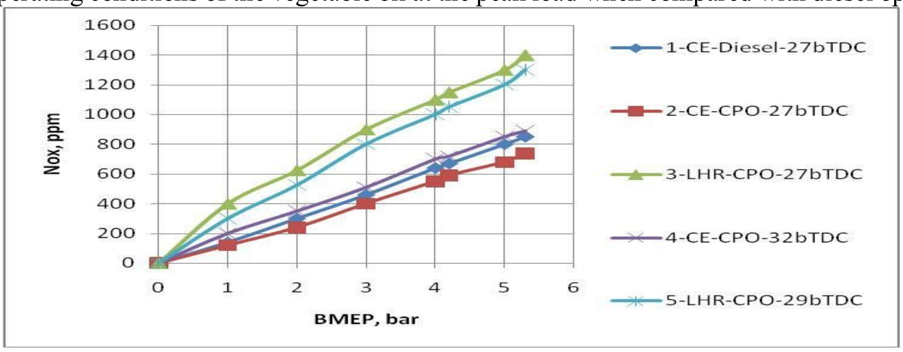


FIGURE 8: VARIATION OF NOX LEVELS WITH BMEP IN BOTH VERSIONS OF THE ENGINE AT RECOMMEND AND OPTIMUM INJECTION TIMINGS

This was due to lower heat release rate because of high duration of combustion causing lower gas temperatures with the vegetable oil operation on CE, which reduced NOx levels. Increase of combustion temperatures with the faster combustion and improved heat release rates in LHR engine cause higher NOx levels. As expected, preheating of the vegetable oil decreased NOx levels in CE and reduced the same in LHR engine when compared with the normal vegetable oil. This was due to improved air fuel ratios and decrease of combustion temperatures leading to decrease NOx emissions in the CE and decrease of combustion temperatures in the LHR engine with the improvement in air-fuel ratios leading to decrease NOx levels in LHR engine.

From Table 6, it is noticed that NOx levels increased with the advancing of the injection timing in CE at different operating conditions of vegetable oil. Residence time and availability of oxygen had increased, when the injection timing was advanced with the vegetable oil operation, which caused higher NOx levels in CE. With the increase of injection pressure, fuel droplets penetrate and find oxygen counterpart easily. Turbulence of the fuel spray increased the spread of the droplets which causes the decrease the gas temperatures marginally thus leading to decrease in NOx levels, as the availability of oxygen and increase of gas temperatures were the two factors, responsible for formation of NOx levels

TABLE 6: DATA OF NOX LEVELS AT PEAK LOAD OPERATION

Injection Timing (°bTDC)	Test Fuel	NOx Levels (ppm)											
		Conventional Engine						LHR Engine					
		Injeciton Pressure (Bars)						Injection Pressure (Bars)					
		190		230		270		190		230		270	
		NT	PT	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT
27	DF	850	----	810	----	770	---	1300	--	1280	--	1260	--
	CPO	675	625	625	575	575	525	1080	1030	1030	980	980	930
29	DF	900	--	860	--	820	--						
	CPO	775	725	725	675	675	625	980	930	930	880	880	830
30	DF	935	---	900	---	860	--	1225	--	1205	--	1185	--
	CPO	875	825	825	775	775	725	1030	980	980	930	930	880

31	DF	1020	---	980	---	940	---	1150	--	1130	--	1110	--
	CPO	975	925	925	875	875	825	--	--	--	--	--	--
32	DF	1105	----	1060	---	1020	---	--	--	--	--	--	--
	CPO	1075	1025	1025	975	975	925	--	--	--	--	--	--
33	DF	1190	----	1150	---	1110	---	--	--	--	--	--	--

However, marginal decrease of NOx levels was observed in LHR engine, due to decrease of combustion temperatures, which was evident from the fact that thermal efficiency was increased in LHR engine due to the reason sensible gas energy was converted into actual work in LHR engine, when the injection timing was advanced and with increase of injection pressure.

IV. Combustion Characteristics

From Table 7, it could be observed that peak pressures were lower in CE while they were higher in LHR engine at the recommended injection timing and pressure, when compared with pure diesel operation on CE. This was due to increase of ignition delay, as vegetable oil require large duration of combustion. Mean while the piston started making downward motion thus increasing volume when the combustion takes place in CE. LHR engine increased the mass-burning rate of the fuel in the hot environment leading to produce higher peak pressures. The advantage of using LHR engine for vegetable oil was obvious as it could burn low cetane and high viscous fuels. Peak pressures increased with the increase of injection pressure and with the advancing of the injection timing in both versions of the engine, with the vegetable oil operation. Higher injection pressure produces smaller fuel particles with low surface to volume ratio, giving rise to higher PP. With the advancing of the injection timing to the optimum value with the CE, more amount of the fuel accumulated in the combustion chamber due to increase of ignition delay as the fuel spray found the air at lower pressure and temperature in the combustion chamber. When the fuel- air mixture burns, it produced more combustion temperatures and pressures due to increase of the mass of the fuel. With LHR engine, peak pressures increases due to effective utilization of the charge with the advancing of the injection timing to the optimum value. The value of TOPP decreased with the advancing of the injection timing and with increase of injection pressure in both versions of the engine, at different operating conditions of vegetable oils. TOPP was higher at different operating conditions of vegetable oil in CE, when compared with pure diesel operation on CE. This was due to higher ignition delay with the vegetable oil when compared with pure diesel fuel. This once again established the fact by observing lower peak pressures and higher TOPP, that CE with vegetable oil operation showed the deterioration in the performance when compared with pure diesel operation on CE. Preheating of the vegetable oil showed lower TOPP, compared with vegetable oil at normal temperature. This once again confirmed by observing the lower TOPP and higher PP, the performance of the both versions of the engine improved with the preheated vegetable oil compared with the normal vegetable oil. This trend of increase of MRPR and decrease of TOMRPR indicated better and faster energy substitution and utilization by vegetable oils, which could replace 100% diesel fuel. However, these combustion characters were within the limits hence the vegetable oils could be effectively substituted for diesel fuel.

TABLE 7: DATA OF PP, MRPR, TOPP AND TOMRPR AT PEAK LOAD OPERATION

Injection Timing (^{0}bTDC)/ Test Fuel	Engine Version	PP (Bar)				MRPR (Bar/deg)				TOPP (Deg)				TOMRPR (Deg)			
		Injection Pressure (Bar)				Injection Pressure (Bar)				Injection Pressure (Bar)				Injection Pressure (Bar)			
		190		270		190		270		190		270		190		270	
		NT	PT	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT	NT	PT
27/Diesel	CE	50.4	--	53.5	---	3.1	---	3.4	--	9	-	8	--	0	0	0	0
	LHR	48.1	--	53	--	2.9	--	3.1	--	10	--	9	--	0	0	0	0
27/CPO	CE	46.5	47.9	48.1	49.4	2.1	2.2	2.9	2.8	12	11	12	10	1	1	1	1
	LHR	56.6	58.7	61.1	62.8	3.2	3.3	3.4	3.4	11	10	10	9	1	1	1	1
29/CPO	LHR	59.15	60.8	63.1	64.2	3.3	3.4	3.5	3.5	10	9	9	9	0	0	0	0
32/CPO	CE	50.4	51.7			3	3.1			11	10			0	0		

V. Conclusions

CPO operation at 27^{O}bTDC on CE showed the deterioration in the performance, while LHR engine showed improved performance, when compared with pure diesel operation on CE. Preheating of the vegetable oil improved performance when compared with normal vegetable oils in both versions of the engine. Improvement in the performance was observed with the advancing of the injection timing and with the increase of injection pressure with CPO operation on both versions of the engine. CE with CPO operation showed the optimum injection timing at 32^{O}bTDC, while the LHR engine showed the optimum injection at

29^{O}bTDC at an injection pressure of 190 bar. At the recommended injection timing and pressure, CPO operation on CE increased smoke levels, decreased NOx levels, while LHR engine decreased
smoke levels and increased NOx levels when compared with pure diesel operation on CE. Preheating of the crude vegetable oil decreased smoke levels and NOx levels slightly in both versions of the engine. CE with CPO operation decreased smoke levels and increased NOx levels, while LHR engine decreased smoke and NOx levels with the advancing of the injection timing. With increase in injection pressure, smoke and NOx levels decreased in both versions of the engine. Lower peak pressures and more TOPP were observed with normal CPO in CE. LHR engine with CPO operation increased PP and decreased TOPP when compared with CE. Preheating increased PP and decreased TOPP when compared with normal CPO operation on both versions of the engine. Lower peak pressures and lower peak gas temperatures were observed in CE, while higher peak pressures and higher gas temperatures were found out in the LHR engine with CPO operation at the recommended injection timing and pressure.

Acknowledgements

Authors thank authorities of Chaitanya Bharathi Institute of Technology, Hyderabad for providing facilities for carrying out research work. Financial assistance provided by All India Council for Technical Education (AICTE), New Delhi, is greatly acknowledged.

References

[1]. Pramanik, K., (2003), Properties and use of jatropha curcas oil and diesel fuel blends in compression ignition engine, Journal of Renewable Energy, vol.28 (2), 239- 48.

[2]. Pugazhvadivu, M. Jayachandran, K., (2008), Investigations on the performance and exhaust emissions of a diesel engine using preheated waste frying oil as fuel, Renewable energy, vol.30(14), 2189-2202.

[3]. Agarwal, D. and Agarwal, A. K., (2007), Performance and emission characteristics of a jatropha oil (preheated and blends) in a direct injection compression ignition engine, Journal of Applied Thermal Engineering, vol.27, 2314-2323.

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

[5]. Jabez Dhinagar, S., Nagalingam, B. and Gopala Krishnan, K.V., (1993), A comparative study of the performance of a low heat rejection engine with four different levels of insulation, Proc. of IV International Conference on Small Engines and Fuels, Chang Mai, Thailand, 121-126.

[6]. Kamo, R., et al., 1999, Injection characteristics that improve performance of ceramic-coated diesel engines, SAE paper No 1999-01-0972.

[7]. Jaichandar, S. and Tamilporai, P., (2003), Low heat rejection engines - an overview, SAE paper No.2003-01- 0405,.

[8]. Taymaz, I., Cakir, K., Gur, M. and Mimaroglu, A., (2003), Experimental investigation of heat losses in a ceramic cooled diesel engine, Surface and Coating Technology, vol.3,.169-170.

[9]. Ahmaniemi, S. et al., (2004), Characterization of modified thick thermal barrier coatings, Journal of Thermal Spray Technology, vol.13 (3), 361-369.

[10]. Parlak, A., Yasar, H. and Eldogan O., (2005), the effect of thermal barrier coating on a turbocharged Diesel engine performance and exergy potential of the exhaust gas, Energy Conversion and Management, vol.46 (3), 489–499.

[11]. Ekrem, B., Tahsin, E. and Muhammet, C., (2006), Effects of thermal barrier coating on gas emissions and performance of a LHR engine with different injection timings and valve adjustments, Journal of Energy Conversion and Management, vol.47, 1298-1310.

[12]. Bhaskar, T., Nagalingam, B. and Gopala Krishan, K.V., (1993), The effect of two ignition improving additives on the performance of jatropha oil in low heat rejection diesel engine, Proc. of IV International Conference on Small Engines and their Fuels, Thailand, 14-19.

[13]. Jabez Dhinagar,S., Nagalingam, B.N., Gopalakrishna, K.V., (1993), Experimental investigation of non-edible vegetable oil operation in a LHR diesel engine for improved performance", SAE Paper No-932846.

[14]. Murali Krishna, M.V.S., (2004), Performance evaluation of LHR diesel engine with alternate fuels, PhD Thesis,

[15]. J.N.T. University, Hyderabad.

[16]. Rajendra Prasath, B., P. Tamilporai, P. and Mohd.Shabir, F., (2010), Analysis of combustion, performance and emission characteristics of low heat rejection engine using biodiesel, International Journal of Thermal Sciences, vol.49, 2483-2490.

[17]. Modi, A.J. and Gosai, D.C. (2010). Experimental study on thermal barrier coated diesel engine performance with blends of diesel and palm bio-diesel. SAE International Journal of Fuels and Lubricants, vol.3 (2), 246-259.

[18]. Mohamed Musthafa, M., Sivapirakasam, S.P. and Udayakumar,M., (2011), Comparative studies on fly ash coated low heat rejection diesel engine on performance and emission characteristics fueled by rice bran and pongamia methyl ester and their blend with diesel, Journal of Energy, vol.86, 2343-2351.

[19]. Ch.Kesava Reddy., 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 pongamia oil, International Scholarly Research Network (ISRN) Renewable Energy, Article ID 489605, 1-10.

Biography

Chirra.Kesava Reddy received his B.Tech degree in Mechanical Engineering, from Gulbarga University, Karnataka, India in 1997, the M.Tech degree in Thermal Engineering from Jawaharlal Nehru Technological University, Hyderabad, India in 2001. He was a Teaching Assistant, Assistant Professor and presently working Senior Assistant Professor with Department of Mechanical Engineering, MGIT affiliated to JNT University, Hyderabad. His researach interests include IC Engines, Alternative fuels, Combustion and renewable energy. At present, he is engaged in alternative fuels research work. He published more than 10 papers in National and Internatinal journals and attended several National and International conferences.