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COMPLEMENT TIMING OF INJECTION ON DIESEL ENGINE FUELED WITH TAMARIND BIO-DIESEL

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ABSTRACT

There is lot of demand for alternative fuels as fossil fuels are expending day by day. Oils from seeds of plants are acceptable for diesel fuel, as there is no necessary for swapping engine model. But snag related to oils from seeds of plants like glutinous consistency and low flammable characteristics led to change of oils from seeds of the plant into biodiesel by the process known as esterification. However, biodiesel has moderate viscosity which calls for low heat rejection (LHR) engine, with air gap piston, air gap liner and ceramic coated cylinder head with the layer of coating 0.3 mm. Workability parameters were identified with LHR engine and correlated to normal engine, with tamarind biodiesel by differing timing of injection and opening pressure of injection. BTE hiked by 7 %, while at full lad operation- soot particle density got down by 38 % relatively with LHR engine with biodiesel at 30^{o}bTDC with respect to normal engine operated by diesel at 27^{o}bTDC and a pressure of injection of 190 bars.

KEYWORDS: *Diesel Fuel, Ceramic Coated Cylinder, Low Heat Rejection*

Article History

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INTRODUCTION

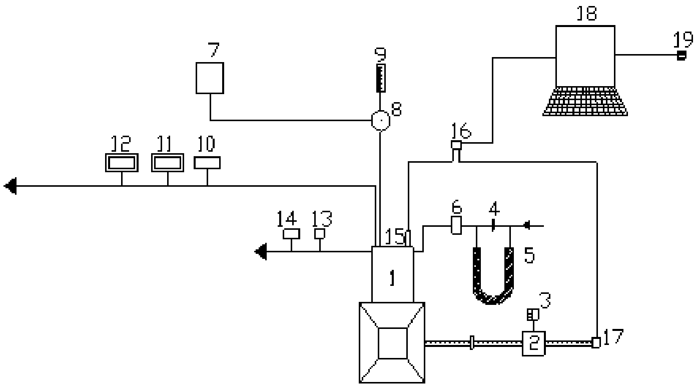
There was scarcity of conventional fuels, with exhaustion of sources, multiplication of products of exhaust with natural fuels and load on economy sector India due to bring in petroleum the explore for different fuels is relevant. Oils from seeds of the plant and alcohols are treated as other fuels in diesel engines as they are regenerated. But, utilize of alcohols need changes of engine moderation as its cetane number is less. Oils from the seeds of the plant can conveniently be reused in diesel engines due to comparable cetane number. But the snags of low vaporous and glutinous consistency of oils from the seeds of plants had shown the importance of LHR engine. Cooling of the engine is inevitable in order to prevent the expansion of the piston and other components of the engine. The output power indicates sum of the BTE, coolant heat losses and exhaust gas enthalpy. If the coolant heat losses are prevented with thermal insulation, either BTE would increase or exhaust gas enthalpy would increase. There are wide varieties of LHR engines like, incorporating divergent approaches like spraying layers on the parts of the engine, creation of air gap in the various constitutes of the engine.

It was noticed that there was an advance in BTE with ceramic layer components. [1-2]. It was described that there was depletion in BSFC with an insulated piston with incorporation of air gap. [3-4]. they further narrated that that poor performance at full load. There were some snags in insulation incorporated with engine to attain the principle of LHR. It was described there was poor performance of LHR engine. [5]. There was an endeavor to on welded design, which gave rise to failure of air gap piston. [6]. some researchers established the poor workability of the engine with delay in timings of injection. [7-8]. Some researchers asserted enhanced in the workability of the engine with delayed timing of injection.[9]. Trials were undergone fuelled with diesel, at dissimilar timings of injection on various arrangements of insulated parts which contained layers made of ceramic [10]. They narrated hike in BTE, in the range of 2% and lowered in smoke levels and maximum pressures. [10]. But the concept of the stud structure provided by them for the piston, which incorporated crown made of superni and layer of ceramic on the engine parts were not sufficient to incorporate sealing for the insulation. Trials were undergone with LHR engine comprising of piston incorporated with crown made of dissimilar materials with differing air gap thickness and timings of injection. [11] He finally narrated that superni material with 3-mm air gap showed 5% savings in BSFC at 29.5^{o}bTDC at 190 bar. However, sufficient insulation was not incorporated in other parts like liner cylinder head etc. Trials were undergone with air gap insulated piston with air gap insulated liner with 3-mm air gap with superni inserts with different substituted fuels.[12]. He finalized that LHR engine enhanced the workability of the engine with oils from the seeds of the plants and biofuels. However, the extent of insulation incorporated was low as insulation was not provided on cylinder head. Trials were undergone with waste frying vegetable oil collected from restaurants was used in conventional diesel engine [13]. They narrated that workability decreased with waste fried oil blends. Injection was hiked to improve spray characteristics with bio-diesel operation in conventional engine. [14-17]. However, due to high glutinous consistency of the oils from the seeds of plant, these oils were substituted in LHR diesel engine**.** [12, 18]. However, in their experiments, the degree of insulation was incorporated only in piston and cylinder head. Experiments were taken up two degree of air gap insulation with 0.5 mm layer of ceramic coating with biodiesel. [19-22]. they finalized that workability enhanced with LHR engine and hiked NO_x emissions with respect to base engine.

From the above discussions, it was finalized that, no organized studies were delineated so far on the workability of LHR engine, which contained piston and liner provided with an air gap, and layer of ceramic on cylinder head with varied timing of injection timing with tamarind biodiesel. The present paper endeavored to estimate the workability of LHR engine with biodiesel operation at distinct timings of injection and pressures of injection with respect to normal diesel engine.

MATERIALS AND METHODS

The major drawback of the tamarind oil and other oils from the seeds of plant, for use in diesel engine is its high glutinous consistency, which is about 10-12 times that of diesel fuel. Conversion of the oil to its methyl esters (bio-diesel) was given in Reference 19. The description of insulated piston, insulated liner and ceramic coated cylinder head employed in the test was given in Reference.19.Experimental setup used for the investigations of LHR diesel engine with neat diesel is shown in Figure. 1.



1. Engine, 2. Power Measuring Device, 3.Variable Rheostat. 4. Dischrage Measuring Device, 5.Pressure Measuring Device, 6. Pulsating Air Box 7. Fuel Storage, 8, Heating Coil, 9. Fule Flow Rate Device, 10. EGT Indicator, 11. AVL Smoke Meter, 12. Netel Chromatograph Nox Analyzer, 13. Coolant Temperature Indicator, 14. Coolant Flow Meter, 15. Transducer, 16. Console, 17. TDC Encoder, 18. Pentium Personal Computer and 19. Printer.

Figure 1: Schematic Diagram of Experimental Set-Up

RESULTS AND DISCUSSIONS

Performance Parameters

The conventional engine (5 HP @15 00 rpm) had an aluminum alloy piston (size 80 mm× 110mm). The ratio of compression was 16.5:1. The recommended timing of injection and pressure as prescribed manufacturer were 27^{o}bTDC and 200 bars. The fuel injector had 3 apertures with size 25 micro meters. The combustion chamber was DI. There was no different facility for swirling motion of air. Electric dynamometer was incorporated to determine the power of the engine. Flow rate method by means of burette was provided to measure fuel consumed. Air box method determined the requirement of air for the engine. There was water cooling system. The outlet temperature of coolant was fixed at 80^{o}C by acclimating the rate of flow of water. Sensors were incorporated to vary timing of injection and pressure. The peak pressure of injection was limited to 280 bars due to practical problems. Temperature sensors were provided to measure EGT and coolant temperature. The products of exhaust of smoke and NO_x were registered by AVL smoke meter (AVL-237) and Netel Chromatograph NO_x analyzer (Netel-400) respectively at the full load operation of the engine. The combustion parameters were registered by TDC encoder, Piezo electric pressure transducer and specially designed pressure-crank angle software package. In the present study, biodiesel was used as 100% substitute for diesel fuel. The experiments were conducted on normal engine (CE) and LHR engine. The properties of biodiesel were shown in Table.1

From Figure 2 it is noticed that biodiesel operation followed the similar tendencies of normal diesel operation at all loads.

There was a decrease of BTE at all loads with biodiesel operation with respect to pure diesel operation. This was due to low calorific value of biodiesel. However, BTE enhanced with advanced timing of injection due to improved atomization characteristics. The best timing of injection was noticed to be 31obTDC with normal engine.

From Figure 3, it is noticed that LHR engine enhanced BTE with respect to normal diesel engine at all loads, due to improved heat release rates. The best timing of injection was recorded to be 30obTDC. The best timing of injection timing was occurred much earlier than CE, with the biodiesel operation as combustion chamber was maintained very hot.

The variation in the value of peak BTE in different versions of the engine with biodiesel operation at different injection pressures is shown in Table-2.

Peak BTE enhanced with hike of pressure of injection with two models of the engine, due to enhanced fuel spray parameters..

Table 3 shows data of brake specific energy consumption (BSEC) at full load operation.

BSEC declined with the promoting of the timing of injection timing in normal engine with the biodiesel operation. Beginning of combustion at early stage improved BSEC at full load. BSEC declined drastically with LHR engine with biodiesel operation due to enhanced het release rates. BSEC at full load decreased marginally with enhanced injection pressure, due to enhanced spray characteristics.Table.4 shows the data of EGT.

Enhanced injection pressure and timing of injection reduced EGT at full load in two models of the engine with biodiesel operation. With advanced timing of injection, more time was obtained for biodiesel to elaborate in the combustion chamber thus disallowing lower amount of heat and hence causing lower EGT. Combustion improved with an increase of injection pressure thus reducing amount of heat rejection, causing lower EGT with both versions of the engine with biodiesel operation.

Table.5 shows data of volumetric efficiency at full load.

Biodiesel operation declined volumetric efficiency in two models of the engine with respect to diesel operation on normal engine. Hike partially burnt fuel mixture probably declined intake of in the normal engine. In the LHR engine the intake air gets heated because of the hot combustion chamber walls, which reduced volumetric efficiency marginally with respect to normal engine with biodiesel operation. Volumetric efficiency hiked marginally with the advancing of the timing of injection and with the hike of injection pressure in two models of the engine, because of improved spray characteristics of fuel.

Table.6 shows data of coolant load on two models of the engine

Coolant load of CE with biodiesel operation was similar with CE with diesel operation, due to its high cetane number and existence of oxygen in its atomic structure. There was a decrease of coolant load with advanced timing of injection and with the increase of injection pressure in two models of the engine, due to improved atomization characteristics and spray characteristics.

Table 1: Properties of Test Fuels

Test Fuel	Glutinous Consistency at 25°C (Centi-Poise)	Specific Gravity at 298 K	Cetane Number	Low Heat of Combustion (kJ/kg)
Diesel	12.5	0.84	55	42000
Biodiesel	25	0.87	60	40000

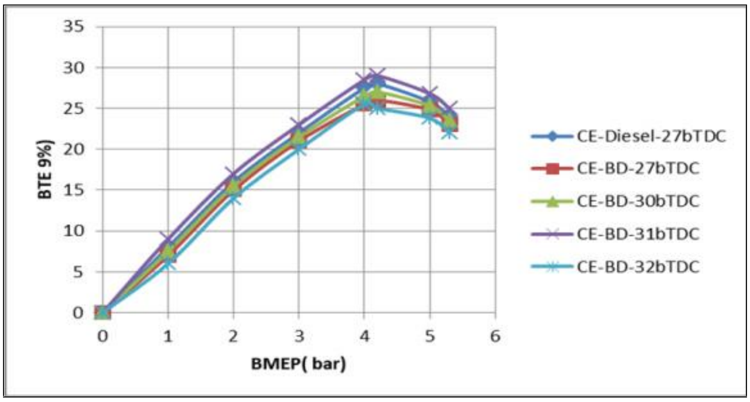


Figure 2: Variation of BTE with BMEP in Normal Engine.

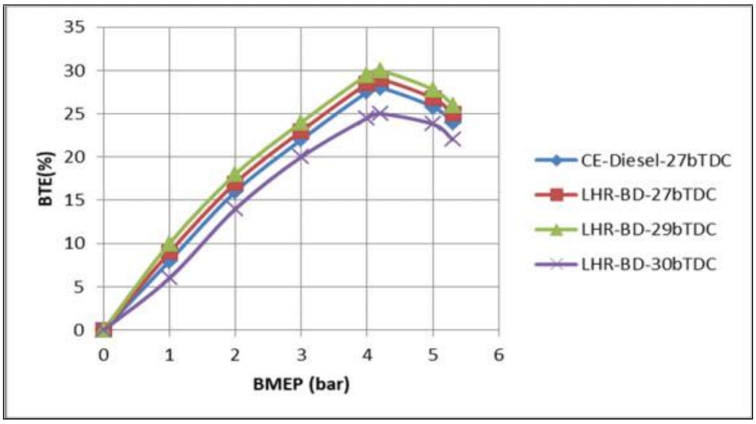


Figure 3: Variation of Brake Thermal Efficiency with Brake Mean Effective Pressure in LHR Engine.

Table 2: Data of Peak BTE

Timing of Injection (°bTDC) /Fuel	Peak Brake Thermal Efficiency (%)					
	Normal Engine			LHR Engine		
	Pressure of Injection (bar)			Pressure of Injection (bar)		
	200	240	280	200	240	280
27/D	28	29	30	27	27.5	28
27/BD	26	27	28	29	30	31
30/BD	--	--	--	30	31	32
31/BD	29	29.5	30	--	--	--

D- Diesel fuel, BD-Biodiesel

Table 3: Data of Brake Specific Energy Consumption (BSEC) at Full Load Operation

Timing of Injection (°bTDC) /Fuel	Brake Specific Energy Consumption (kW/kW)					
	Normal Engine			LHR Engine		
	Pressure of Injection (bar)			Pressure of Injection (bar)		
	200	240	280	200	240	280
27/D	4.0	3.8	3.6	4.2	4.0	3.8
27/BD	4.2	4.0	3.8	3.6	3.4	3.2
30/BD	--	--	--	3.4	3.2	3.0
31/BD	3.8	3.6	3.4	--	--	--

D- Diesel fuel, BD-Biodiesel

Table 4: Data of Exhaust Gas Temperature (EGT) at Peak Load Operation

Timing of Injection (°bTDC)/Fuel	Exhaust Gas Temperature (°C)					
	Normal Engine			LHR Engine		
	Pressure of Injection (bar)			Pressure of Injection (bar)		
	190	230	270	190	230	270
27/D	425	410	395	500	480	460
27/BD	450	425	400	475	450	425
30/BD	--	---	--	425	400	375
31/BD	400	375	350	--	--	--

Table 5 Data of Volumetric Efficiency

Timing of Injection (°bTDC)/Fuel	Volumetric Efficiency (%)					
	Normal Engine			LHR Engine		
	Injection Pressure (bar)			Injection Pressure (bar)		
	200	240	280	200	240	280
27/D	85	87	89	75	76	77
27/BD	82	84	86	78	80	82
30/BD	---	---	---	80	82	84
31/BD	84	86	88	--	--	--

D- Diesel fuel, BD-Biodiesel

Table 6: Data of Coolant Load at Full Load Operation

Timing of Injection (°bTDC)/Fuel	Volumetric Efficiency (%)					
	Normal Engine			LHR Engine		
	Pressure of Injection (bar)			Pressure of Injection (bar)		
	200	240	280	200	240	280
27/D	4.0	4.2	4.4	4.2	4.0	3.8
27/BD	4.2	4.4	4.6	3.6	3.4	3.2
30/BD	--	--	--	3.4	3.2	3.0
31/BD	3.8	4.0	4.2	--	--	--

D- Diesel fuel, BD-Biodiesel

Pollution Levels

Table.7 shows data of smoke levels. Smoke levels were noticed to be lowered at the full load operation in two models of the engine with biodiesel operation with respect to normal engine, due to high cetane number and existence of oxygen in its atomic structure.

However, biodiesel operation on LHR engine slightly declined smoke levels with respect to normal engine due to improved combustion. Smoke levels declined with the facilitating the timing of the injection and with increase of pressure of injection, in two models of the engine, with biodiesel, due to upgrading spray parameters of the fuel at elevated pressure of injection and improved air entrainment, at the advanced injection timings.

Table.8 shows data of NO_x at full load operation. NO_x levels were marginally higher in normal engine, while they are drastically higher in the LHR engine with biodiesel operation at the full load with respect to normal engine with diesel operation. Existence of O2 in its atomic structure of biodiesel improved combustion temperatures in normal engine with biodiesel operation increased NO_x levels with normal engine. Hike of heat release rate associated with faster rate of combustion in the LHR engine caused higher NO_x levels.

NO_x levels declined with the advanced timing of injection and hike of pressure of injection in LHR engine, due to low combustion temperature in the LHR engine with the development in air-fuel ratios leading to decline NO_x levels in the LHR engine. However, in the normal engine, NOx levels increased with hike of pressure of injection and timing of injection. This is because of increase of residence time and gas temperatures in normal engine. With the hike of pressure of injection, penetration of fuel droplets took place which leads to increase of gas temperatures and hence NO_x levels.

Table 7: Data of Smoke Levels at Full Load Operation in Hartridge Smoke Unit.

Timing of Injection (°bTDC)/Fuel	Smoke Levels (HSU)					
	Normal Engine			LHR Engine		
	Pressure of Injection (bar)			Pressure of Injection (bar)		
	200	240	280	200	240	280
27/D	48	38	34	63	55	45
27/BD	40	35	30	35	30	25
30/BD	---	---	---	30	25	20
31/BD	35	30	25	--	--	--

D- Diesel fuel, BD-Biodiesel, HSU- Hartridge smoke unit

Table 8: Data of Oxides of Nitrogen (NO_x) at Full Load Operation

Timing of Injection (°bTDC)/Fuel	NOx Levels (ppm)					
	Conventional Engine			LHR Engine		
	Pressure of Injection (bar)			Pressure of Injection (bar)		
	200	240	200	240	200	280
27/D	850	900	950	1400	1380	1360
27/BD	900	950	1000	1250	1200	1150
30/BD	--	--	--	1150	1100	1050
31/BD	950	1000	1100	--	--	--

D- Diesel fuel, BD-Biodiesel

Combustion Characteristics

Table 9 shows data of peak pressure (PP) at full load operation. With biodiesel operation, maximum pressures were declined in the normal engine while they were elevated in the LHR engine, with respect to normal engine with diesel operation, due to this lower calorific value of the fuel. LHR engine enlarged heat release rate and faster rate of burning of fuel.

Peak pressures enhanced with the increase of pressure of injection and with the advancing timing of injection timing in CE, with the biodiesel operation due to increase of depth of penetration of fuel particle in O2 zone. With the advancing of the timing of injection to the with biodiesel operation, more amount of the fuel stored in the combustion chamber due to increase of delay in ignition delay as the fuel spray evaluated the air at lower pressure and temperature in the combustion chamber. Suddenly the fuel air mixture got exploded giving rise to huge peak pressures. In case of LHR engine PP decreased with advanced timing of injection and enhanced fuel pressure of injection due to improved combustion with faster rate of combustion and high heat release rate.

Table.10 shows data of time of occurrence of peak pressure (TOPP) at full load operation

TOPP at full load operation was similar with biodiesel operation in the normal engine with respect to normal engine with diesel operation. This once again accepted the fact by observing marginal similar peak pressures and TOPP at full load, that conventional engine with biodiesel operation showed the similar performance when compared to normal engine with diesel operation. TOPP declined (nearer to TDC) with hike of pressure of injection and advancing of timing of the injection in two models of the engine with biodiesel operation.

Table.11 shows the data of maximum rate of pressure rise (MRPR) at full load operation The trend of MRPR was similar to that of peak pressure in both versions of the engine at recommended injection timing and optimum pressure. MRPR at full load was elevated in LHR engine and similar to normal engine with biodiesel operation. MRPR increased with advancing of injection timing and injection pressure in two models of the engine with biodiesel operation.

Table 9: Data of Peak Pressure at Full Load Operation

Timing of Injection (°bTDC)/Fuel	Peak Pressure (bar)					
	Normal Engine			LHR Engine		
	Pressure of Injection (bar)			Pressure of Injection (bar)		
	200	240	280	200	240	280
27/D	50.4	51.7	53.5	46.1	48.4	51.1
27/BD	48.6	50.1	51.3	68.8	64.4	60.1
30/BD	--	--	--	64.9	60.4	56.4
31/BD	50.4	51.7	53.5	46.1	48.4	51.1

Table 10: Data of Time of Occurrence of Peak Pressure (TOPP) at Full Load

Timing of Injection (°bTDC)/Fuel	Time of Occurrence Peak Pressure (deg)					
	Normal Engine			LHR Engine		
	Pressure of Injection (bar)			Pressure of Injection (bar)		
	200	240	280	200	240	280
27/D	9	8	7	11	10	10
27/BD	10	9	8	9	8	7
30/BD	--	--	--	8	7	6
31/BD	9	8	7	--	--	--

Table 11: Data of Maximum Rate of Pressure Rise (MRPR) at Full Load Operation

Timing of Injection (°bTDC)/Fuel	Maximum Rate of Pressure Rise (bar/deg)					
	Normal Engine			LHR Engine		
	Pressure of Injection (bar)			Pressure of Injection (bar)		
	200	240	280	200	240	280
27/D	5.4	5.8	6.2	6.6	7.0	7.4
27/BD	5.0	5.4	5.8	7.4	7.0	6.6
30/BD				7.0	6.6	6.2
31/BD	5.6	6.0	6.4	--	--	--

D- Diesel fuel, BD-Bio-diesel

CONCLUSIONS

On the Basis of Configuration of the Engine

LHR engine with biodiesel operation improved performance parameters and the products of exhaust with respect to normal engine with biodiesel operation

However, LHR engine with biodiesel operation at full load-hiked slightly EGT, declined volumetric efficiency and hiked NO_x levels.

On the Basis of Test Fuel

Biodiesel operation slightly improved the performance parameters and products of exhaust. However, biodiesel operation at full load-increased hiked NO_x levels.

On the Basis of Injection Timing

Advanced injection timing with biodiesel operation improved performance parameters and products of the exhaust. However, advanced injection timing increased NO_x levels with normal engine.

On the Basis of Injection Pressure

Increased injection pressure with biodiesel operation improved performance parameters of However, increased injection pressure increased NO_x levels with CE..

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