Experimental investigations on combustion characteristics of carbureted butanol and plastic oil

B.T.Naik[1], M.V.S. Murali Krishna[2] and P. Usha Sri[3]

[1]PhD Scholar, Mechanical Engineering Department, Osmania University, Hyderabad

[2]Mechanical Engineering Department, Chaitanya Bhrathi Institute of Technology, Hyderabad,

[3]Mechanical Engineering Department, Osmania University, Hyderabad

ABSTRACT

Background of the problem: In the context depletion of fossil fuels, ever increases of fuel prices international market causing economic burden on government of India and ever increases of pollution levels with fossil fuels, the search for alternative fuels has become pertinent. Alcohols and vegetables oils are important substitutes for diesel fuel as they renewable in nature. However, the drawbacks of vegetables oils (high viscosity and low volatility) and alcohols (low energy content and cetane number) call for semi-adiabatic diesel engine (SADE).The high energy content of plastic oil and high volatility of butanol can be taken together in order to have minimum pollution levels. Plastic is not biodegradable. It causes harm to cattle and human beings. Hence plastic is converted into oil and used in internal combustion engine. However, plastic oil has high viscosity which calls low heat rejection diesel engine, which provide hot combustion chamber by providing thermal insulation to the path of the coolant.

Aim: Investigations were carried out to evaluate the combustion parameters of the conventional engine (CE) and low heat rejection (LHR) diesel engine with carbureted butanol and injected plastic oil blended with diethyl ether by 20% with varied injection timing..

Design Variables: Configuration of the engine, injection timing, test fuels of diesel and carbureted butanol along with plastic oil.

Methodology: The experimental engine was single cylinder, four-stroke, water cooled, 3.68 k W at the rated speed of 1500 rpm engine with ceramic coated cylinder head (partially stabilized zirconium of thickness 500 µm coated over inside portion of cylinder head). Combustion characteristics of peak pressure, time of occurrence of peak pressure, and maximum rate of pressure rise were determined at full load operation of the engine. Combustion parameters were determined by pressure transducer, fitted on cylinder head, TDC encoder filled on extended portion of dynamometer shaft and a special pressure-crank angle software package. Injection timing was varied with sensor. Butanol was carbureted into the engine through variable jet carburetor installed at the inlet manifold of the engine at different percentages of crude plastic oil, blended with an optimum quantity (15%) of diethyl ether at full load on mass basis. Crude plastic oil blended with 15% diethyl ether was injected through injector in conventional manner. The purpose of adding diethyl ether was to improve cetane number and reduce viscosity of the plastic oil.

Brief Results: LHR engine **wi**th carbureted butanol and injected plastic oil blended with diethyl ether improved the combustion parameters when compared with neat diesel on conventional engine.

Keywords: Alternative fuels; Butanol; Plastic oil; SADE; Performance Parameters

1.INTRODUCTION

The purpose of a literature review it to identify inconstancies, gaps in research, conflicts in previous studies, open questions left from other research, identify the need for additional research, identify the relationship of works in the context of its contribution to the topic and to the other works. The research review was conducted on the following topics. Research gaps were identified at the end of the section. Objectives were defined in order to complete the task. Several researchers experimented the use of vegetable oils as fuel on conventional engines (CE) and reported that the performance was poor, citing the problems of high viscosity, low volatility and their polyunsaturated character causing the problems of piston ring sticking, injector and combustion chamber deposits, fuel system deposits, reduced power, reduced fuel economy and increased exhaust emissions .[1-4]. Plastic oil extracted from plastic is used as alternative fuel for diesel engine.[5-8]. Plastic oil deteriorated the performance of the conventional engine, though its calorific value is comparable to diesel fuel, due to presence of high carbon. The concept of semi adiabatic diesel engine (SADE) is to reduce heat loss to the coolant thus increasing thermal efficiency of the engine. There are two types of the SADE. Ceramic coated diesel engine and air gap insulated engines. Ceramic, partially stabilized zirconium (PSZ) of thickness 500μm was applied on the inner side of the cylinder head to reduce heat loss to the coolant. [9-11]. The performance of the SADE with ceramic coating with diesel operation improved marginally in comparison with neat diesel operation on conventional engine. The performance of the SADE with ceramic coating with vegetable oil operation improved marginally in comparison with neat diesel operation on conventional engine.[12-14]. Alcohols were used as blends in conventional diesel engine. [15-18]. They reported marginal improvement in the performance of the engine with blended alcohols. Alcohols were carbureted and used in SADE with vegetable oil. [19-21]. Change of injection timing was adopted to improve the performance of the engine. [22-24]. The performance of the SADE was evaluated with carbureted butanol and compared with neat diesel on conventional engine.To determine maximum induction of butanol with CE and SADE.To determine optimum injection timing, To evaluate the performance of the both versions of the engine at recommended injection timing and optimum injection timing

2.MATERIALS AND METHODS

2.1 Fabrication Of Insulated Cylinder Head

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

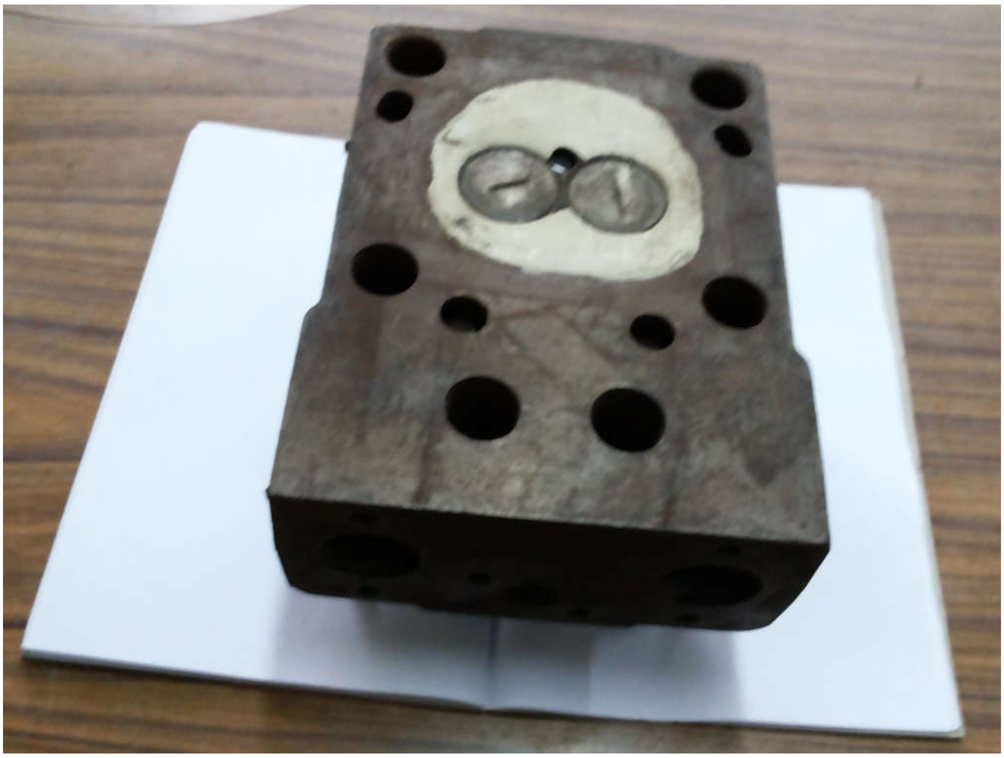


Fig.1. Photographic view of ceramic coated cylinder head

2.2. Manufacturing Of Butanol :

Alcohols have high volatile fuels and low C/H ratio (C= Number of carbon atoms, H-Number of hydrogen atoms in fuel composition). However, they have low Cetane number making less combustible in diesel engine. Butanol is produced from organic materials such as grains, fruit, wood and even municipal solid wastes and waste or specifically grown biomass. The municipal solid wastes can be converted to alcohol. The wastes are first shredded and then passed under a magnet to remove ferrous materials. The iron free wastes are then gasified with oxygen. The product synthesis gas is cleaned by water scrubbing and other means to remove any particulates, entrained oils, H_2S and CO_2. CO-shift conversion for H_2 / CO / CO_2 ratio adjustment, alcohol synthesis, and alcohol purification are accomplished. Table 1 shows the properties of butanol and diesel fuel.

Table.1

Properties of butanol and Diesel fuels

(Courtesy from IICT, Hyderabad)

Property	**Diesel**	**Butanol**	**ASTM Standard**
Specific gravity at 15^{O}C	0.84	0.81	ASTM D 4809
Latent heat of evaporation (kJ/kg)	600	1110	-
Self-ignition temperature (º C)	220	600	-
Cetane number	55	10	ASTM D 613
Lower calorific value (kJ/kg)	42000	36000	ASTM D 7314
Stoichiometric air fuel ratio	15.5:1	10.4:1	-

2.3.Preparation of Plastic Oil

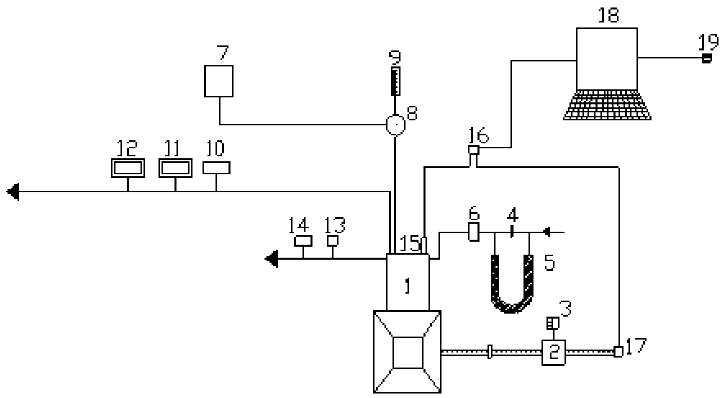
Thermal cracking or pyrolysis involves the degradation or cracking of the polymeric materials by heating them to a very high temperature. +The heating should be carried out in the absence of oxygen to make sure that no oxidation of the polymer takes place. The temperature ranges between 350 and 900°C. The products formed include a carbonized char (solid residues) and a volatile fraction. A portion of the volatile fraction can be condensed to give paraffins, isoparaffins, olefins, naphthenes, and aromatics, while the remaining is a non-condensable high calorific value gas. Table.2 shows the properties of waste plastic oil. The plastic oil was blended with diethyl ether by 20% as it was found to be optimum by earlier researchers.

Table.2
Properties of Waste Plastic oil (WPO)

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

2.4 Diesel Operation

The performance of the conventional engine and low heat rejection diesel engine (LHR) deteriorated with plastic oil as contained high carbon content, as reported by many researchers. Hence work in that direction was left over. Instead, the author used carburetion technique to induct butanol and crude plastic oil was injected in conventional manner. The schematic diagram of the experimental setup used for the investigations with diesel operation is shown in Fig..2. The specifications of the engine are shown in Table 3. The naturally aspirated engine is provided with water-cooling system in which outlet temperature of water was maintained at 80^0 C by adjusting the water flow rate. Injection timing varied with sensors.



1.Engine, 2.Electical Dynamometer, 3.Load Box, 4.Orifice meter, 5.U-tube water manometer, 6.Air box, 7.Diesel tank, 8 Three-way valve, 9.Burette, 10. Exhaust gas temperature indicator, 11.AVL Smoke meter, 12.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.Personal Computer and 19.Printer.

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

2.5.Combustion Characteristics: Combustion characteristics of peak pressure, time of occurrence of peak pressure and maximum rate of pressure were evaluated at full load operation of the engine. The pressure transducer (15) [AVL Austria QC34D] was located on cylinder head. TDC (17) [AVL Austria 365 x] encoder was provided at the extended length of dynamometer shaft. Console (16) was connected to the pressure transducer and TDC encoder. It converts the pressure signal from pressure transducer and magnetic signal from TDC encoder to electrical signal which fed to the computer(18). Computer read pressure, crank angle data and also all combustion parameters at full load operation, which fed to the printer(19).

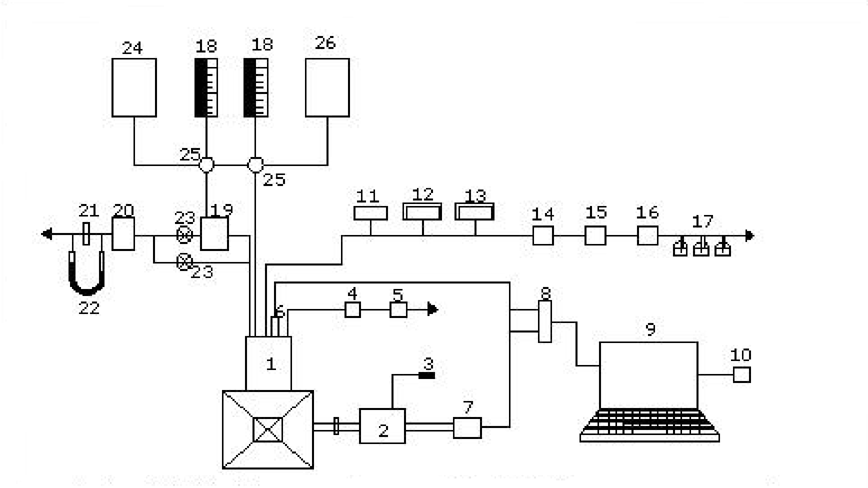
Table.3.

Specifications of The Test Engine

Description	Specification
Engine make and model	Kirloskar (India) AV1
Maximum power output at a speed of 1500 rpm	3.68 kW
Number of cylinders ×cylinder position× stroke	One × Vertical position × four-stroke
Bore × stroke	80 mm × 110 mm
Method of cooling	Water cooled
Rated speed (constant)	1500 rpm
Fuel injection system	In-line and direct injection
Compression ratio	16:1
Aspiration	Natural
BMEP @ 1500 rpm	5.31 bar
Manufacturer's recommended injection timing and pressure	27^0 bTDC × 190 bar
Dynamometer	Electrical dynamometer (Kirlosker make)
Number of holes of injector and size	Three × 0.25 mm
Type of combustion chamber	Direct injection type
Fuel injection nozzle	Make: MICO-BOSCH No- 0431-202-120/HB
Fuel injection pump	Make: BOSCH: NO- 8085587/1

2.6 Carbureted Alcohol-Crude Plastic Oil Operation

Fig.3 gives the schematic diagram of the experimental setup used for the investigations on the LHR engine with carbureted butanol and crude plastic oil. A variable jet carburetor is fitted at the inlet manifold of the engine for inducting alcohol at different percentages of full load operation of vegetable oil on mass basis during the suction stroke of the engine. Two separate fuel tanks and glass burette arrangements are made for measuring plastic oil and alcohol consumptions using stop watch. By-pass arrangement is provided for the engine to run with either diesel/plastic oil or carbureted alcohol-vegetable oil.



1.Engine, 2.Electical Dynamometer, 3.Load Box, 4.Outlet jacket water temperature indicator, 5.Outlet-jacket water flow meter 6.Piezo-electric pressure transducer, 7.TDC encoder 8.Console, 9.Personal Computer, 10. Printer, 11.Exhaust gas temperature indicator, 12.AVL Smoke Meter, 13.Netel Chromatograph NOx Analyzer, 14.Filter, 15.Rotometer, 16.Heater,17.Round bottom flask containing DNPH solution, 18.Burette, 19.Variable jet carburetor, 20.Air box, 21.Orifice flow meter, 22.U-tube water manometer, 23.By-pass valve, 24.Alcohol tank, 25.Three-way valve, 26.Vegetable oil tank.

Fig.3. Schematic diagram of the experimental setup for alcohol-plastic oil operation

2.7 Operating Conditions

Test fuels used in the experimentation were diesel, crude plastic oil along with carbureted butanol. Various injection timings attempted in the investigations are 27–34^{0}bTDC. The various combustion chambers used in experiment were conventional combustion chamber and ceramic coated combustion chamber.

3.RESULTS AND DISCUSSION

The performance of the both versions of the engine with crude plastic oil was evaluated. However, the performance of the both versions of the engine deteriorated with neat plastic oil. This is due to high carbon content of plastic oil.

The author carbureted butanol through variable jet carburetor at different percentages of diesel fuel at full load on mass basis. Crude or waste plastic oil blended with diethyl ether by 15% was injected through conventional injection system. The maximum induction of butanol with conventional engine was 35%, while it was 45% with SADE. [25] The optimum injection timing was observed to be 32^{o}bTDC with CE, while it was 31^{o}bTDC with SADE, [25] as the optimum injection timing was obtained earlier than CE with maximum induction of butanol as combustion chamber was maintained hotter.

3.1. Combustion characteristics of both versions of the engine at recommended and optimum injection timing .

It is necessary to determine combustion parameter if there is a change of design of combustion chamber for any new alternative fuel.

Fig.4 presents bar chart showing the variation of peak pressure (PP) at full load with both versions of the engine at RIT and OIT with plastic oil operation with maximum induction of butanol. PP at full load increased with CE, while it decreased with LHR engine with advanced injection timing. This is due to accumulation of air and fuel mixture with advanced injection timing as delay period increased with CE. In case of LHR engine, there was reduction of delay period as duration of combustion of fuel and air mixture decreased with high heat release rate and faster rate of combustion with LHR engine. Butanol in both versions of the engine improved combustion due to the presence of oxygen in its molecular composition.

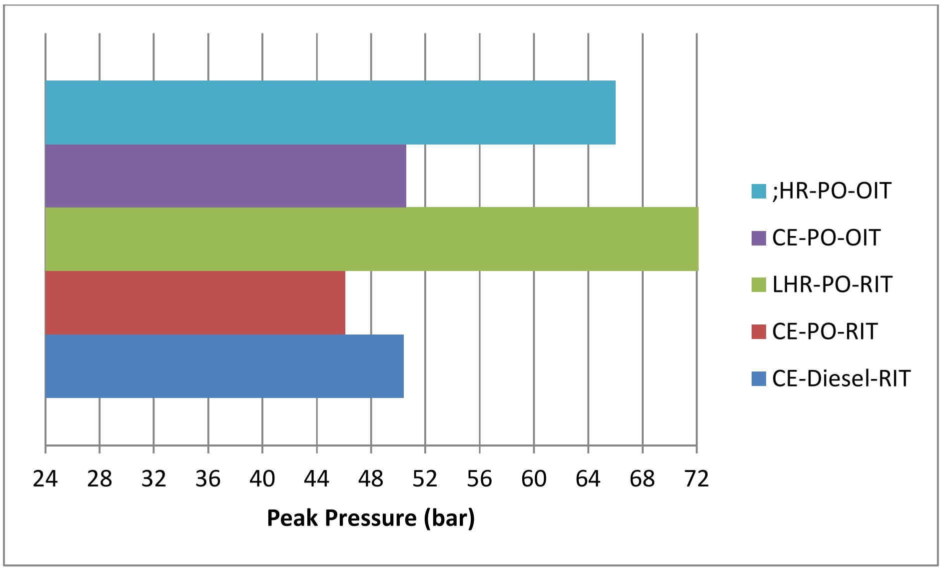


Fig.4. Bar chart showing the variation of peak pressure at full load

CE marginally decreased PP at full load at RIT when compared with CE with diesel operation. This is due to deterioration in combustion with CE with plastic oil, due to its high viscosity and low volatility. LHR engine drastically increased PP at full load at RIT, as combustion temperatures were very high with LHR engine. Increase of NO_x emissions with LHR engine showed enough evidence with high peak pressures at full load operation.

Fig.5 presents bar chart showing the variation of time of occurrence of peak pressure (TOPP) at full load with both versions of the engine at RIT and OIT with plastic oil operation with maximum induction of butanol. TOPP at full load decreased with advanced injection timing with both versions of the engine. This is due to improved combustion with both versions of the engine. Reduction of TOPP at full load with advanced injection timing confirmed that combustion improved with advanced injection timing. CE with plastic oil operation at RIT showed marginally higher TOPP at full load when compared with neat diesel operation on CE. Butanol in both versions of the engine improved combustion due to the presence of oxygen in its molecular composition.

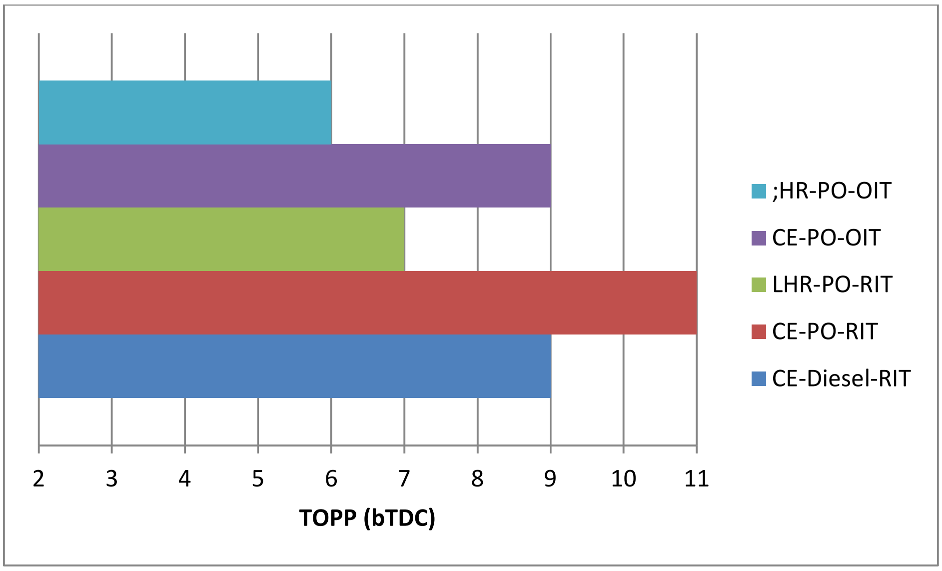


Fig.5. Bar chart showing the variation of time of occurrence of peak pressure (TOPP) at full load

This showed that combustion deteriorated with CE with plastic oil operation as the duration of combustion with CE was high when compared with diesel operation on CE. LHR engine at different injection timings drastically reduced TOPP at full load than CE with diesel fuel and plastic oil. This is due to faster rate of burning of fuel with LHR engine causing reduction of TOPP at full load.

Fig.6 presents bar chart showing the variation of maximum rate of pressure rise (MRPR) at full load with both versions of the engine at RIT and OIT with plastic oil operation with maximum induction of butanol.

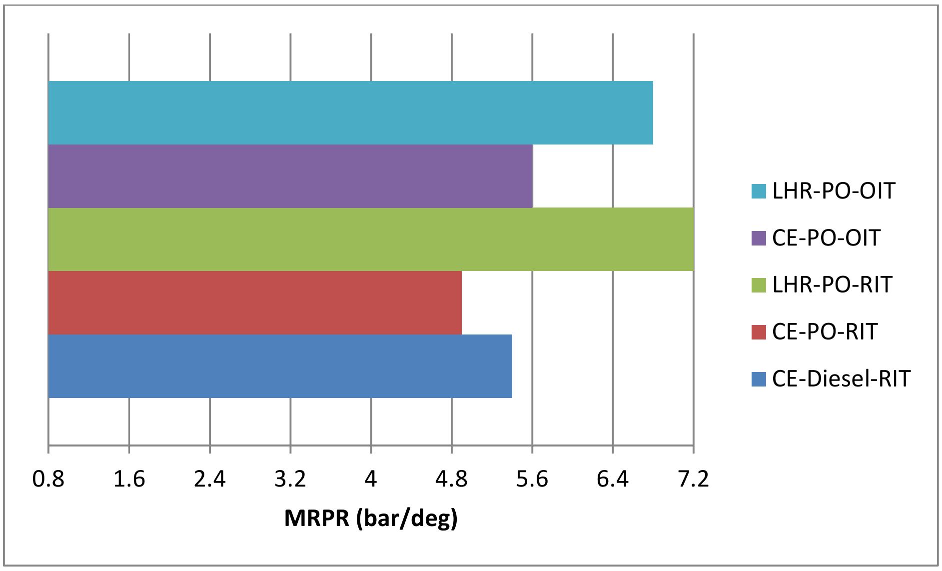


Fig.6. Bar chart showing the variation of Maximum Rate of Pressure Rise (MRPR) at full load

MRPR at full load followed the similar trends with PP at full load. MRPR at full load increased with CE while it decreased with LHR with advanced injection timing. This is due to increase of combustion temperatures with CE, and reduction of the same with LHR engine. LHR engine drastically increased MRPR at full load at RIT with plastic oil operation. This is due to faster rate of combustion, high heat release rate and decrease of combustion duration of the fuel. CE with plastic oil operation showed marginally lower MRPR at full load in comparison with neat diesel operation on CE. This is due to increase of combustion duration of fuel with CE with plastic oil Butanol in both versions of the engine improved combustion due to the presence of oxygen in its molecular composition. In addition to that, combustion deteriorated with CE with plastic oil operation due to poor volatility of the fuel.

4.CONCLUSIONS

1. On the basis of test fuel (diesel or carbureted butanol and injected plastic oil blended with diethyl ehter)

Carbureted butanol and injected plastic oil improved the combustion parameters at full load (PP, TOPP and MRPR)

2. On the basis of configuration of the engine (conventional engine and LHR engine)

LHR engine improved the combustion parameters,

3. On the basis of injection timing (advanced injection timing)

Advanced injection timing improved the combustion parameters

5 Future scope of the work

1. Investigations are to be carried out with exhaust gas circulation and to be correlated with supercharging.
2. Any gaseous fuels can be tried in LHR engine
3. The degree of insulation for insulated engine can be increased and supercharging can be employed.
4. Swirl ratio can be improved for the improved performance;
5. Pollution levels can be studied.

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