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Engine Combustion Analysis of an IDI-Diesel Engine with Rice Bran Methyl Ester and Isopropanol Injection at suction end

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Abstract-The choice of biodiesel is also a criterion to replace the petro diesel with the suggested one. In this present context the IDI engine is tested with the conventional petro-diesel and biodiesel along with biodiesel and several additive compositions. The additive used is Isopropanol (C3 H8 O) in various percentages viz. 2%, 3%, 4% and 5% of Isopropyl alcohol (additive) is injected calculated with reference to 1litre/hr. biodiesel and RBME is injected through the regular pintel nozzle in a dual fuel mode. Isopropanol is injected into the air inlet at 3 bar without effecting the volumetric efficiency. Fast rise of combustion pressure in the pre-combustion chamber as is the case with the neat diesel operation is contained with the usage of 2% Isopropanol in biodiesel. The combustion is shared judiciously in both the chambers leading to normalization and lesser heterogeneity of combustion. This implies smoother combustion in both the chambers increasing the combustion efficiency and heat release rate. Systematic combustion in the main chamber shall be of importance in the better torque conversion.

Keywords— IDI Engine,Rice bran methyl ester,Isopropanol, Electronic Injector,combustion pressure, Cumulative heat release rate.

I. Introduction

The use of vegetable oil in place of diesel fuel in conventional diesel engines requires modification in properties. Considerable efforts have already been made to develop vegetable oil derivatives that would approximate the properties and performance of the petro- diesel. The problem of substituting pure vegetable oils for diesel fuels is mostly associated with their high viscosities [1, 2]. Reduction of viscosity can be effected by any of the processes like transesterification, mineralization, preheating and pyrolysis. Mineralization consumes more time and pyrolysis brings about irregular molecular break down. Hence transesterification of vegetable oil is taken up in this work to experiment on a laboratory-based IDI engine with the dual fuel mode using rice bran methyl ester injection and Isopropanol as secondary injected fuel at the air suction inlet at 3 bar pressure. IDI engine is preferred to ensure complete combustion and reduce crank case oil dilution which normally occurs in case of neat biodiesel application and thinner additive mixing.

Injection timings and quantities of additives like methyl and ethyl alcohols have affected the ignition delay and maximum pressure rise during combustion, [3].

The oxygenated alternative fuels such as methanol and ethanol have provided more oxygen during combustion. Therefore, the oxygenated alternative fuels and blends with gasoline and diesel fuel are more clean combustion processes than that of diesel and gasoline fuels [4-10]. The studies related to the alternative fuels should be enhanced for diesel engines especially for indirect injection (IDI) diesel engines. Because, they have a simple fuel injection system and lower injection pressure level. They do not depend upon the fuel quality and have lower ignition delay (ID) and faster combustion than direct injection (DI) diesel engines. In this paper, simple isopropyl alcohol injection at air suction end at 3bar along with the usual Injection system for biodiesel with pintel nozzle is resorted to. The results obtained are appreciable with least modification of the engine almost keeping other parameters intact. Authors in the above said references have not taken care of the combustion propensities in the pre and main chambers. Methanol or ethanol additives to some extent deter the quantum of heterogeneity used along with biodiesel. Injection timings, pressures and quantities and methods of introducing the additives have been varied in an usual way leading to marginal changes in performance. But in this paper, a novel way was introduced by injecting Isopropanol at 3bar in to the stream of air at the air inlet. This has yielded good results with uniform perspective using fuel reference 1liter/hr. Even though this results in higher percentages of additive at lower loads with fixed reference quantity, 2% Isopropanol in biodiesel yielded better results at almost all loads.

Characterization of fuels Used

S.No	Name of the oil sample → ↓Characteristics	Diesel	Rice Bran Methyl Ester	Isopropanol
1	Density @ 33^{0}c (kg/m^3)	833	868.6	803.4
2	Lower calorific value (kJ/kg)	43000	38552	24040
3	Cetane number	51	63.8	4-10
4	Kinematic viscosity @ 33^{0}c (cSt)	2.58	3.57	1.7
5	Stoichiometric air –fuel ratio	15	13.8	9
6	Latent heat of evaporation (kJ/kg)	250	260	840
7	Flash point (^{0}c)	68	185	11.7
8	Fire point (^{0}c)	72	196	24

Table -1: Properties of the fuel used

II.EXPERIMENATL SETUP

The experimental test rig shown in Fig.1consisting of IDI diesel engine (Bajaj RE100) is erected in the Engines Laboratory of Department of Marine Engineering, Andhra University [Fig.1]. Isopropanol (C_3 H_8 O) is injected at the suction end at a pressure of 3 bar. The injection is controlled electronically and it is timed to inject after full suction valve opening [Fig.2&3]. Assuming diesel consumption 1liter/hr at full load and the proportion of Isopropanol is calculated at the rate of 2%, 3%, 4% and 5%. The crank case oil dilution is regularly tested to verify the extent of contamination if any. Experimentation is carried out at various engine loads (Engine Loading device is eddy current dynamometer) to record the cylinder pressure and to compute heat release rates with respect to the crank-angle.

The experimental test rig consists of the following equipment:

1. Single cylinder engine loaded with eddy current dynamometer
2. Engine Data Logger
3. Electronic fuel injector

Fig.1 Experimental test rig set up

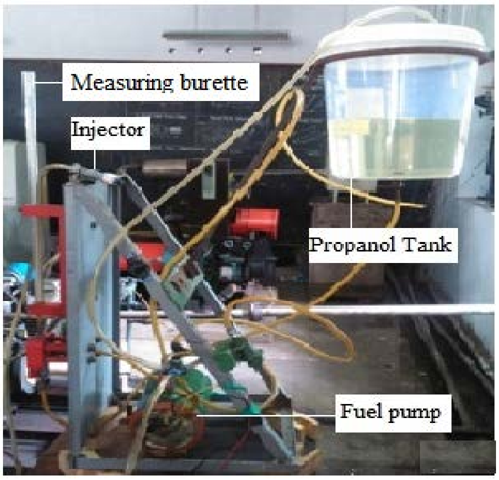

Fig.2 Fuel tank, pump and electronic Injector system of Isopropanol.

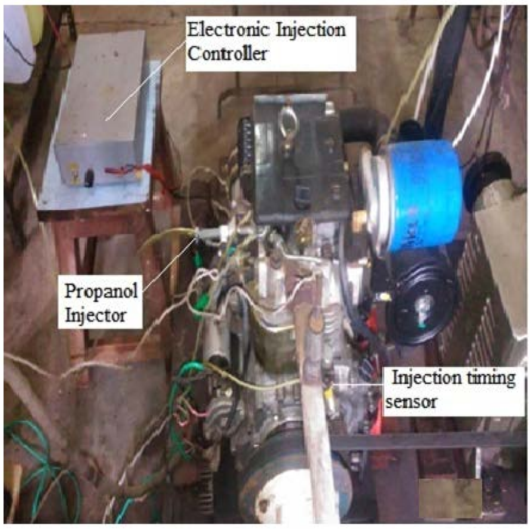

Fig.3Injection with the timing sensor

Indirect Diesel Injection (IDI) Engine test rig :

The IDI diesel engine (make Bajaj Company) is used for conducting the experimentation .The details of the engine are given below in the Table .2

Engine manufacturer	Bajaj RE Diesel Engine
Engine type	Four Stroke, Forced air and Oil Cooled
No. Cylinders	One
Bore	86.00mm
Stroke	77.00mm
Engine displacement	447.3cc
Compression ratio	24±1:1
Maximum net power	5.04 kw @ 3000 rpm
Maximum net torque	18.7 Nm @ 2200 rpm
Idling rpm	1250±150 rpm
Injection Timings	8.5^0 to 9.5^0 BTDC
Injector	Pintle
Injector Pressure	142 to 148 kg/cm^2
Fuel	High Speed Diesel
Starting	Electric Start

Table .2 Specifications of the IDI- Diesel Engine

III. EXPERIMENTAL PROCEDURE:

Experimental test rig comprising loading device and combustion data logger is established in the department of marine engineering, Andhra University. IDI variable speed diesel engine (Bajaj Make) for automobile purpose is chosen. Reason for this choice is that the engine constitutes two combustion chambers and is known for lower exhaust emissions. Notwithstanding the greater heat transfer because of greater surface area of the combustion chambers, the engine is chosen for its clean combustion.

The additive used is Isopropanol (C_3 H_8 O) in various percentages viz. 2%, 3%, 4% and 5% of Isopropyl alcohol (additive) is injected calculated with reference to 1litre/hr. Experimentation is carried out at various engine loads with eddy current dynamometer as the loading device. Combustion pressures at each degree of crank revolutions are recorded with C7112 Software and heat release rates are computed with pressure data as the input data.

The schematic diagram [Fig.4] represents the instrumentation set up for the experiment. The Piezo electric transducer is fixed (flush in type) to the cylinder body (with water cooling adaptor) to record the pressure variations in the combustion chamber. Crank angle encoder sends signals of crank angle with reference to the TDC position and will be transmitting to the data logger. The data logger synthesizes the two signals and final data is presented in the form of a graph on the computer using c7112 software.

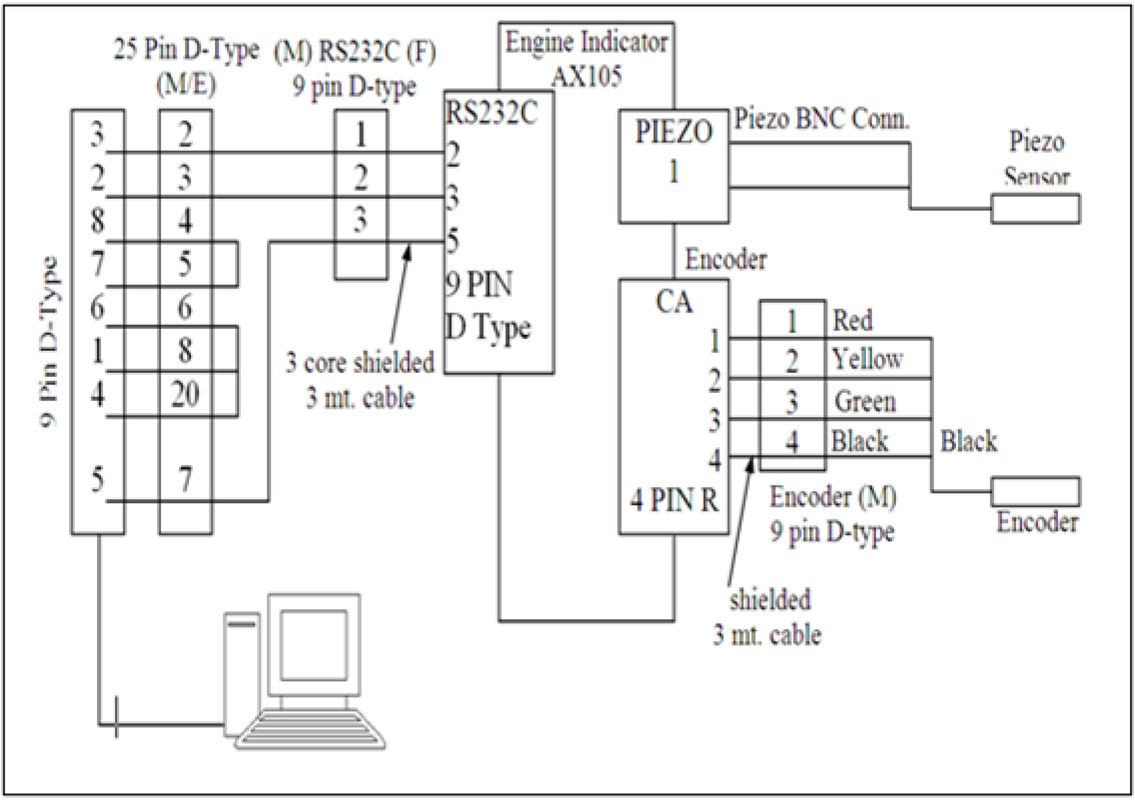

Fig.4 Schematic diagram of Data Integration circuit taking data from the encoder and pressure transducer.

IV. Combustion Analysis:

Investigation of combustion pressure data and derived heat release rate:

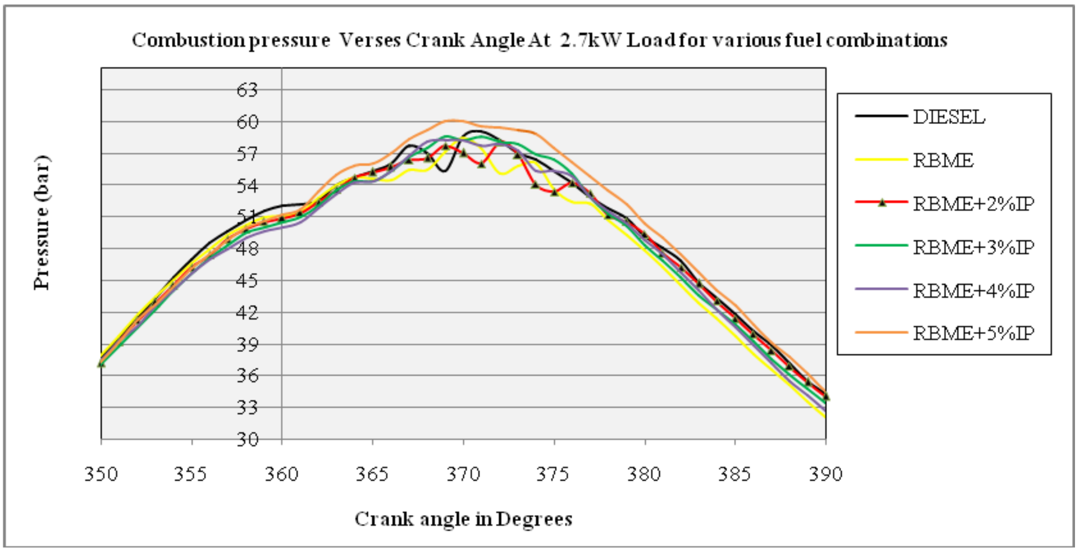

Fig.5 Combustion pressure variation (at 2.7kW load) with one degree resolution and with average of six samples for each plot.

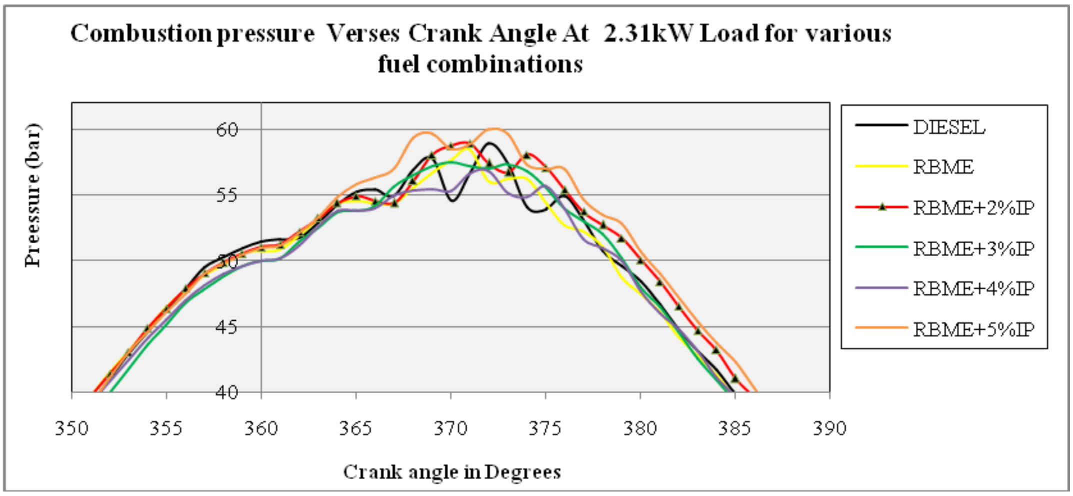

Fig.6 Combustion pressure variation (at 2.31kW load) with one degree resolution and with average of six samples for each plot

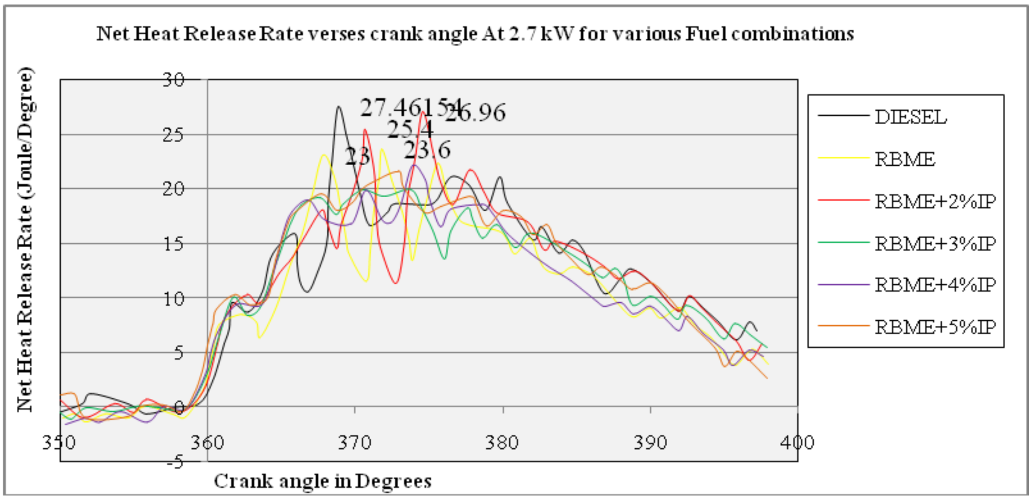

Fig.7 Net Heat release rate plots for the fuel combinations at 2.7kW Load on the engine

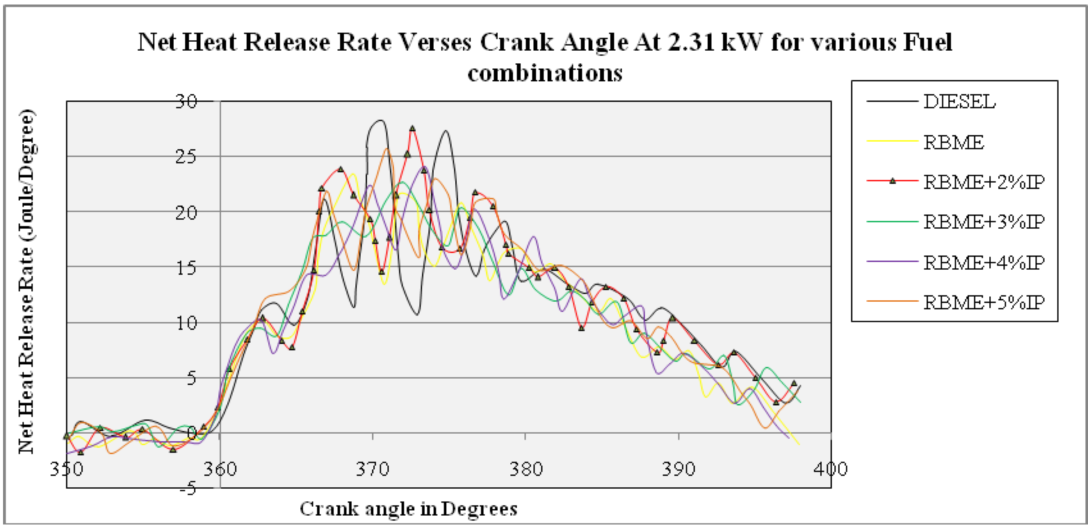

Fig.8 Net Heat release rate plots for the fuel combinations at 2.31kW Load on the engine

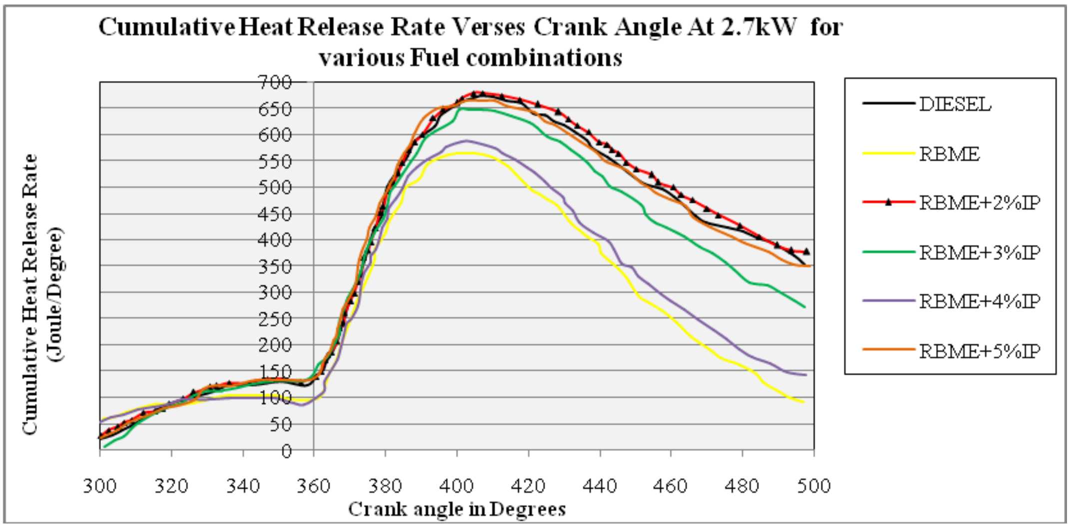

Fig.9 Cumulative Heat release rate plots for the fuel combinations at 2.7kW Load on the engine

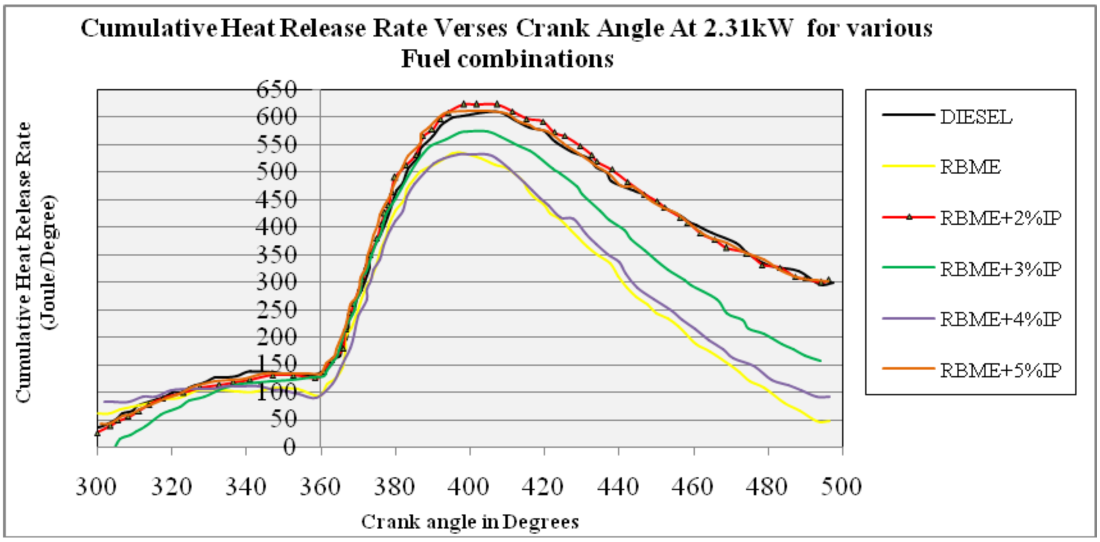

Fig.10 Cumulative Heat release rate plots for the fuel combinations at 2.31kW Load on the engine

The Figures 5&6 depict the combustion pressure variation at two loads respectively. The pressure variation is shown in between 350 and 390 degrees of crank variation which encompasses the pressure variation 10 degrees ahead and 30 degrees later of TDC position envisaging clear trend for various fuel combinations used in the engine. The observations one can make is that the combustion in pre-combustion chamber and main chamber are distributed uniformly in the case of 2% additive mixing with comparatively smoother start of combustion (neither violent nor subdued). The trailing two peaks after TDC position indicate better preparation and part combustion in the pre-combustion chamber dwelling more amount of time in the same chamber leading to better diffused combustion in the main chamber contributing to better torque conversion. The combustion in the main chamber altogether is comparatively improved when compared to the neat biodiesel in both the cases of load. This phenomenon also leads to lesser phase change of the fuel in the main chamber due to heat transfer paving way for lesser crank case oil dilution and higher thermal efficiency due to lesser convective heat transfer especially in the main chamber.

Figures 7&8 indicate the net heat release rate plots calculated with the input of pressure variation in the combustion chamber in the range from 350^0 to 400^0 crank angle duration. The Figures envisage starting of combustion and generation of heat energy in the order of Bio diesel, Diesel and 2% Isopropanol in Biodiesel. This order is based on the respective Cetane number of the fuel combinations. One can infer that 2% Isopropanol in Biodiesel is the better one to set to combustion in both chambers irrespective of the load. The plots at maximum load and part load indicate the same combustion propensity.

The reason for the better performance in the case of 2% Isopropanol in biodiesel may be systemization of combustion enabling to reduce heterogeneity in various zones of combustion chamber.

Maximum heat release in Joule/Degree is maximum for the diesel and there upon in order for 2% Isopropanol in Biodiesel and neat Biodiesel.

The peak NHRR in the pre and main combustion chamber for the loads mentioned are shown in the table.3 It can be observed that the performance of the hear release for 2% Isopropanol in biodiesel has gained betterment on par with neat diesel oil where as neat biodiesel remains inferior. More Isopropanol quantity than 2% in the biodiesel also proved inferior in combustion quality.

Same combustion quality is reflected in the cumulative plots from Figures 9&10 at the two strategic loads presented. At maximum load and part load, it can be observed a difference of 115J/degree, and 88J/degree respectively in between neat biodiesel & 2% in biodiesel in generating maximum CHRR albeit minor difference in the angle of occurrence after TDC.

The peak cumulative heat quantities calculated are represented in Table.2. The inference one can make is that 2% Isopropanol in biodiesel is the best choice to confirm it as selected fuel to run the IDI engine for better performance.

Table.3 Net Heat Release Rate (NHRR) J/ degree**:**

Load	Fuel	Crank angle after TDC & Peak value in pre-combustion chamber	Crank angle after TDC & Peak value in main combustion chamber
2.7 kW Load	Biodiesel	7.83^0, 23	11.81^0,23.6
	Diesel	6^0, 15.73	$8,86^0$, 27.46
	Biodiesel+2% IP	10.77^0, 25.4	14.6^0, 26.96
2.31 kW Load	Biodiesel	8.65^0, 23.42	11.74^0, 21.63
	Diesel	10.73^0, 28.05	14.78^0, 27.34
	Biodiesel+2% IP	7.86^0, 23.87	12.57^0, 27.58

Table.4 Cumulative Heat Release rate: (CHRR in J/degree)

Load	Fuel	Location of degree after TDC	CHRR peak value
2.7 kW Load	Biodiesel	39.92^0	563.97
	Diesel	46.9^0	673.44
	Biodiesel+2%IP	44.58^0	678.46
2.31 kW Load	Biodiesel	38.2^0	534.4
	Diesel	43.9^0	609.05
	Biodiesel+2%IP	39.2^0	622.7

V. Conclusions:

1. It is observed that the combustion in pre-combustion chamber and main chamber are distributed uniformly in the case of 2% additive mixing with comparatively smoother start of combustion. Rapid combustion in the pre combustion chamber is slowed down to marginal extent leading to less friction losses in the transit from one chamber to another and this aspect saves the combustion energy to greater extent increasing the thermal efficiency of the engine. Higher pressure generation in the pre combustion also increases the heat transfer from pre-chamber surface area. The trouble of scavenging the burnt gases and increase in the compression ratio is mandatory in case the pre-chamber when it is hotter. This problem can be reduced when neat biodiesel is implemented without Isopropanol additive component

2. The combustion in the main chamber altogether is comparatively improved when compared to the neat biodiesel in both the cases of load. There is sufficient preparation time for the additive with higher auto ignition temperature in the pre-chamber. Unburned Isopropanol component should not enter into the main chamber with the realization that it may condense the main fuel because of higher latent heat of the additive.

Isopropanol in fully vapor form leads to lesser phase change of the fuel in the main chamber due to heat loss paving way for lesser crank case oil dilution by the biodiesel in liquid form and higher thermal efficiency due to lesser convective heat transfer especially in the main chamber

3. The reason for the better performance in the case of 2% Isopropanol in biodiesel may be systemization of combustion enabling to reduce heterogeneity in various zones of combustion chamber. Maximum heat release in Joule/Degree is maximum for the diesel and there upon tappers in order for 2% Isopropanol in Biodiesel and last comes neat Biodiesel. If it is taken into account cumulative heat release rate, 2% Isopropanol exceeds even diesel fuel values at every degree and this merit gives overwhelming priority to the above said fuel with additive in replacing diesel fuel.

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