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An Experimental Evaluation of Combustion & Performance Attributes of Mono Cylinder CI Engine through Jatropha biodiesel Interact With Diesel as an Alternate Fuel

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Abstract- *The aim of this survey is to disclose performance of engine, chemical & physical properties and combustion characteristics of Jatropha biodiesel-diesel blends used in diesel engine at various load conditions. Now, biodiesels are more important due to essentiality of substitute energy source because of fossil fuel deadlock. But it is seen that using edible oil it would affect food chain & may lead to lack of food. Thus, Jatropha as non-edible biodiesel blended with general fuel is implied for balancing the usage. Jatropha methyl esters (JMEs) can be produced from seeds of Jatropha. They are blended with diesel using different volumetric percentages for evaluating variation of fuel properties. Combustion tests are taken on single cylinder CI engine using different JMEs-diesel blends. At higher loading condition brake thermal efficiency is higher & brake specific fuel consumption is lower. According to different papers amount of CO_2 & NO is rising with higher loading condition and amount of O_2 & CO is decreased. As per research blends of JMEs-diesel with little content by volume is useful in diesel engine without modification of engine.*

Keywords- *CI Engine; Jatropha Oil; Biodiesel; Engine Performance; Combustion Characteristics.*

I. INTRODUCTION

Biofuel is best option as an alternative to the fossil fuels with reduced greenhouse gas effects. It is highly preferable due to it is classified under renewable energy resource category and it is environment friendly [1]. Biofuel is made of FAMEs and it is used in pure form or by blending it with diesel in current diesel engines. Government has given the orders and laws for using biodiesel. It is suggested by government to use biodiesel in the blend form of biodiesel and diesel. This blends are indicated as “B” & “D” following by number which indicates the percentage of biodiesel and diesel in volume. E.g. B100D0 is neat form of biodiesel & B20D80 means biodiesel is 20 vol. %& diesel is 80 vol. %. Currently for chlorpyrifos effect in mixed concentrate formulation, biodiesel is also blended by consolvent & surfactants [2].Biodiesel production by using edible oils can affect the current energy situation policies & social movements. So, oil crops which are non-edible & is grown on large scale are used for alternative fuel feedstock as biodiesel which can not affect oil market [3]. Jatropha curcas plant is non-edible plant which is widely spread in all regions of world. It is also used for controlling erosion and reclaim land & also grown for live fence. This plant seeds have 27 to 40 wt.% oil and based on dry mass average rate of 34.4 wt.% oil [4].Generally all biodiesel has more CFPP, KV, density & lower oxidation stability according to diesel. For low CFPP, fuel is formed in solid size which is enough to become engine inoperable because of plugging of fuel filter. Biodiesel does not have good flow properties at low temperature which causes problems like fuel line & filter clogging in engine fuel supply system. That limits the usage of biodiesel as fuel in cold climate conditions. Some properties like heating value & cetane number are dependent on density of biodiesel [5]. Biodiesel having higher KV may produce undesired problems for using it in engine like not good fuel atomization at time of spraying, fuel pump element’s and injector’s wearing, engine deposits & extra energy desire for pumping fuel [6]. Due to power oxidation stability of biodiesel than diesel, blending of biodiesel by diesel can causes more problems in oxidation stability. So, it is a major issue for using of blends. For making use of blended fuel, fuel properties are regulated according to mandates of the world. Performance of engine & emission are main issues for usage of biodiesel in engine as alternate fuel to diesel [7, 8]. For describing CI engine performance the BSFC&BTHE are most important parameters BTHE measured for engine is dimensionless which is used for converting thermal energy for getting brake effective power. BTHE is taken as actual brake work at single cycle which is divided by consumed fuel’s heating value [9]. BSFC is taken as total consumed fuel’s mass which is further divided by brake effective power. Biodiesel has higher BSFC than diesel which shows higher density & lower heating rate of biodiesel [10, 11]. The BTHE, BSFC, temperature of exhaust gas & nitrogen oxide contents is higher using Jatropha-diesel blends in CI engine [12]. The concentration of NO_x is increased and concentration of carbon monoxide (CO) & hydrocarbons (HCs) is decreased in emission using Jatropha biodiesel [13].The prime objective of this study is to investigate performance and combustion characteristics of JMEs & diesel blends in CI engine.

II. TRANSESTERIFICATION PROCESS

Transesterification also known as alcoholysis is generally chemical reaction process. This process converts triglycerides & alcohol in to esters & glycerols in existence of catalyst. This process covers three sequential reversible reactions. First reaction is converting triglycerides in to diglycerides. Second is converting diglycerides in to monoglycerides. The last reaction is conversation of glycerides in to glycerol. In every step one ester is separated. For improving reaction rate catalyst is generally used so reaction does not consumes much time. There are two types of catalysts, acid catalyst & basic catalysts. Basic catalyst is preferable than acid catalyst due to higher reactivity & smoother process conditions like low temperature required [14]. Because of reversible process excess alcohol is required to get the product. After successful process glycerol and ester are produced. Esters are desired products of this reaction and glycerine is side product which is also valuable for numerous applications [15]. Catalyst used for this reaction can be acids, alkalis & enzymes [16]. This reaction occurs in three reversible steps. This equations are shown below.

$$\text{Triglyceride} + ROH \leftrightarrow \text{Diglyceride} + RCOOR_1$$

$$\text{Diglyceride} + ROH \leftrightarrow \text{Monoglyceride} + RCOOR_2$$

$$\text{Monoglyceride} + ROH \leftrightarrow \text{Glycerol} + RCOOR_3$$

Alcohols have hydrogen or carbons atoms bonded to hydroxyl group. E.g. methanol, ethanol etc. generally methanol & ethanol are mostly used. Methanol is less costly & it has advantageous physical & chemical properties as short chain & polar alcohol. So, it is most preferable [16]. Methanol can easily dissolve alkali catalyst & quickly reacts with triglycerides. Also, methanol has lower boiling point which causes explosion risk. So, during production of biodiesel careful handling is required [17].

III. REACTION MECHANISM

Triglycerides are esters of trihydric alcohol glyceride with unsaturated & saturated monocarboxylic acids. It is main component of animal fats & vegetable oils. In this reaction triglycerides are stepwise converted to diglyceride then monoglyceride & at last in to glycerol in presence of alcohol & catalyst. Generally, for producing biodiesel alcohol preferred is methanol due to it is less costly [17].Stoichiometrically to complete a transesterification, triglyceride's 1 mol reacts with alcohol's 3 mol to get 1 mol glycerol & 1 mol fatty acid ester. It is shown in figure 1 [17]. In practice, more alcohol is used then triglyceride to get max. ester yield from equilibrium state. In this reaction catalyst can be used are acids, alkalis & enzymes [18]. During transesterification process water & fatty acids present in it gives negative effects, since alkali catalyst reacts with FFA to reduce catalyst effectiveness & form soap. So, conversion is lower. During saponification reaction water originates from fats & oils. It retards transesterification reaction from hydrolysis reaction because water can form more amount of FFA by hydrolysing triglycerides in to diglycerides [16, 17]. The reaction of hydrolysis is shown below in figure 2 [19].

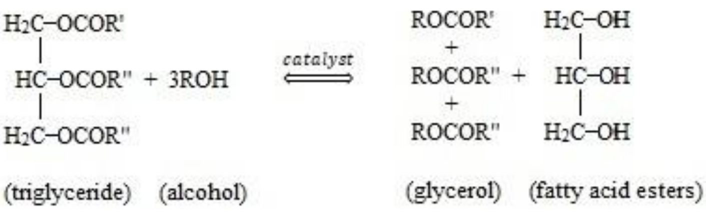

Figure 1.Reaction mechanism

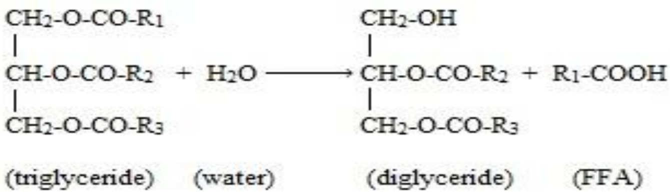

Figure 2.Hydrolysis reaction[19]

IV. FUEL PROPERTIES

The appropriate operation of CI engine is depends on fuel properties. Flash point, pour point, cetane number, viscosity, heating value, density and others are fuel's most important properties. Performance &combustion of CI engine is depends on this. Table 1 indicates discussed fuel properties.

Table 1.Physio-chemical properties of Jatropha biodiesel[20]

Sr. No.	Parameter	Unit	Result
1	Density @15°C	kg/m^3	896
2	Kinematic viscosity @40°C	CP	14.69
3	Kinematic viscosity @100°C	CP	9.82
4	Flash point	°C	135
5	Sulphur content	kg/kg	14
6	Carbon residue contents	% by mass	0.015
7	Sulphated ash content	Ppm	26
8	Water content	mg/kg	1054
9	Total contamination	mg/kg	11
11	Cetane number	-	61.2
12	Acid value	mgKOH/gm	24
13	Methanol content	% by mass	0.14
14	Ethanol content	% by mass	0.18
15	Ester content	% by mass	98.11
16	Free glycerol content	mg/kg	152
17	Total glycerol content	% by mass	0.14
18	Oxidation stability @ 110°C	-	9
19	Iodine value	-	122
20	CCR (10% Bottom)	% by mass	0.040(100)

V. EXPERIMENTAL SETUP

The engine used for experiment ismono cylinder with variable compression ratio, straight injection &naturally aspirated CI engine. It is cooled using circulation of water. The moving approach of CI engine could be altered from petrol to diesel & vice-versa by using some mandatory alternations. In any approach the compression ratios can be varied without discontinuing engine &changing combustion cavity dimension usingpredominantly designed cylinder block. Theprovisions of engine are revealed in table 3. The illustrative figure of setup is embellished in figure 3. The CI engine is integrated by eddy current dynamometer with electronic controls which offerrequired load to anengine. Fuel consumption of engine ismeasured using single burette. It is associated in such way that fuel rate records arereflected through the sensors. Spark spot& injection position would be stained for study. This setup is well-appointed with essential instruments for measuring fuel line pressure, burning pressure & cranking position. These signals can identified using PC for several graph & statistical data. Somegadgets are established to collaborate with fuel & flow of air.

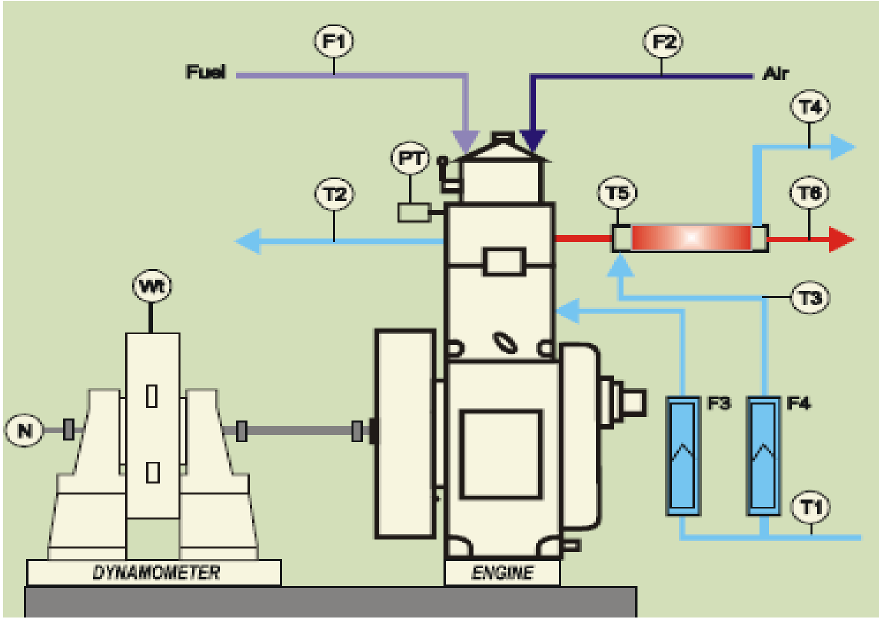

Figure3.Diagram of InvestigationalSetup[21]

Some sensors & thermocouples are used to examine performance & combustion characteristics of engine. Primarily, different powers like indicated, frictional & brake power, then BMEP & IMEP, several efficiencies like brake thermal, indicated thermal & mechanical efficiency, SFC, fuel-air ratio entering into ignition chamber, burning examinations & heat equilibrium. The pressures inside engine are calculated using pressure transducers. Table 2 indicates the sensors engaged in engine for measurement.

Table 2. Various Sensors engagedwithin Engine [21]

Symbol	**Name of sensor**
N	Engine Speed Sensor
W	Load Sensor
F1	Fuel Flow Sensor
F2	Air Flow Sensor
PT	Cylinder-Injection Pressure Sensor
T1-T6	Temperature Sensor

The experiments are taken atexpected engine speed e.g. 1500 rpm & at various load range e.g. 100%, 75%, 50% & 25% of appraised power. Total five blend ratio of Jatropha and diesel are as 100%, 75%, 50%, 25% & 0% (V/V %) are experienced at each load. They are titled as D0B100 to D100B0 in consequent study.Table 3 indicates the engine specifications on which whole test is carried out.

Table 3.Engine Specifications [21]

Parameters	**Details**
Engine	Single Cylinder Water Cooled Diesel Engine
Type	Variable Compression Ratio
Number of Strokes	4
Capacity	553 CC
Bore × Stroke	80 mm × 110 mm
Compression Ratio	6:1 to 10:1 (for petrol)
	12:1 to 18:1 (for diesel)
Maximum Power	5 horse power or 5.2 kilo-Watt
Rated Speed	1500 rpm
Calorimeter	Type Pipe in pipe
Piezo sensor	Combustion: Range 5000 PSI
	Diesel Column: Range 5000 PSI

VI. RESULTS & DISCUSSION

In this unit, the investigational results are represented & discussed from engine running on fuel blends D0B100, D25B75, D50B50, D75B25 and D100B0 with various load range. The blends are adapted with conventional fuel operations. The analysis is concentrating on engine performance & combustion characteristics.

Figure 4 reveals the p-θ graph of altered blends counting peak pressure hike. The result propose that high blending ratio like D0B100 has insignificant result at highest pressure correspond tooperative condition of engine. However mean blending ratio like D50B50 has eminent peak pressure which is displayed in graph. The p-θgraphproves that average concentration has enhanced results than other blends. Whichspecifies that engine gives most favourable peak pressure using D50B50 blend ratio.

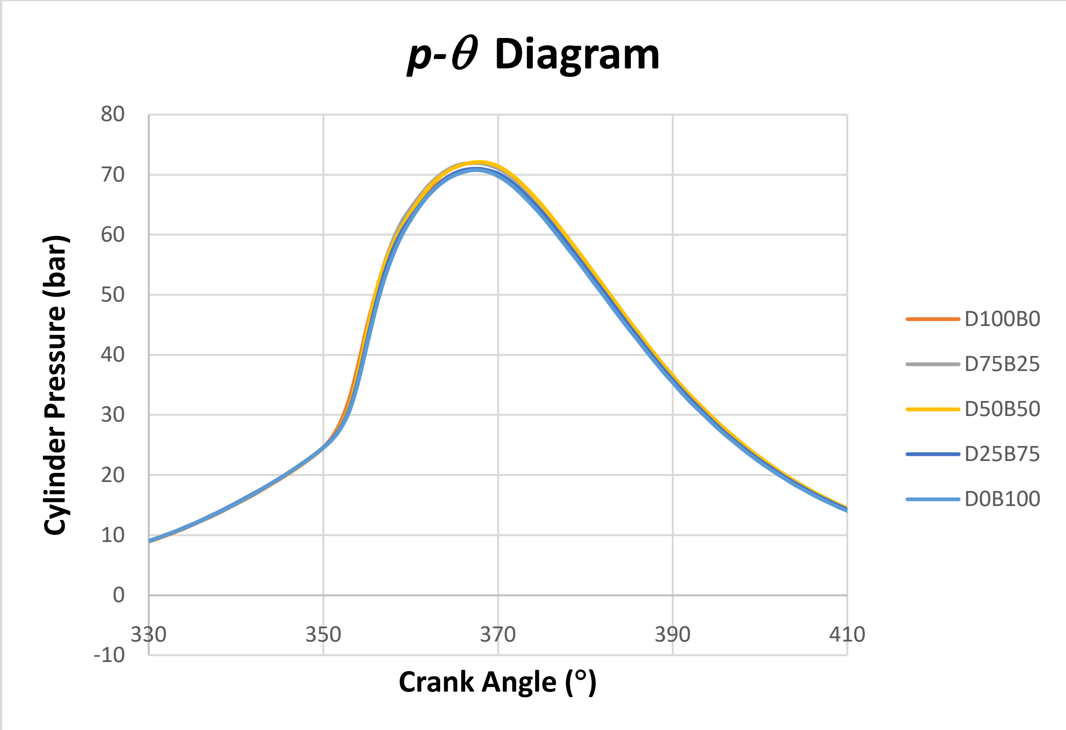

Figure 4.p-θDiagram for different blends

The *p-V* diagram of different blends is demonstrated in figure. 5, which indicates that mean blend of diesel-Jatropha has eminent peak pressure than other fuel blends. Therefore it provides enhanced performance whenever main concern is combustion characteristics. In *p-V* diagram mean blended fuel D50B50 has eminent peak pressure & other blend's cycles are trailed by it such as demonstrated in figure 5.

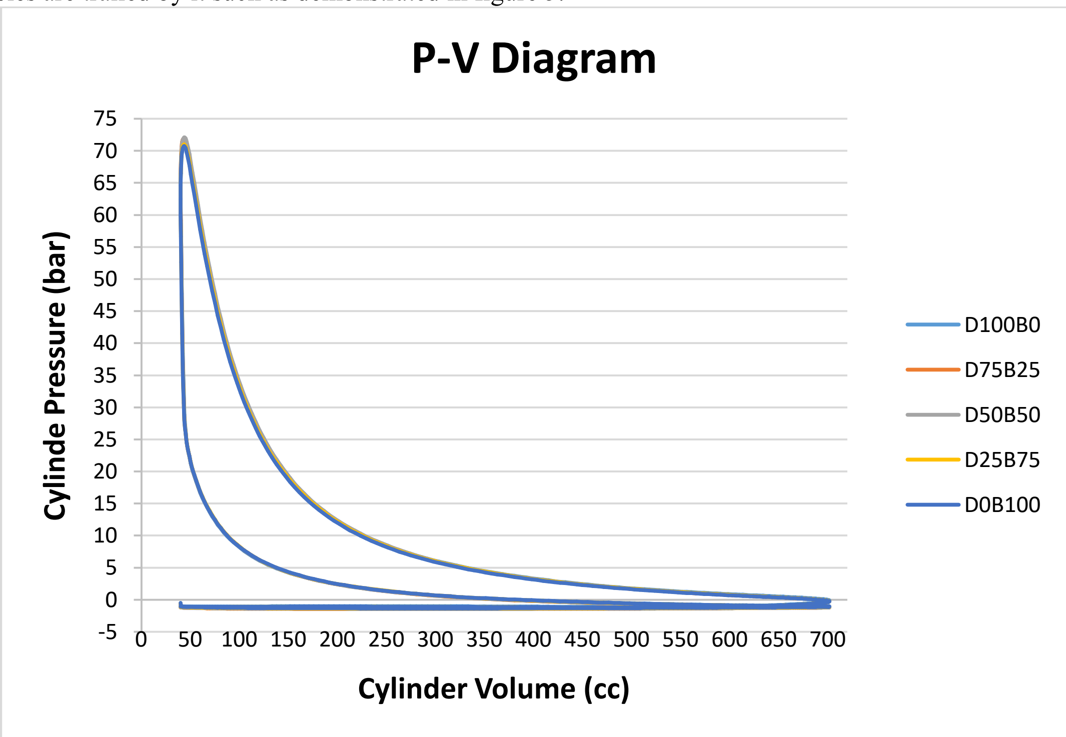

Figure 5.p-V diagram for different blends

VII. ENGINE PERFORMANCE

This unit contains the performance limitations of varied fuel blends regarding different loads. Engine performance exposesfuel blends behaviour at whole load range & it displays results in graphical demonstration. Engine performance covers such characteristics like Fuel Consumption rate, IMEP, BMEP, BTHE, SFC and Mechanical Efficiency. They are listed in subsequent portion.

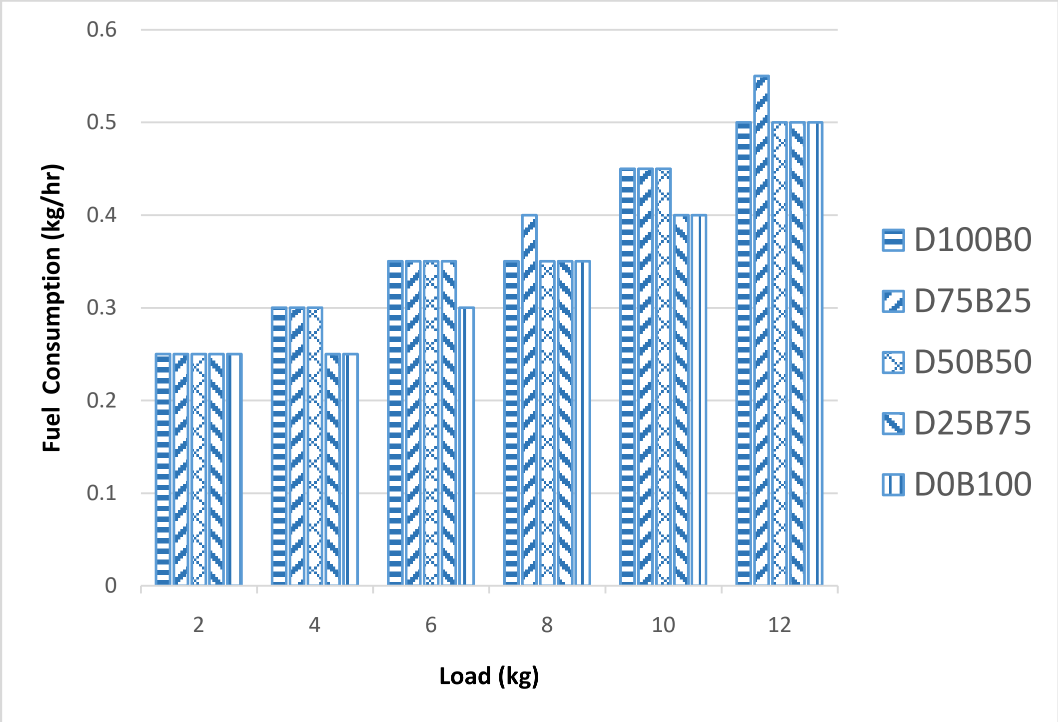

Figure 6.Fuel consumption rate at different engine loads

Figure 6 represents fuel consumption rate of different fuel blends regarding varied engine loads. At part loads blends with higher concentration of Jatropha oil like D0B100 & D25B75 has better results than other blends & engine consumes less fuel. However at full load condition the values of high concentrated Jatropha oil is nearly same to diesel. Hence, rate of fuel consumption is enhanced in high concentrated Jatropha oil blend like D0B100 compared to other blends.

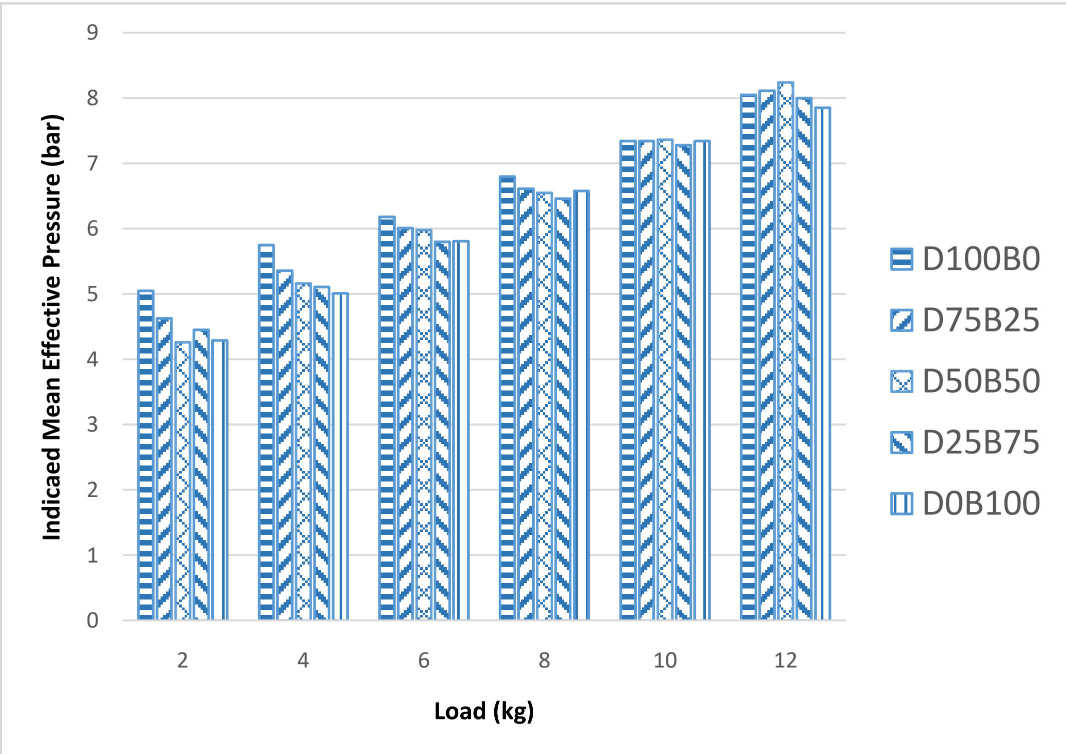

Figure 7.Indicated mean effective pressure at different engine load

The Indicated Mean Effective Pressure illustrated in figure 7. After reviewing the chart data, it is accepted that at low load to part loadcondition, D100B0 has improved results. But at full load condition, mean blended fuel D50B50 has better results. Hence equally concentrated Jatropha-Diesel blend isbetter than diesel & other blends at full or higher load condition whenIMEP is concerned.

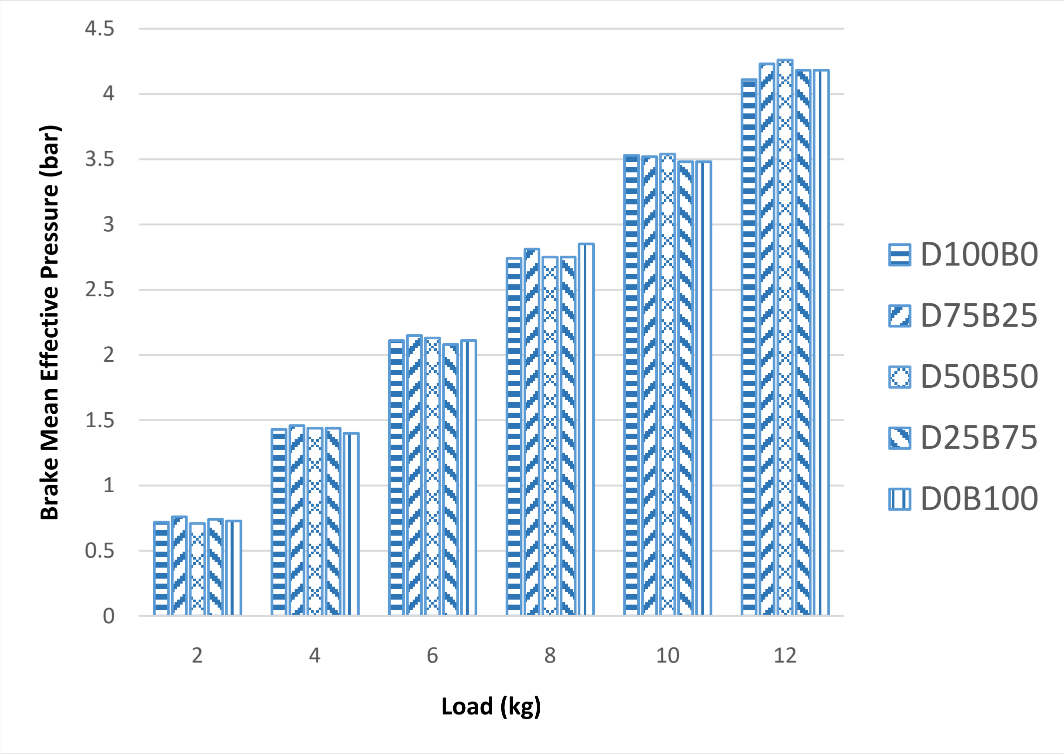

Figure 8. Brake mean effective pressure at different engine load

As demonstrated in figure 8, the BMEP is growing considerably as load increases. At part load the BMEP of low blend fuel e.g. D25B75 has higher digit. At full load condition mean blended fuel e.g. D50B50 has greater digit. Hence it exemplifies positive characteristics when BMEP is concerned.

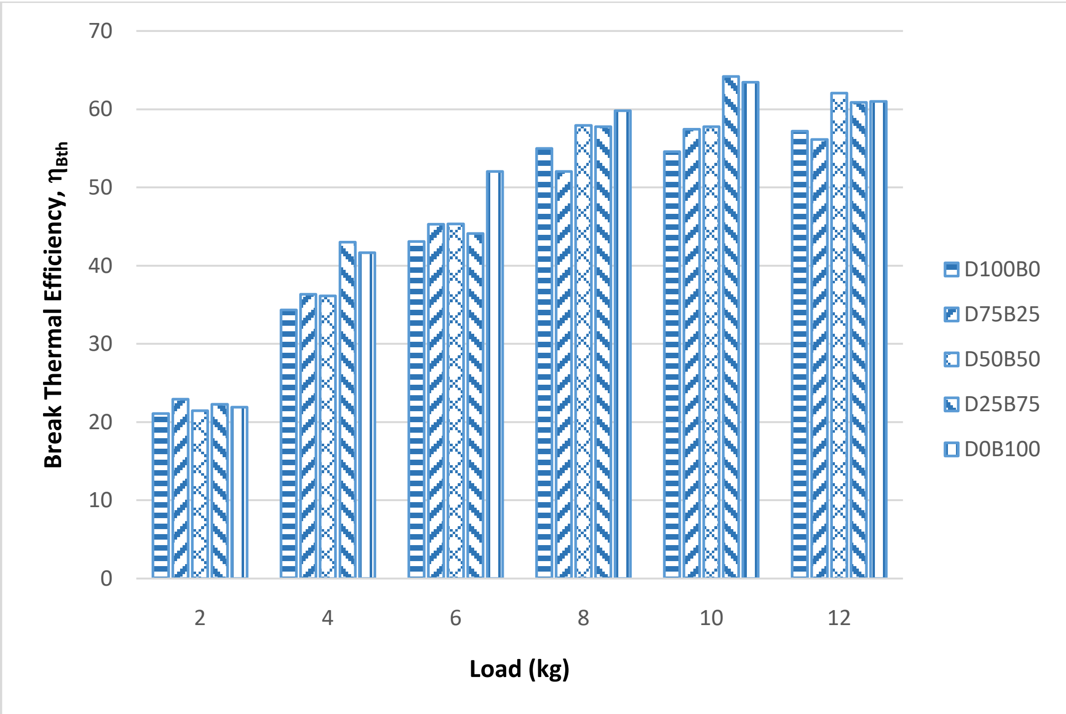

Figure 9. Brake thermal efficiency at different engine load

Concerning η_{Bth} of several concentrations at different loads as specified in figure 9, lower BTHE point out that engine operated less efficiently when Jatropha is used at low load. But at part loads and higher loads pure Jatropha biodiesel has better results.

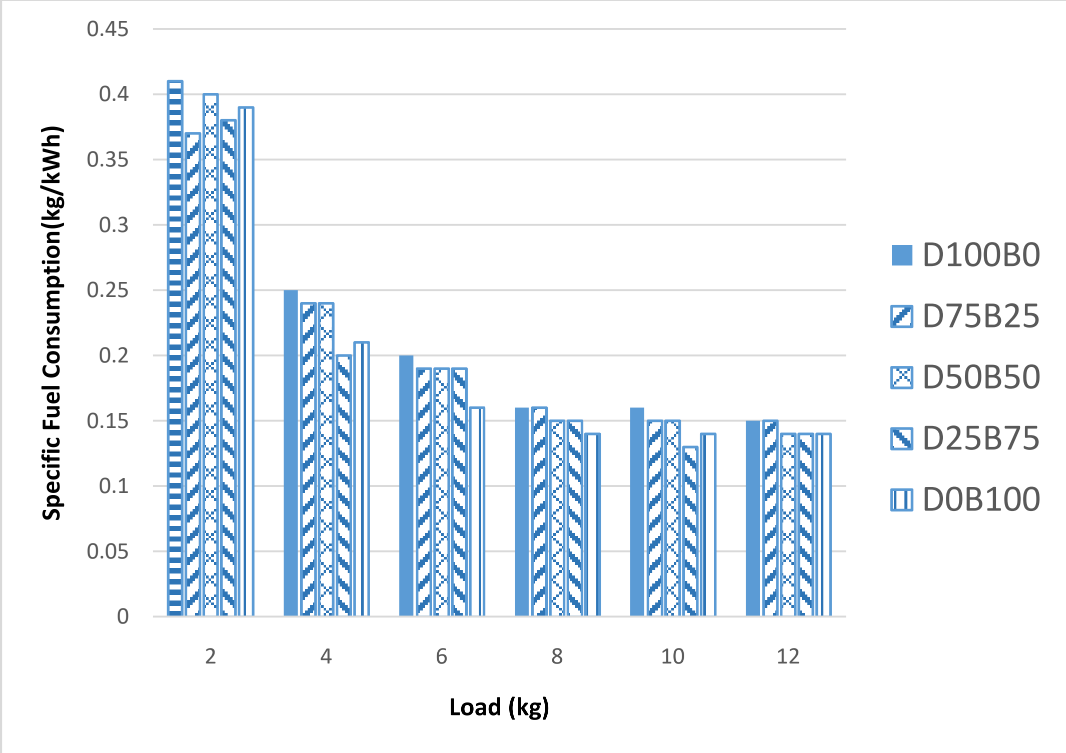

Figure 10. Specific fuel consumption at different engine load

As shown in figure 10, the SFC is reducing significantly with rise in load, therefore at higher load both diesel and Jatropha blend has corresponding properties and either diesel or Jatropha does not affect the performance of engine. And they have minor difference in performance especially in SFC which could be negligible. Pure Jatropha biodiesel has low specific fuel consumption at any load condition.

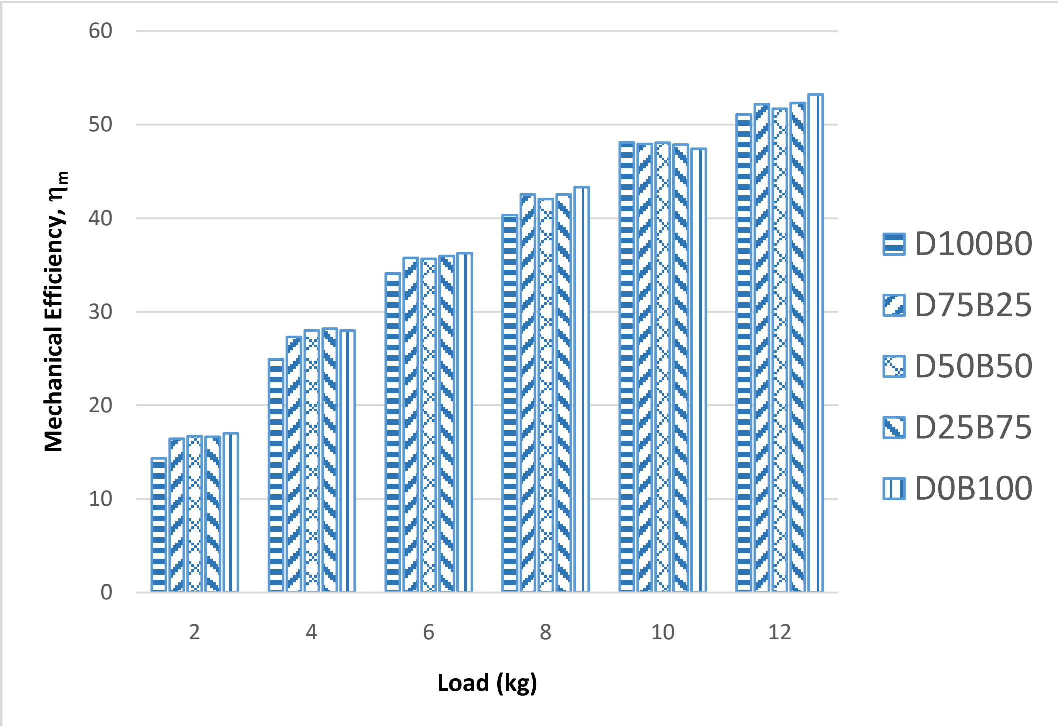

Figure 11. Mechanical efficiencyat different engine load

As demonstrated in fig 11. Mechanical Efficiency increases gradually with increase in loads. At lower loads, mechanical efficiency is minimum and at full load condition, we get maximum mechanical efficiency. Using pure Jatropha biodiesel in place of diesel, we get maximum Mechanical Efficiency.Increasing Blending ratio from 0% to 50%, gives positive impact on Mechanical Efficiency as it seems increasing.

VIII. CONCLUSIONS

Single cylinder CI engine is operated on jatropha biodiesel and its blend smoothly without any engine modification. Hence we can concede that Jatropha biodiesel is compatible for CI engine as an alternate fuel or bio-diesel.The consequent conclusions derived from experimental results are as under:

- Fuel consumption decreases with increase in blend proportions and it seems minimum for 75% to 100% Blend proportion at any load condition.
- At higher loads, Break mean effective pressure is highest for 50% Blend proportion. Peak pressure gradually increases with increase in Blend Proportion for 0% to 50% Blend at higher loads.
- At higher load 50% blend of Jatropha biodiesel with 50% diesel fuel has higher value of peak pressure than diesel fuel. There is a consistent decrease in peak IMEP with increase in blend proportion of Jatropha biodiesel.
- BTHE seems lower for Diesel Fuel and Higher for Blend Proportions with higher Jatropha biodiesel like 75% to 100%. So, thermal efficiencies are increasing with increase in blend proportion of Jatropha biodiesel in diesel fuel.
- Specific fuel consumption is maximum for Diesel Fuel than any of the Blend Proportion for lower and higher loads. Thus specific fuel consumption consistently decreases with increase in percentage of Jatropha biodiesel in diesel fuel.
- Increasing Blending ratio from 0% to 50%, gives positive impact on Mechanical Efficiency.It becomes almost constant from 40% to 60% proportion of Jatropha biodiesel.
- Using pure Jatropha biodiesel in place of diesel, we get maximum Mechanical Efficiency.

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