Influence of Fuel Injection Pressure on Performance of CIDI Engine using Rice Bran Oil Methyl Ester

Sirivella Vijaya Bhaskar, G. Satish Babu

Abstract— **In this research work, the main objective is investigate the effect of fuel injection pressure on the performance characteristics in terms of Brake Thermal Efficiency (BTE), Brake Specific Fuel Consumption (BSFC), and Exhaust Gas Temperature (EGT) of a single cylinder, 4-stroke, compression ignition direct injection (CIDI) engine when fuelled with Rice Bran Oil Methyl Ester (RBOME). The experimental results of diesel engine fuelled with different blends (B20R, B40R, B60R and B100R) of RBOME at different fuel injection pressures have revealed that neat biodiesel has lower BTE, higher BSFC, slightly higher BSEC and moderately higher EGT at all tested injection pressures. The biodiesel percentage in blend is affecting inversely proportional to performance characteristics. The performance characteristics are optimal at fuel injection pressure of 220 bar and it can be treated as optimum injection pressure to generate higher engine performance.**

Index Terms— **Biodiesel, Optimization, Taguchi Method, Exhaust Emissions, Design of Experiments**

I. INTRODUCTION

Biodiesel was identified as a potential alternative to petro-diesel fuel because plant based biodiesel and their diesel blends have diesel fuel like performance and emission characteristics. They are biodegradable, less toxic and easily available worldwide. Moreover, the biodiesel is an eco-friendly fuel which consists of fewer aromatic hydrocarbons, is less toxic and generates lower greenhouse gas emissions that contribute towards reducing global warming. The biodiesel production is a value addition to improve the rural economy by increasing the local employment [1]. In the biodiesel preparation the feedstock plays a major role in terms of cost and availability. The past research studies have identified many vegetable oils such as sunflower, jatropha, palm, rapeseed, safflower, soybean, and peanut oils etc., were recognized as suitable feedstock in many countries [2,3]. Several countries including USA, Australia, Canada, Germany, and Malaysia have already begun substituting the conventional diesel by a certain amount of biodiesel [5-7]. Vegetable oils can be directly used as fuel in diesel engine, but it is not preferable [4]. It contain free fatty acids (generally 1–5%), phospholipids, phosphatides, arotenes, tocopherols, sulfur compounds and traces of moisture [9]. Vegetable oils will have high viscosity that causes severe problems in diesel engines such as thermal cracking, chocking, injector fouling, etc. Further, it is very challenging to operate the engine in cold weather conditions due to poor flow of biodiesel fuel and its diesel blends [8]. The past research studies published that the biodiesel has slightly lower thermal efficiency and higher brake specific fuel consumption with superior lubricity [10, 11].

The previous research reviews have identified that many engine parameters such as compression ratio, injection timings, injection pressure and percentage of biodiesel content in fuel, diesel additives, and engine operating speed influence the performance and exhaust emissions of the diesel engine. Murthy et.al were conducted experiments using vegetable oil in a conventional diesel engine, which showed the deterioration in the performance, while LHR (Low Heat Rejection) engines showed improved performance, when compared to pure diesel operation on conventional engine. The increase in fuel injection pressure increased the engine efficiency and decreased emission levels of the engine [12]. Jindal et al., were evaluated the diesel engine fuelled with 100% Jatropha methyl ester for best performance and emission characteristics and concluded that a compression ratio of 18 and injection pressure of 250 bar were the optimum working conditions to run the engine without any compromise on engine performance and emission characteristics [13]. Raheman et al., have conducted performance analysis of Ricardo E6 engine using biodiesel obtained from neat Mahua oil and its blend with high speed diesel (HSD) at varying compression ratio (CR), injection timing (IT) and engine loading (L). The brake specific fuel consumption (BSFC) and exhaust gas temperature (EGT) increased, whereas brake thermal efficiency decreased with increase in the proportion of biodiesel in the blends at all compression ratios (18:1–20:1) and injection timings (35–45° before TDC) tested. However, a reverse trend for these parameters was observed with increase in the CR and advancement of IT. The BSFC of B100 and its blends with high speed diesel reduced, whereas BTE and EGT increased with the increase in L for the range of CR and IT tested. The differences of BTEs between HSD and B100 were also not statistically significant at engine settings of CR20IT40 and CR20IT45. Thus, even B100 could be used on the Ricardo engine at these settings without affecting the performance obtained using HSD [14]. Amba Prasad Rao et al., have investigated the effect of supercharging on the performance of a DI diesel engine and noticed a reduction in BSFC of about 15% when cottonseed oil used as fuel. It was reported that the performance deteriorated with increased injection pressure under naturally aspirated and supercharged conditions [15].

II. MATERIALS AND METHODS

The crude rice bran oil was collected from local vendor and biodiesel was prepared using transesterification process. As shown in Figure 1, in the transesterification process the triglycerides (vegetable oil/fat) which has three-long chain fatty acids reacts with methyl alcohol in the presence of a

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catalyst sodium hydroxide (NaOH) and produces methyl ester of oil which is called biodiesel and glycerol as by-product. After the transesterification process, the heavy glycerol will be separated and the light weight producer is left is a crude biodiesel. This crude biodiesel was purified prior to use in diesel engine.

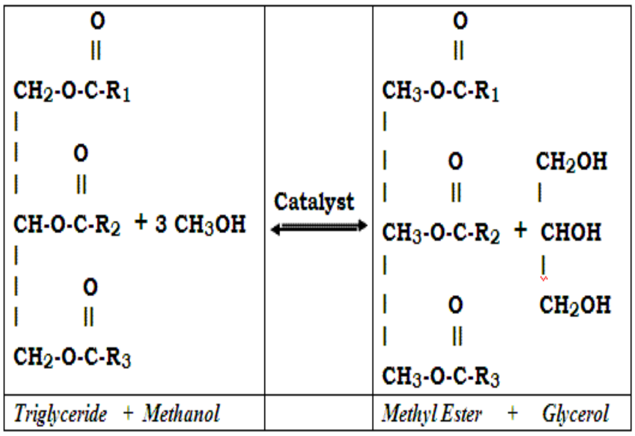

Fig 1.Transesterification Process

The properties of rice bran oil methyl ester which was separated after transesterification and mineral diesel were presented in Table 1.

Table 1. Properties of Diesel and Biodiesel

Fuel Property	Unit	ASTM Standards	Diesel	RBOME
Kinematic Viscosity @ 40^0C	CST	D445	3.52	5.36
Flash Point	^{0}C	D93	49	164
Density @ 15^0C	kg/m^3	D1298	830	880
Calofic Value	kJ/kg	D4868	42850	39230
Cetane Number	--	D613	50	52
Ash	% by mass	D1119	0.01	Nil

III. Experimental Setup

In this study, a single cylinder, 4-stroke water cooled compression ignition direct injection (CIDI) engine using rice bran oil methyl ester (RBOME) as fuel. The schematic diagram of experimental setup is shown in Figure 2 and the photographic view is illustrated in Figure 3. As shown in Figures the Kirloskar Engine is mounted on the ground and directly coupled to an eddy current dynamometer with suitable switching and control facility to apply the different engine load. After the engine reached the stabilized working condition, fuel flow rate was measured for each tested fuel and calculated BTE, BSFC, BSEC and EGT. The engine specifications are given in Table 2.

Table 2. Specifications of Test Engine

Engine Make:	Kirloskar AV1, India
Engine Details:	Single Cylinder, Four stroke, Water cooled
Bore & Stroke:	80 × 110 mm
Rated Power :	3.7 KW (5 HP) at 1500 rpm
Injection Pressure:	200 bar
Type of Injection:	Direct Injection
Compression Ratio:	16.5:1
Dynamometer:	Eddy Current

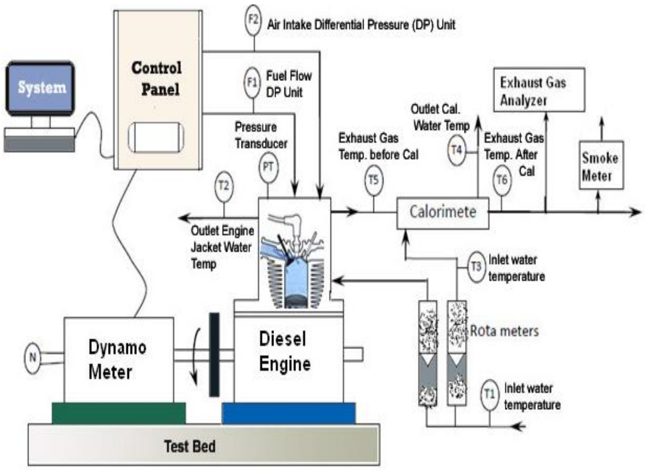

Fig. 2 Schematic Diagram of Experimental Setup

Fig. 3 Photographic View of Test Setup

IV. Results and Analysis

A. *Brake Thermal Efficiency (BTE)*

The variation of brake thermal efficiency with injection pressure at constant engine speed of 1500 rpm at full load condition is illustrated in Figure 4. As shown in graph, increase of BTE was observed from 200 bar to 220 bar of injection pressure and decreased at 230 bar and 240 bar of fuel injection pressure of the engine when fueled with rice bran oil methyl ester . The highest BTE was noticed at fuel injection pressure of 220 bar and can be considered as optimum injection pressure. The reduction of BTE was observed with the increase of biodiesel percentage in the blend. For increase of every 20% of the biodiesel content in the blend, an average of 6.87% decrease in brake thermal efficiency was observed with biodiesel when compared with diesel fuel. The rate of increase in brake thermal efficiency is higher at lower loads and low at higher loads.

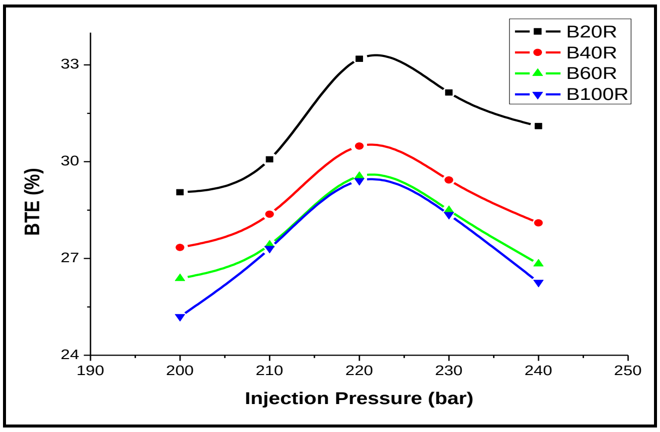

Fig 4. Injection Pressure vs. BTE for different blends

B. *Brake Specific Fuel Consumption (BSFC)*

Figure 5 shows variation of BSFC with fuel injection pressure of a single cylinder diesel engine at full load condition when rice bran biodiesel and its blends used as fuel. The higher BSFC observed at rated injection pressure of 200 bar and then gradually decreased from 200 bar to 220 bar and then raised slowly from 220 bar to 240 bar of injection pressure. The graph clearly indicated that the test engine's BSFC was affected by the biodiesel percentage in the blend. As percentage of biodiesel increases in the blend, the increase in brake specific fuel consumption was observed. The low BSFC was noticed at 220 bar of injection pressure. As the biodiesel content percentage increases in the blend, the BSFC also increased. The lower brake specific fuel consumption was observed with B20R blend of rice bran biodiesel and highest noticed with biodiesel in its neat form.

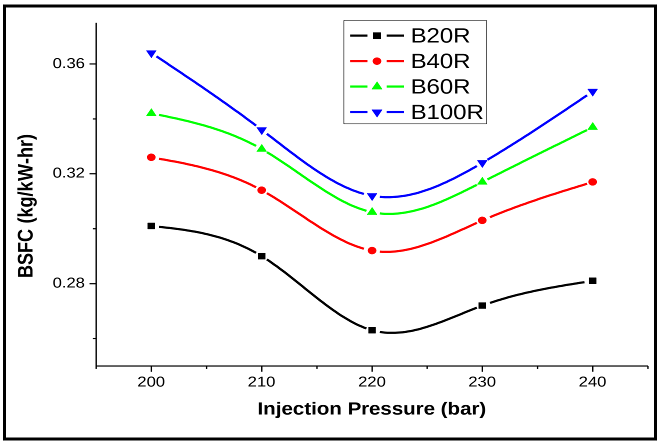

Fig 5. Injection Pressure vs. BSFC for different blends

C. *Brake Specific Energy Consumption (BSEC)*

Brake specific energy consumption (BSEC) can be defined as the energy required producing a unit power in unit time. Figure 6 illustrates the variation of BSEC with injection pressure for different blends of rice bran oil methyl ester (RBOME) biodiesel. The BSEC of the engine with neat rice bran biodiesel at all engine loads is higher and B20R biodiesel was lower when compared with all blends. This is because of the lower calorific value of biodiesel. For addition of 20% biodiesel content in the blend increasing the brake specific energy consumption (BSEC).

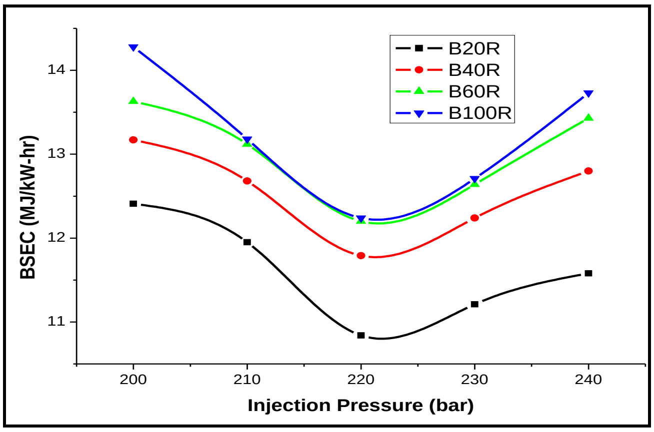

Fig 6. Injection Pressure vs. BSEC for different blends

D. *Exhaust Gas Temperature (EGT)*

The exhaust gas temperature (EGT) reflects the amount of energy used the engine by converting it into useful work, which in turn represents the engine's thermal efficiency. Figure 7 shows the variation of EGT with the injection pressure for different blends of rice bran biodiesel. B20 blend has lowest and rice bran biodiesel in its neat form has highest EGT when compared with all blends. EGT initially decreased from 200 bar to 220 bar and then increased, but 220 bar has lowest exhaust temperature. As biodiesel content in the blend increases, the EGT has increased.

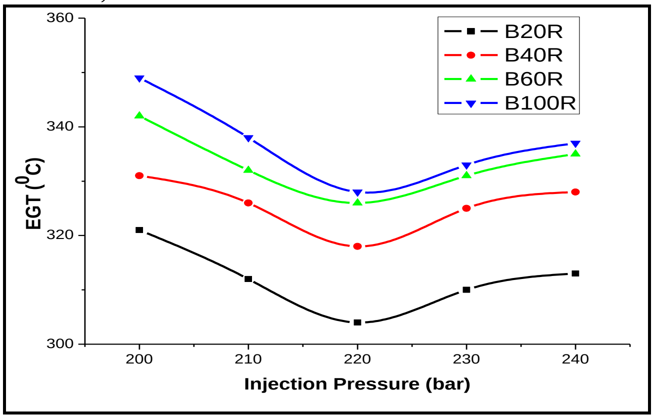

Fig 7. Injection Pressure vs. EGT for different blends

V. Conclusion

The experimental results of the present research work in a single cylinder, four stroke, water cooled diesel engine fuelled with different blends (B20R, B40R, B60R and B100R) of rice bran oil methyl ester (biodiesel) at fuel injection pressures of 200 bar, 210 bar, 220 bar, 230 bar and 240 bar at full load condition revealed that B20R blend has highest brake thermal efficiency (BTE), lowest BSFC, BSEC and EGT when compared with all blends of biodiesel. The optimum engine performance characteristics were found at 220 bar of injection pressures. The results have also shown that the BTE has decreased and the BSFC, BSEC and EGT increased with the increase of biodiesel percentage in the blend. The test results recommended that it is better to operate diesel engine at 220 bar of injection pressure to obtain higher performance that at rated injection pressure of 200 bar.

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