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A Numerical Study on the Effect of Engine Characteristics by Using Ethanol-moringa-diesel Fuel

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ABSTRACT

Environmental contamination has been increasing day by day due to increase in use of fossil fuel, therefore world is moving towards unconventional sources of energy generation. In this study, a diesel engine characteristic was analysed in a single cylinder, four strokes, water cooled, direction injection (DI) diesel engine by using two different fuel blends, one is non-edible oil (Moringa oleifera) and another one is alcohol (Ethanol) and operating at different engine load. Diesel engine characteristics were examined in terms of engine performance, emission and combustion characteristics by using Diesel-RK software and before that validate the numerical result with experimental result. The result shows that MB20 has reduction of 2.26%, 7.37%, 2.6%, 8.3% and 15.02% in BTE, EGT, Smoke emission, MRPR and NOX respectively and increases 8.9% and 12.34% in SFC and CO2 emission. The MBE20 has increased by 2.9% and 18.75% in SFC and CO2 emissions and decrease of 1.25%, 2.45, 5.44%, and 3.06% in BTE, EGT, MRPR and NOX respectively was found as compare to diesel fuel. In this paper, mixing various blends 20% of Moringa Oleifera biodiesel fuel with 20% of ethanol gives optimum blends ratio.

Keywords: Combustion; Diesel engine; Emission; Ethanol; Moringa oleifera; Performance analysis.

INTRODUCTION

The progress of nation depends on how much the nation is technologically fit. Maxi- mum energy fulfilled from fossil fuel like petroleum, natural gas and coal. In the field of automotive and agriculture industries diesel engine is widely used. Generally, it will transform chemical energy into mechanical energy [1, 2]. In diesel engine NOX and PM emission is a serious problem, and this will be a challenging task to reduce the emission [3]. Sulphur is the main constituent of acid rain and its presence in diesel cause fatal effect on environment as well as humans and other species [4]. The use of biofuel also includes many reasons such as environ- mental concern like climate change and depletion on fossil fuel. Due to good mixing characteristics of air and wide flammability limit and self-ignition temperature gaseous fuels are considered to be good for internal combustion engines. These properties enable it to operate with lean mixtures or higher compression ratio hence improving thermal efficiency and reducing emission like HC, CO2, NOX, SOX and particulate matter etc. These include natural gas, hydrogen, biogas, and other fuel constituted gaseous fuel are used in internal combustion engines [5]. Mofijur et al. [6] evaluated properties of Moringa biodiesel fuel at different speed at full load condition, and blends are 10% (B10) and 20% (B20) by volume and com- pare to diesel fuel. They have found that average reduction of brake power and BSFC is more as compared to diesel fuel. Blend fuel reduces hydrocarbon and carbon monooxide but increases nitric oxide slightly. M.M. Rashid et al. [7] checked the performance and emission characteristic of 20% Moringa oleifera biodiesel and compared the results of 20% Palm, 20% Jatropha biodiesel and 100% diesel. Here, Palm biodiesel has better result as compare to Moringa and Jatropha blend. This paper shows that brake power is lower at (6.92 to 8.75%) and BSFC is higher at

(5.42 to 8.39%) as compare to diesel fuel. U. Rajak et al. [8] described the paper numerically by using Diesel RK software and shows 9 different biodiesel characteristics after that result were compared with diesel fuel. Result shows less ignition delay as compared to diesel fuel, smoke and PM value decreases in biodiesel and with an increase in engine load SFC decreases. Kamel Bencheikh et al. [9] this article shows that the characteristics and performance of ternary biodiesel-diesel-propanol, biodiesel blend made from waste cooking oil. Result improved the BSEC, BSFC, and reduces exhaust gas temperature, smoke, CO etc. and also propanol has been added in diesel to improve cold flow properties, density, kinematic viscosity, and to maintain cetane number and high heating value. Datta A et al. [10] mixed alcohol (ethanol, methanol) in diesel fuel, and checked the performance and emissions by Diesel RK software and validate the experimentally. Result shows that higher brake thermal efficiency, higher specific fuel consumption and also reduction of NOX emissions. If separate use of ethanol 15% and methanol 15% are used in this paper and mix with palm oil then result shows that decrease in NOX emissions by 30% and 19% respectively. Alcohol blended biodiesel has peak pressure rise is lower. In this paper ethanol is mixed in diesel and moringa biodiesel by an amount of 20%. The blend fuel MBE20 (80% biodiesel- diesel and 20% Ethanol) are tested on single cylinder, four stroke, 17.5 CR, 1500 rpm, 23.5 injection timing and variable engine loading condition (25%, 50%, 75%, 100%) by diesel RK software. The engine behavior was studied for performance, combustion, emission parameter.

MATERIAL AND METHOD

As In the present research work, properties of moringa biodiesel fuel and its blends were taken from the previous published research article and it is shown in Table 1. In this investigation, diesel RK software is used to evaluate the effect of different biodiesel blends, analyse their engine behaviour in based on performance, emission and combustion by mixing 20% of moringa oleifera with 20% ethanol. Table 2 shows the specification of engine that is single cylinder four stroke, water cooled, Engine speed 1500rpm, injection timing 23.5˚ bTDC, compression ratio 17.5 and loading condition varies at 25%, 50%, 75% and 100% during simulation.

Table 1. Physio-chemical chattels of biodiesel, diesel ethanol and moringa [11], [8] & [13]

Properties	**Density (kg/m3)**	**Viscosity (mm2/s)**	**Calorific Value (MJ/kg)**	**Flash point (°C)**	**C (%wt.)**	**H (%wt.)**	**O (%wt.)**	**Cetane number**
Diesel (B0)	**829-850**	**2.87-3.63**	**41-45.36**	**56-76**	**86.1**	**13.8**	**0.1**	**52.4-59**
Moringa oleif- era biodiesel (MB100)	**859-866**	**4.03-5.05**	**39-40.6**	**162-189**	**76.7**	**12.5**	**10.8**	**54-56**
Ethanol (E100)	**789**	**1.15**	**27-32**	**12**	**52.2**	**13**	**34.8**	**5-7**

Table 2. Specification of Test Engine

Parameters	**Specification**
Engine	Single cylinder, four strokes
Fuel injection	Direct injection
Compression ratio	17.5:1
Cooling	Water cooled
Load	25%, 50%, 75%, 100%
Bore diameter	80 mm
Connecting rod length	235 mm
Dynamometer	Eddy current type
Injection timing	23.5° bTDC
Rated power	3.5 kW
Orientation	Vertical

UNCERTAINITY ANALYSIS

To retain accuracy of experiment uncertainty analysis must be performed. Instrument selection, calibration, environment, observation and operating conditions etc causes error in experiment. Linearized approximation method of uncertainty was used to determine (BSFC) brake-specific fuel consumption [6]. Percentage uncertainties of the device used in the experimentation was source for calculation of the percentage uncertainties of a variety of factor such as brake power, brake specific fuel consumption (BSFC), brake specific energy consumption (BSEC) and brake thermal efficiency (BTE) [12]. Total uncertainties are 1.56%. Table 3 shows the uncertainties of all measurement.

Table 3. Uncertainties in Engine

Instruments	**Abrasion of instruments**	**Type**	**Uncertainty (%)**
Temperature	TS	K	±0.1
Sensor			
Pressure sensor	PS	Kistler	±0.15
Speed sensor	SS	-	±0.1
Crank angle	CAE	-	±0.5
Encoder			
Load cell	LC	-	±0.2
Burette for fuel	BFM	-	±1
measurement			
Smoke	S	AVL437	±1
Exhaust gas		AVL Di	
Analyser		Gas 444	
CO2	-	-	±0.15
O2	-	-	±0.3

DIESEL RK TOOL VALIDATION

Conservation of mass

Rate of change mass across the boundary of the system are given in below equation

$$\frac{dm}{dt} = \Sigma_i m_i \quad (1)$$

Species conservation

The estimation of species has been given on the basis of mass fraction in equation.

$$Y_i = \frac{m_i}{m} \quad (2)$$

Conservation of energy

For an open thermodynamic system, a general energy equation can be given as

$$\frac{d(mu)}{dt} = -P\frac{dv}{dt} + \frac{dQ_{ht}}{dt} + \Sigma_i m_i h_i \quad (3)$$

Fuel consumption

BSFC of an engine is defined as fuel consumption per unit time per brake power. And mathematically given in equation

$$SFC = \frac{m_f}{P_b} \quad (4)$$

For evaluating brake mean efficiency pressure and brake power it is important to perform modelling of engine friction and losses associated with it. McAulay et al. [13] recommended that there is linear deviation of entire loss in solitary cylinder compression ignition engine among peak pressure in the interior of cylinder as well with piston speed. Diesel RK software gives all loses in conditions of frictional mean effective pressure

$$FMEP= \alpha+\beta P\_max+\gamma S\_p \quad (5)$$

Where α, β, γ are constant that are depends on engine geometry.

Heat release process is described in diesel RK software with help of multizone combustion model. Heat release rate is in four process i.e. delay period, controlled combustion period, premixed combustion period, and burning period model. Physical and chemical features of all four process are distinct but HRR is affected.

SIMULATION VALIDATION

The experimental result was accomplished on four strike diesel engines with single cylinder at the throttle valve fully open. The setup helps us to study the in-cylinder pressure, heat release rate at constant injection timing (23.5 bTDC), constant speed 1500 rpm and CR 17.5 with diesel fuel using diesel-RK tool for validation. Fig.1 (cylinder pressure) Fig.2 (heat release rate) is shows that result from experiment and from numerical has better concurrence. Due to variation in condition between the experiment and simulation theory, error deviation is observed in table 4. An error deviation of 1.68%was found for in-cylinder pressure and for 2.6% heat release rate with crank in this study, which can be clearly seen from graph (Figure 1 & 2).

Table 4. Experimental and numerical results at full load condition for tool validation

Parameter	Experimental	Simulation	Error Deviation
Cylinder pressure (bar)	85.578	87.047	1.68%
HRR (J/deg)	84.1	81.967	2.6%

RESULT AND DISCUSSION

PERFORMANCE CHARACTERISTICS

Specific Fuel Consumption

SFC of an engine is defined as fuel consumption per unit time per power. SFC and thermal efficiency are inversely proportional. Figure 3 shows variation of SFC at different load for different blends with diesel and diesel fuel. Biodiesel blends has more specific fuel consumption than diesel because of increase of amount of density, viscosity and injected fuel are increases [16, 17]. Result shows that with an increase in loading condition SFC decreases. The SFC was found to be more of MB20 than B0. The SFC for diesel B0, MB20, MBE20 at CR 17.5 and engine speed 1500rpm are found to be 248.19, 270.39, and 255.48 respectively at 100% load. Blend MBE20 at engine speed of 1500 rpm and 17.5 CR which is 2.9% more as compare to diesel fuel (B0) gives better performance.

Brake Thermal Efficiency (BTE)

Figure 4 shows that on increasing loading condition BTE increases. Biodiesel have lower BTE as compare to diesel because higher viscosity and lower density and less amount of oxygen and this will affects fuel atomization [18, 19]. It was observed from the simulation that the BTE for B0 ranges from 21.342% to 34.508% and for MBE20 ranges from 20.489 to 34.074% at 25% and 100% loading respectively. Blend MBE20 at engine speed of 1500 rpm and 17.5 CR which is 1.25% lesser as compare to diesel fuel (B0) gives better performance.

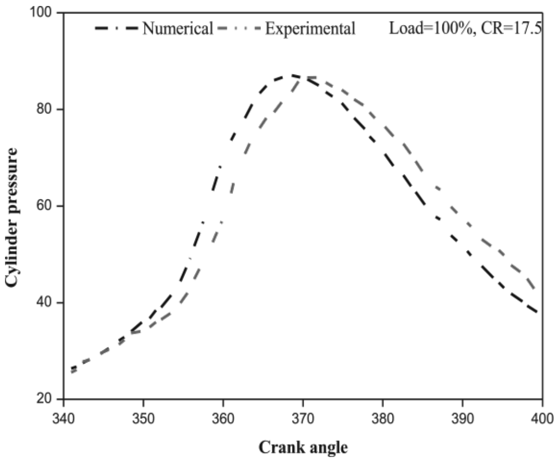

Figure 1. Validation of CP versus crank angle

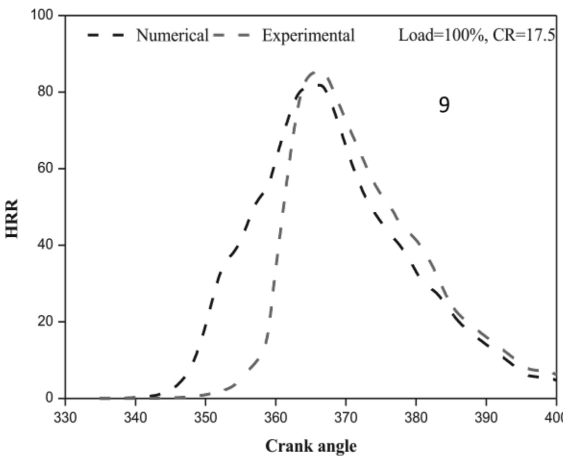

Figure 2. Validation of HRR versus crank angle

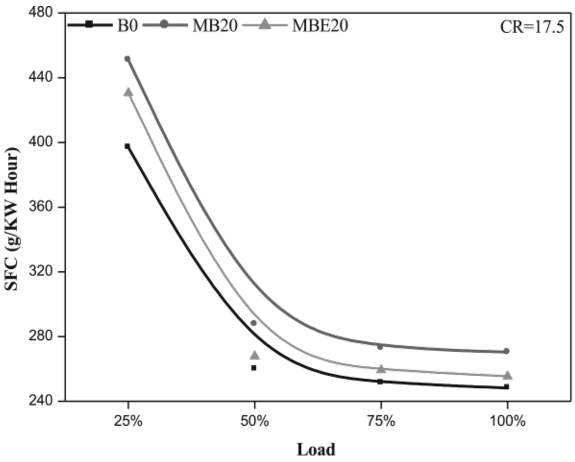

Figure 3. Variation of SFC with engine load

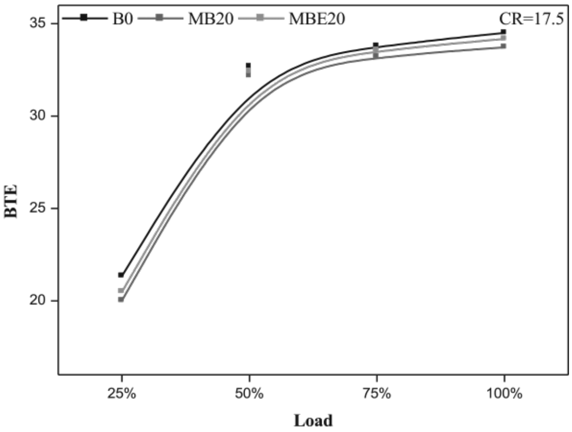

Figure 4. Variation of BTE with engine load

Exhaust Gas Temperature

EGT imitates the quality of combustion in engine cylinder. Quantity of oxygen in fuel has higher effect on EGT. To determine exhaust gas temperature ignition delay is important parameter. The longer the ignition delay longer is the combustion that results the higher EGT [20]. Figure 5 shows deviation of EGT with altered blends at various engine loads. Biodiesel and its blends having lesser EGT values for all load condition than diesel fuel, this is because of complete combustion of biodiesel fuel. EGT for B0, MB20, and MBE20 at CR 17.5 was found to be 760.87, 705.07 and 742.6. It is observed from the result that value of EGT of MBE20 and B0 are very near. The EGT was found to be reduced by 7.3% in MB20 and in 2.4% MBE20 as compared to B0.

COMBUSTION CHARACTERISTICS

Cylinder Pressure

Cylinder pressure is lower in biodiesel blends from those of diesel fuel because of small calorific value and higher viscosity. The change of cylinder pressure and certain crank angle at different loading condition are given in figure 6. The cylinder pressure of diesel fuel is higher than the biodiesel blend at 1500rpm and 17.5 CR. At 363˚CA cylinder pressure was found to be 85.3, 81.9, 84.3bar for B0, MB20 and MBE20 respectively. Cylinder pressure has lowered by 1.17% at B0 in MBE20.

Ignition Pelay

The changes in ignition delay with different loading condition (25%, 50%, 75%, and 100%) at 17.5 are shown in figure 7. It indicates that when load increases ignition delay decreases because of maximum heat generated before the cycle. Diesel fuel (B0) has maximum ignition delay as compare to biodiesel blends because in diesel fuel oxygen is more. The ignition delay for diesel fuel (B0) is 16.245, 15.282, 14.606, 14.105 at 25%, 50%, 75%, 100% respectively. Blends MB20 shows 14.326, 13.428, 12.852, 12.421 at 25%, 50%, 75%, 100% respectively and the optimum result is MBE20 that are 14.879, 13.973, 13.353, 13.065 at 25%, 50%, 75%, 100% respectively. Optimum result MBE20 was decreased by 7.37% as compare to diesel fuel at 100% loading condition.

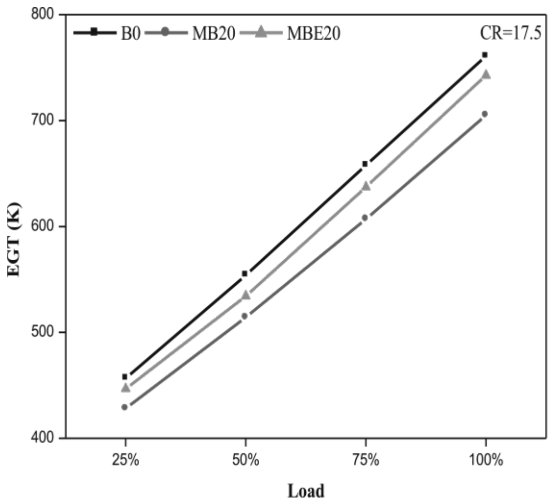

Figure 5. Deviation of EGT with engine load

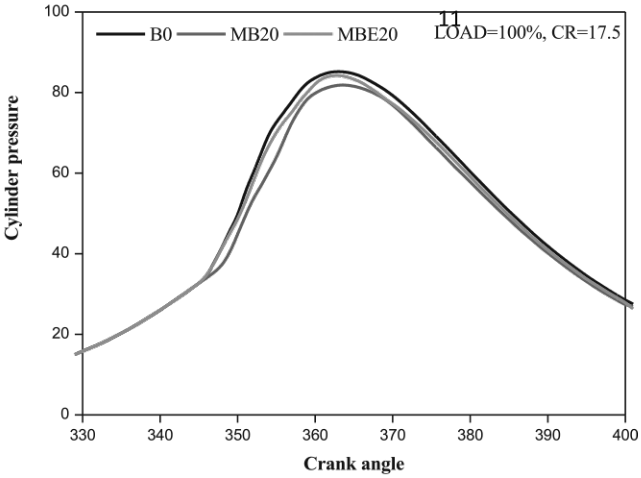

Figure 6. Deviation of cylinder pressure with crank angle

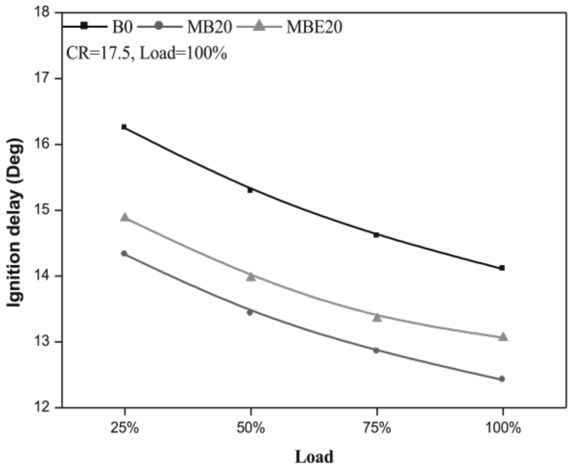

Figure 7. Variation of ignition delay with load

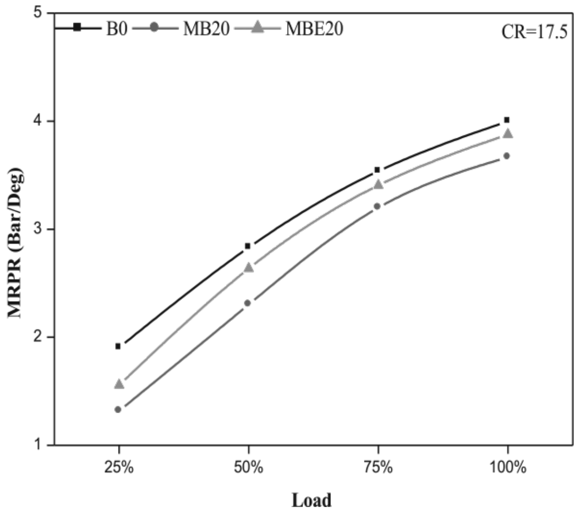

Figure 8. Variation of MRPR with load

Maximum Rate of Pressure Rise

Figure 8 shows the deviation of load against MRPR. At different load condition, the MRPR is increases when loading condition increases. It encourages an unwanted occurrence known as knocking [21]. Result was found to be about 14.105, 12.421, and 13.065 for B0, MB20 and MBE20 respectively at CR 17.5 with full loading condition. The MRPR was found to be 7.3% higher for B0 than MBE20 at CR17.5.

EMISSION CHARACTERISTICS

CO2 emission

Figure 9 shows altered engine loads for a mixture of tested fuel blends. Blended fuels have higher emissions as compared to pure diesel. For all loading condition, the CO2 emission of MB20 and MBE20 was found to be more than the B0. At 1500 rpm, 17.5CR and full loading condition the CO2 emission was observed to be 797.89, 896.41, 947.54g/Kw hour for B0, MB20 and MBE20 respectively.

NOx Emission

Alteration in NOx emission for the different diesel - biodiesel - ethanol blends are shown in figure 10. When load increases, emission of NOX increases because of increase in internal temperature of cylinder. Biodiesel blends are lower NOx emission as compare to pure diesel fuel. This is because of higher viscosity and lower calorific value. Pure diesel has NOx emission of 3088.6075 ppm and it is highest among the all tested fuel shown in figure 11. At full loading condition, corresponding values of MB20 and MBE20 are 2624.678 and 1987.423 ppm respectively. Almost for every case, on increasing loading conditions, NOx emission increases. More energy is released during combustion because increasing load requires more fuel.

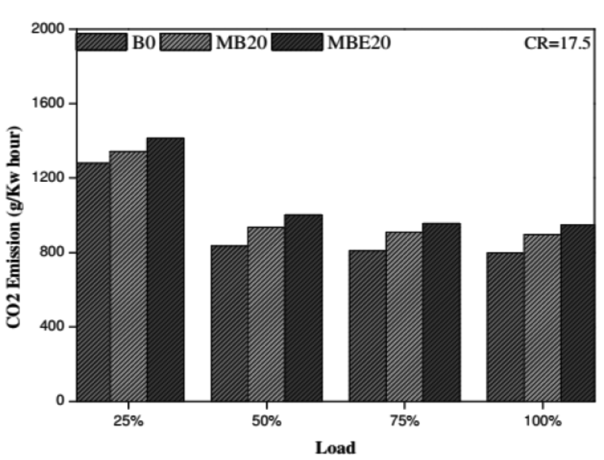

Figure 10. Variation of CO2 emission with engine load

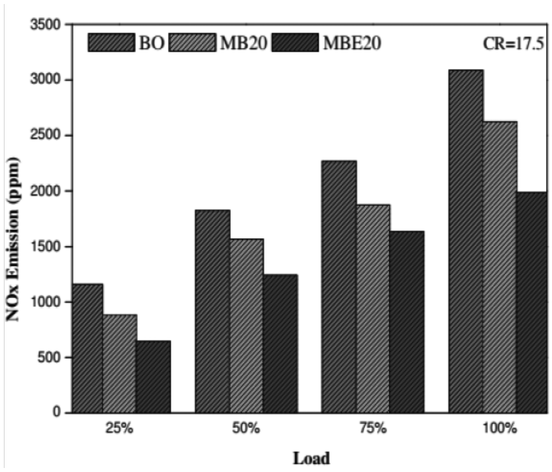

Figure 8. Variation of NOX with engine load

CONCLUSION

Following conclusions are drawn based on the performance, combustion and emission characteristics. Overall performance, combustion and emission characteristic of CI engine at different loading condition (25%, 50%, 75%, 100%) will be effected by varying properties of diesel and its blend fuel. At full load and at CR 17.5 blends MB20, MBE20 has higher SFC of about 8.9% and 2.9% respectively than that of diesel fuel. For all tested fuel, with an increase in loading condition, we have a decreasing pattern of SFC and most optimum result is obtained in MBE20 blend. EGT is higher for blends than diesel fuel for all loading condition. BTE is higher for diesel fuel than biodiesel blends (MB20 andMBE20). Ignition delay is decreases when load increases and minimum ignition delay has MB20 and maximum ignition delay is in B0. MRPR is decrease by 3.06% in MBE20 as compared to B0. By adding alcohols to biodiesel, NOx formation from biodiesel blend can be sorted, when 20% ethanol is mixed in biodiesel blend than NOx emission decreases by 35.6%. Future prospective can be focused on implementation of different blends by varying blends of alcohols and further comparing to blend characteristics with diesel fuel.

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