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Research Article

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Study of Emission Characteristics and Performance Analysis of Ethanol Diesel Blend

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Abstract

In the context of shortage of fossil fuel and environmental issue, this paper is aimed to determine the performance and emission characteristics of a variable compression ratio diesel engine fueled with the blends of diesel and ethanol (20% v/v-E20). It is observed that brake thermal efficiency (BTE) is about 18% when E20 is used as fuel and engine is operated at full load condition. Brake specific fuel consumption (BSFC) follows a reverse trend to BTE and, BSFC increases with increase in blend content of ethanol in diesel; BSFC for 20% v/v of ethanol-diesel blend is higher than diesel. However, beyond this ratio due to phase separation problem, ignition delay occurs, and hence incomplete combustion predominates and thus operation of the engine becomes difficult. Exhaust emissions (CO and NO_x) for blended fuel is found to be less (about 30%) than pure diesel and the reduction becomes more as ethanol concentration increases.

Keywords

Diesel engine, Ethanol, Emission, Performance characteristics, Variable compression ratio

Introduction

The capability and the capacity of a country to let its economy move competitively in all indexes has ignited the race of generating secure and cheap oil production since oil crisis and let the researchers to investigate over increasing the renewable content of petroleum-based diesel. As the society is getting prosperous, the demand of fossil at industries has increased which is depleting oil reservoir and impacting the environment with increase in pollutants.

Biofuels for diesel engine comprise of biodiesels from vegetable oils, animal fats and bioethanol derived from wet biomass containing sugar and starch. These biofuels can be used in its pure form or blended at different concentrations with diesel fuel. Ethanol blended up to 22% with diesel has better resonance with diesel engine, require no engine modification. There are many research works on biodiesel, some of works are presented here. Tongroon et al. [1] investigated feasibility to use ethanol in a compression ignition engine by blending diesel fuel with ethanol in 5%, 7%, and 10% v/v and found that with increase in ethanol concentration break power of engine decreases and emission of unburned hydrocarbon increases. Due to the increase in concentration of ethanol net heat value of fuel is reduced and ignition delay is increased. Gawale et al. [2] investigated the effect of change in mass flow rate of ethanol on dual fuel mode under varying load condition and concluded that ethanol can be the alternative fuel with lesser NO_x (nitrogen oxides), low smoke opacity and better fuel economy with lesser effect on brake power for higher load.

Zhu et al. [3] worked on performance and emission characteristics of ethanol-diesel fuel in a 4-cylinder diesel engine with varying load at maximum torque with engine speed of 1800 rpm and investigated that engine performance with 5% ethanol was good and with increase in concentration of ethanol in blend would increase the CO (carbon monoxide) and HC (hydrocarbon) emission, 5% ethanol has better emission. Gopal et al. [4] investigated the effect of preheating of intake air on performance and emission behavior of cottonseed oil biodiesel-ethanol blend in a CI engine and found preheating reduced the ignition delay, resulting in increase of brake thermal efficiency but with high intake temperature NO_x emission was increased. Ethanol in diesel pronounces different physical-chemical modifications like reduction in Cetane no., low heat content, pour point and flashpoint, etc. These changes affect combustion performance and emission characteristics of fuel. Torres-Jimenez et al. [5] investigated that using additives can avoid phase separation to a certain point of time and raise the flash point of ethanol-diesel blend with ethanol up to 15% v/v concentration. Cova-Bonillo et al. [6] analyzed that at low hydrated ethanol contains water acts as a reactivity inhibitor, probably associated with the endothermic effect of evaporation of the injection liquid. However, water acts as an auto-ignition enhancer, at higher concentrations of hydrated ethanol. De et al. [7] found that various parameters such as thermal efficiency, CO and NO_x emissions are very close to mineral diesel for lower blend concentrations of biodiesel. But it is observed that for higher blend concentrations and performance inferior to diesel. de Carvalho et al. [8] found that using diethyl ether with ethanol blend up to 5% acted as cetane improver for the ethanol-diesel blend fuel. Heidari-Maleni et al. [9] worked on grapheme quantum dot nanoparticles and ethanol biodiesel blend and investigated that adding grapheme quantum dot nanoparticles to blend has increased power and torque by 28.18% and 12.42%, respectively.

Diesel engines utilize only 30 - 35% of total energy content of diesel and rest is wasted of which 30 - 35% is wasted through exhaust gas. Hence exergy analysis is equally important. Agarwal et al. [10] investigated the exergy and energy analysis on biodiesel-diesel-ethanol blends in diesel engine and found that, engine running on pure diesel has higher entropy generation with respect to engine working with 5% blend of ethanol. From the above research works it is realized that performance and emission characteristics of ethanol-diesel blend has many limitations due to its physical and chemical characteristics for higher blend percent. It is found that the problem of phase separation dominated after 15% v/v ethanol blend with diesel. This research work focuses on the compatibility of 20% v/v of ethanol in diesel. In present paper performance and emission characteristics of ethanol-diesel blend is investigated on a 3.4 kW engine coupled with an eddy current type dynamometer for different loading condition. This research work is done with the objective of detecting maximum possible replacement of diesel by ethanol in order to have enhanced performance and emission control.

Table 1: Physical and chemical properties of diesel and anhydrous ethanol [11].

Properties	Diesel	Ethanol
Formula	C_xH_y	C_2H_5OH
Mole Weight	190 - 220	46.07
Density at 20 °C (g/m³)	0.829	0.789
Boiling Point (°C)	180 - 360	78.4
Pour Point (°C)	-1.00	-117.3
Flash point (°C)	65 - 88	13-14
Viscosity (mPaS)	3.35	1.2
Heat Content (MJ/kg)	42.5	26.8
CN	45-50	5.8

Materials and Methods

The experiment was conducted on a constant speed CI engine (Kirloskar) at NIT Sikkim IC engine laboratory. In table 2 research engine specification is framed. The engine is directly coupled to a dynamometer (eddy current type) of maximum 16 kg load capacity. In this research work diesel is blended with ethanol (absolute AR ACS for analysis Fisher chemical CAS: 64-17-5) in the ratio of 20% v/v. Ethanol-diesel blend of 20% v/v is supplied to the engine and the performance with emission characteristic is measured at different loads. The procedure is repeated for pure diesel and then they are compared. Property of ethanol and diesel is compared in table 3. The temperature at all the ends mentioned in figure 1 is measured by PT100 K type thermocouple to analyse exergy. Flow of water into the setup is made by 0.5 HP Kirloskar pump and flow rate in cylinder jacket and exhaust calorimeter is measured by rotameter. The amount of pollutant at exhaust end is measured by fuel gas analyser connected to computer at different loads. The Schematic diagram of research engine setup is shown in figure 1. Additionally pictorial view of the

Table 2: Research engine specification.

Parameter	Value
No of cylinder	1
No of stoke	4
Cylinder diameter	87.5 mm
Stroke length	110 mm
connecting rod length	234 mm
Orifice diameter	20 mm
Dynamometer arm length	185 mm
Power	3.5 kw
Speed	1500 RPM
CR range	12:1 to 22:1
Injection point variation	0 to 25° BTDC

Table 3: Exhaust gas analyser specification.

Pollutant	Range
CO	0 - 15.5%
CO_2	0 - 21%
HC	0 - 20000 ppm

research engine setup is shown in figure 2 and figure 3, respectively. In figure 1, T_1 and T_2 is temperature of water at inlet of engine and exhaust calorimeter, T_2 and T_4 is temperature of water at exit of engine jacket and exit of calorimeter, T_5 and T_6 exhaust gas at the inlet and exit of calorimeter, EGA: exhaust gas analyser, PC: computer.

Results and Discussion

Engine performance and exhaust gas emissions are measured at 4 kg, 8 kg, 12 kg, and 16 kg loads. Parameters like BSFC, BTE, exhaust gas temperature, CO and NO_x are plotted with respect to different loads are obtained and presented in the following sub-sections.

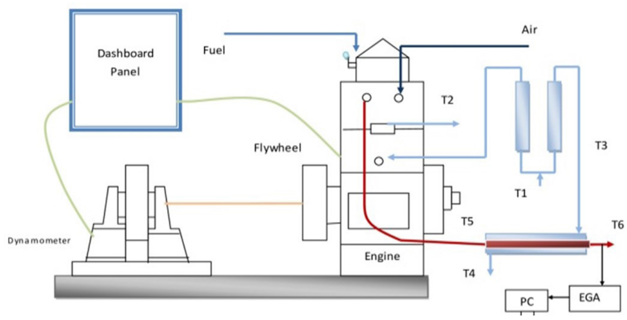


Figure 1: Schematic diagram of experiment setup.

Figure 2: Pictorial view of variable compression ratio engine.

Brake specific fuel consumption

The Variation of BFSC with load for ethanol blended to diesel with 20% v/v (E20) and pure diesel (D100) are shown in figure 4. BSFC is the fuel consumed per unit production of brake power. The BSFC trend seems similar for both E20 and D100; the variation of BFSC of E20 with respect to D100 is from 5% to 13% at different loading condition. BSFC for the E20 is higher due to small energy density of ethanol as compared to pure diesel.

Brake thermal efficiency

Figure 5 represents the variation of BTE with load of pure diesel (D100) and 20% v/v ethanol-diesel blend (E20).

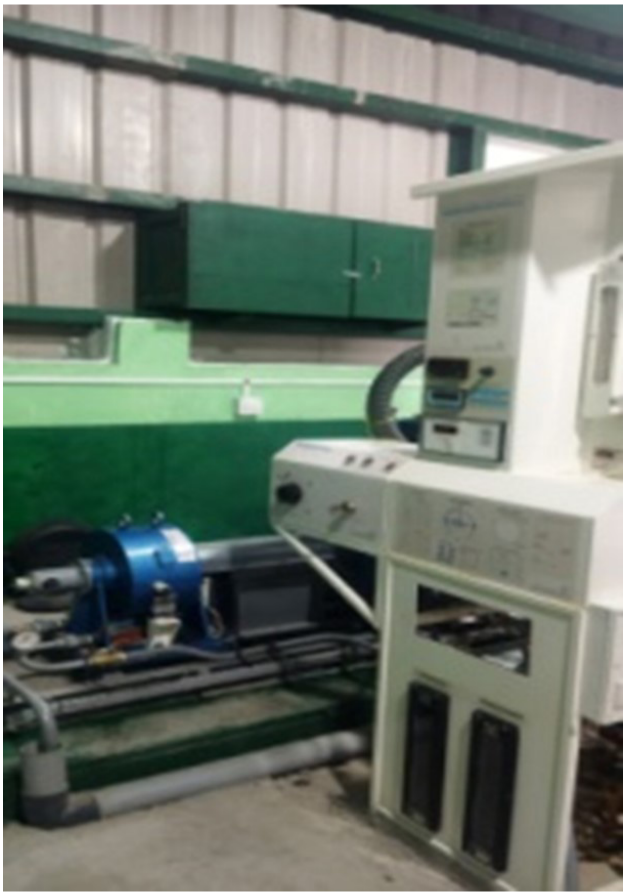


Figure 3: Pictorial view of loading and measuring unit.

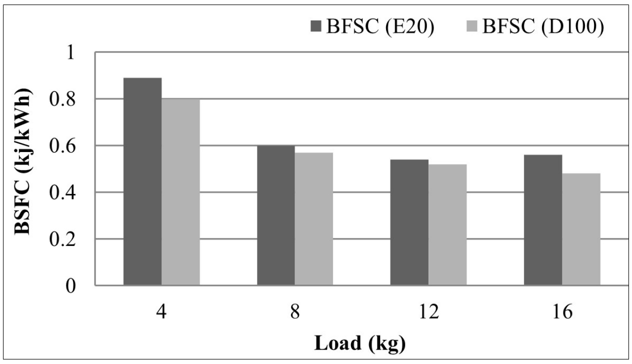


Figure 4: BSFC of E20 and D100 at various loads.

Maximum BTE of 23% was observed for pure diesel at 12 kg load and for 20% blended ethanol-diesel (E20) fuel BTE was around 17% for same load. Reduction in BTE is observed due to higher BSFC of E20 fuel. In general, with the increase in ethanol content in diesel BSFC increases. It is observed that beyond 75% load BTE reduces, it is due to increase in incomplete combustion of fuel.

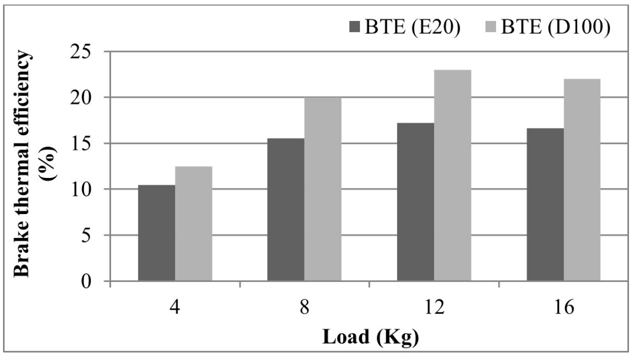


Figure 5: BTE of E20 and D100 at various load conditions.

Exhaust gas temperature

A relation between exhaust gas temperature at various loads for pure diesel and 20% v/v blend of ethanol-diesel is plotted in figure 6. Due to the presence of more OH radicals in ethanol blend fuel with respect to pure diesel exhaust temperature of ethanol blend fuel is low. Lower calorific value could be also a reason for this trend. That is with increase in oxygen content means increase in ethanol content in diesel and hence with increase in ethanol content in diesel will reduce the exhaust gas temperature.

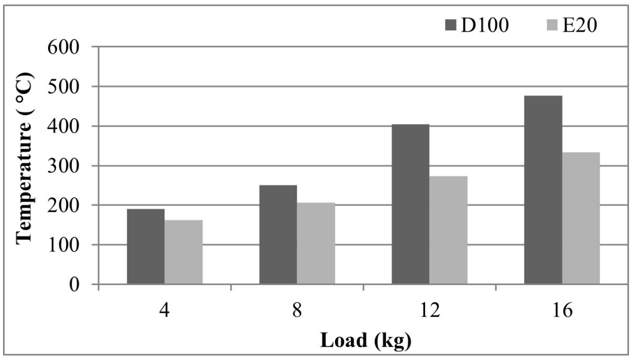


Figure 6: Variation of Exhaust temperature at various loads.

Exhaust emission

CO and NO_x emission were measured by ATS-206A exhaust gas analyzer. Figure 7 represents the variation of CO emitted at different loads for ethanol blend diesel (E20) and pure diesel (D100). Trends show that with the increase in load CO emitted by E20 is quite lower than the pure diesel. Increase in ethanol content in diesel reduces the carbon content in the blend, as diesel belongs to the higher carbon chain compound mentioned in table 3. And also, with increase in ethanol content oxygen to fuel ratio in blend increases this result in complete reaction comparatively.

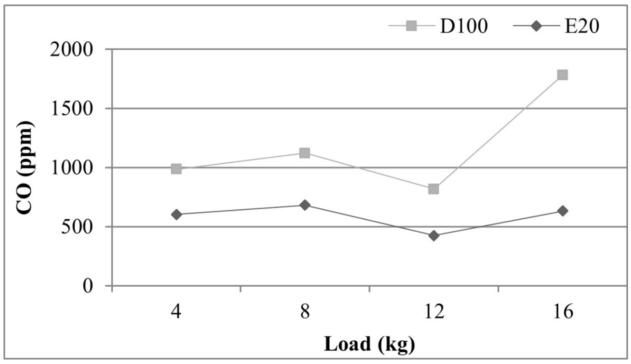


Figure 7: Variation of CO emission with engine load.

Figure 8 represents the variation of NO_x emission at different load condition for 20% v/v ethanol blended with diesel (E20) and pure diesel (D100). From the figure it is evident that with the increase in load NO_x emission increases for all fuels. This is due to the tendency of nitrogen to break into individual atoms at higher temperature and then get oxidized. The exhaust temperature of ethanol blend fuel is less as compared to pure diesel, so inducing ethanol in diesel will reduce NO_x emission.

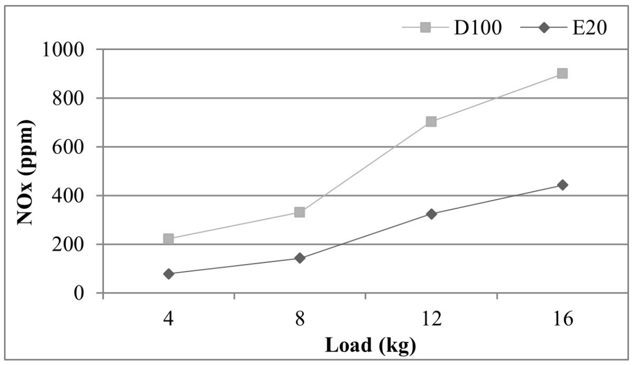
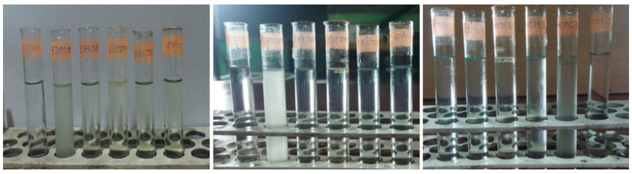


Figure 8: Variation of NO_x with load for pure diesel and ethanol-diesel blend fuel.

Phase separation

Figure 9 represents the pictorial view of different blend, from left to right pure ethanol (E100), 20% v/v ethanol in diesel (E20D80), 15% v/v ethanol in diesel (E15D95), 10% v/v ethanol in diesel (E10D90), 5% v/v ethanol in diesel (E05D95) and pure diesel (D100). Figure 9a Represents initial mixture of different blend at temperature (290 K). At same ambient temperature the mixture was observed after 10 minutes and 50 minutes. It was found that E05D95 and D100 still remained the same with no change. E20D80 blend turned into whitish fluid after 10 minutes. Figure 9c represents 25% of the blended ethanol in E20D80 was separated in 36 minutes, 13% of 15% v/v ethanol in E15D85 is separated in 50 minutes, 10% of ethanol in E10D100 got separated in 3 hours, E05D95 was still stable after 5 hours. Addition of 1% of diethyl ether doubled the phase separation period. Diesel is non-polar in nature while ethanol is polar in nature, a polar and non-polar compound cannot be soluble. So, they require a third compound



(a) (b) (c)

Figure 9: Pictorial view of different blends at 290 K for **(a)** 0, **(b)** 10, and **(c)** 50 minutes.

having the nature of holding both the polar and non-polar compound. Here diethyl ether plays similar characteristic.

Conclusion

This research work was conducted to investigate the variation of different performance and emission characteristics of diesel blended with 20% v/v of ethanol with respect to pure diesel and foresight that BSFC of ethanol–diesel blend increases due to low energy density of ethanol in comparison to pure diesel. As the carbon content of fuel decreases the BTE also decreases, therefore instead of 20% v/v ethanol blend lower v/v concentration of fuel can be used with effective additives to avoid phase separation and ignition lag. Emissions (CO and NO_x) are lower, as compared to pure diesel. But increases as the load is increased. Exhaust gas temperature increases with the load but is lower as compared to pure diesel. This is due to the presence of more OH radicals and lower energy density of ethanol. Analyzing the results obtained from 20% v/v of ethanol in diesel, obtained results can be improved with additives. Once the problem of phase separation and ignition lag is improved it can replace the diesel with same amount. Further this result can be improved with addition of emulsion and additives and also injection of ethanol and diesel separately in the chamber.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Credit Author Statement

AK Singh: Experimentation, Data analysis, Writing - original draft preparation; VP Mishra: Experimentation, Data analysis, Writing - Original draft preparation; S Barman: Conceptualization, Formal analysis, Writing - review and editing, Supervision; K Tiwari: Formal analysis, Writing - review and editing, Supervision; P Mondal: Conceptualization, Formal analysis, Writing - review and editing, Supervision; N Barman: Formal analysis, Writing - review and editing, Supervision. All the authors read and approved the manuscript.

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