An Experimental Study of Emission Characteristics in Compression Ignition Engine with Diesel – Ethanol Blend Using Surfactant

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***Abstract*— Blending of diesel and ethanol is a one of the auspicious method for producing ultra-low oxides of nitrogen and smoke emissions in compression ignition engines. To attempt this, single cylinder four stroke compression ignition engine of rated power 3.7 kW has been used at various load conditions like 25%, 50%, 75% and 100% of maximum load. In this present work, ethanol is blended with diesel at various percentage in volume like 5%,10%,15% and 20% by using span 80 and tween 80 surfactant. From the result of experimental work, there was a reduction in formation of oxides of nitrogen up to 43% at full load condition with E20 and 30 % reduction in smoke at same operation condition for 3% surfactant. There was a noticeable raise in hydrocarbon and carbon monoxide emission due to low temperature combustion by ethanol.**

***Keywords*— Ethanol, Emission, Surfactant, span 80 and tween 80, Diesel-ethanol blend**

I. Introduction

A definitive focus of emission regulation is to push technology to a point where a systematic, inexpensive zero emission vehicle with adequate performance turns into existence. Thus, the majority of vehicle research and development work assets are as yet being connected to the IC engines. Much research has done on IC engine to enhance performance and reduce exhaust emissions. Some of the researches are piston geometry change, catalyst material coating on piston and cylinder, adding additives in fuel, Dual fuel combustion, HCCI combustion, PCCI combustion, alternate fuels to achieve above target. Using of alternate fuel is one of the promising methods to reduce exhaust emission and to enhance the performance of the engine. Ethanol up to 20% added with biodiesel produce ultra low emission and consumes less fuel compare to conventional diesel engine combustion [1]. This alternate fuel has high latent heat of evaporation compared with gasoline which contributes cleaner combustion at various fuel ratios to produce high thermal efficiency [2]. Bio ethanol blend with diesel in compression ignition engine provides low combustion temperature which leads to lower oxides of nitrogen emission [3]-[5]. Different reactive fuels injected at various point and timing also can reduce emissions of IC engine. Low reacting fuel like ethanol injected at the port of the engine during suction stroke and high reactive fuel like diesel injected directly into the combustion chamber at the end of the compression stroke leads to mix inside the cylinder and combustion is purely begins by diesel. This method provides ultra low NOx and smoke [6]. Emulsion of fuels is one of the popular methods to reduce emissions. Emulsification of ethanol and diesel is only stable at room temperature. Separation occurs at various operating temperature due to its difference in surface tension between the fuel layers. Surfactants are used to blend two immiscible fuels irrespective of operating temperature and surface tension difference. Micro emulsion of bio oil with diesel in compression ignition engine with span 80/tween 80 hydrophobic surfactant provides good results in emission control. There was nearly 66% of CO emission reduction, 27% of CO_2 reduction and 15% of oxides of nitrogen emission at full load condition. On other hand smoke density was increased compared to conventional method [7]. In this experimental work, emission characteristics of compression ignition engine were examined with diesel blended with various percentage of ethanol in volume using surfactant.

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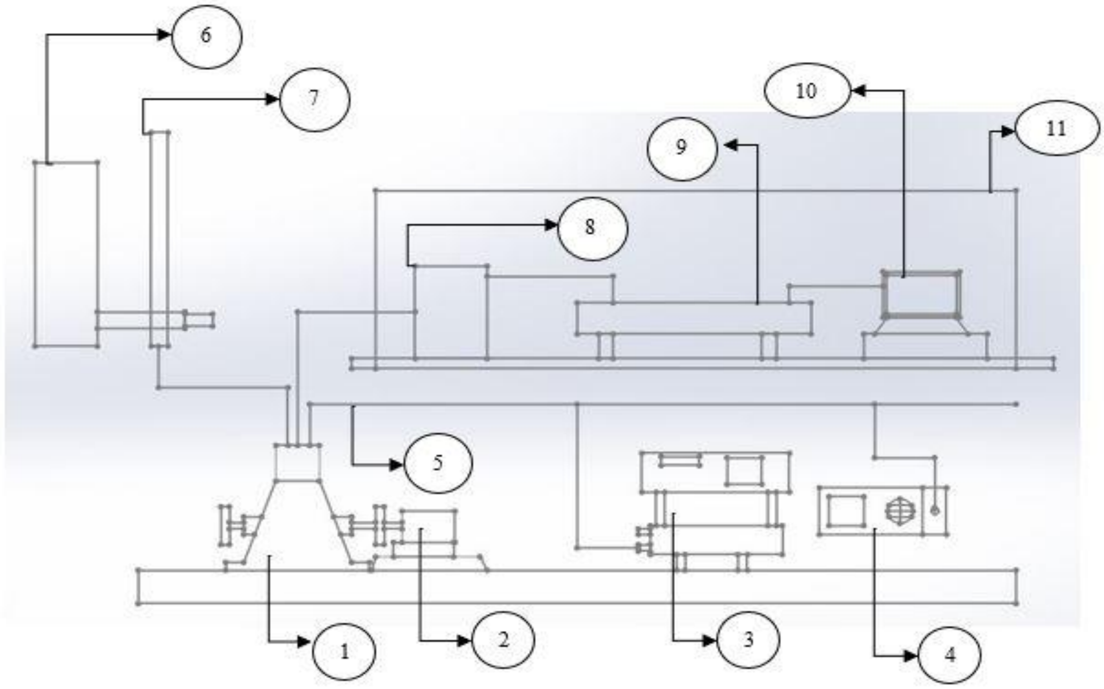
II. Experimental setup and Procedure

In this experimental work, single cylinder four stroke water cooled direct injection compression ignition engine with electrical loading is used for emission characteristic analysis with diesel and ethanol fuel blends. Ethanol is mixable with diesel only at room temperature. It’s getting separated when temperature drops. To overcome this, additives or surfactants were used to blend two immiscible fuels which reduce surface tension between the fuel layers.



. Fig. 1 Experimental Setup

1. *Engine*
2. *Electric Dynamometer*
3. *Smoke Meter*
4. *AVL DI Gas Analyzer*
5. *Exhaust Pipe*
6. *Fuel Tank*

A. *7. Burette*
B. *8. Charge amplifier*
C. *9. Indimeter*
D. *10. Monitor*
E. *11. AVL combustion analyzer*

Span 80 and Tween 80 mixture of 3% in volume were used as a surfactant to blend ethanol with diesel. 3.7 kW brake powered, single cylinder four stroke water cooled conventional diesel engine with electrical loading setup is shown in figure 1.1. Mechanical injector with nozzle opening pressure of 250 bar was used for fuel injection. Engine operates at constant speed of 1500 RPM with all engine operating loads. Engine specifications are shown in the table 1.

TABLE I

Engine Specifications

Engine make	Kirloskar
Number of cylinder	1
Bore	87.5 mm
Stroke	110 mm
Rated Power	3.7 kW
Speed	1500 RPM
Compression Ratio	17.5:1
Cooling System	Water Cooled
Dynamometer Type	Electrical
Injection Timing	23 deg before TDC
Nozzle opening pressure	250 bar

The fuel mass flow rate was measured using burette and stop watch arrangements. Engine exhaust emissions like NO_x (ppm), CO (% by volume) CO2 (% by volume) and HC(ppm) were measured by using AVL 444 die gas analyzer. Smoke density was measured by using an AVL 413 Smoke meter. Thermocouple was used for exhaust gas measurements. Engine cranked with conventional diesel fuel and allowed to run for 30 minutes to become steady state operation. Bench test readings were taken with neat diesel for a constant speed of 1500 RPM at various load conditions.

The same set of procedure was also repeated for various ethanol–diesel blends at constant speed of 1500 RPM. Test results were used for calculations. The various fuel blends were prepared for analysis. Conventional diesel of 92% blended with 5% of ethanol in volume (E5). Fuel and surfactant properties were listed in table 2 and 3.

TABLE II

Physico-chemical Properties of fuels

Properties	Diesel	Ethanol
Density at 15ºC (kg/m^3)	829	789
Kinematic viscosity (cSt) at 40ºC	4	1.20
Flash Point in ºC	74	13
Cetane Number	45	6
Calorific Value kJ/kg	44600	26600

TABLE III

Physico-chemical Properties of surfactant

Properties	Span 80	Tween 80
Density at 15ºC (kg/m^3)	994	1060
Molar mass, g/mol	428.6	1310
Hydroxyl value, mg of KOH/g	193-210	65-85
HLB value	4.3	15.0
Content in 10 HLB (%)	46.7	53.3

Fuel emulsion process is shown in figure 2. Fuels mixed with surfactant at various percentages in volume using magnetic stirrer at the rate of 800 RPM, 40ºC for 10 minutes. Conventional diesel of 87% blended with 10% of ethanol in volume (Referred as E10). Conventional diesel of 82% blended with 15% of ethanol in volume (Referred as E15). Conventional diesel of 77% blended with 20% of ethanol in volume (Referred as E15). For all above blends 3 % of span 80 and tween 80 mixer were used in volumemetric basis.

Fig. 1 Ethanol – Diesel Blend Preparation

III. Result and discussion

Emission test were carried out in compression ignition engine with diesel-ethanol blend for various loads with constant speed of 1500 RPM.

A. *Oxides of Nitrogen Emission*

Effect of ethanol blend with diesel on oxides of nitrogen emission for various load condition is shown in a figure 3.

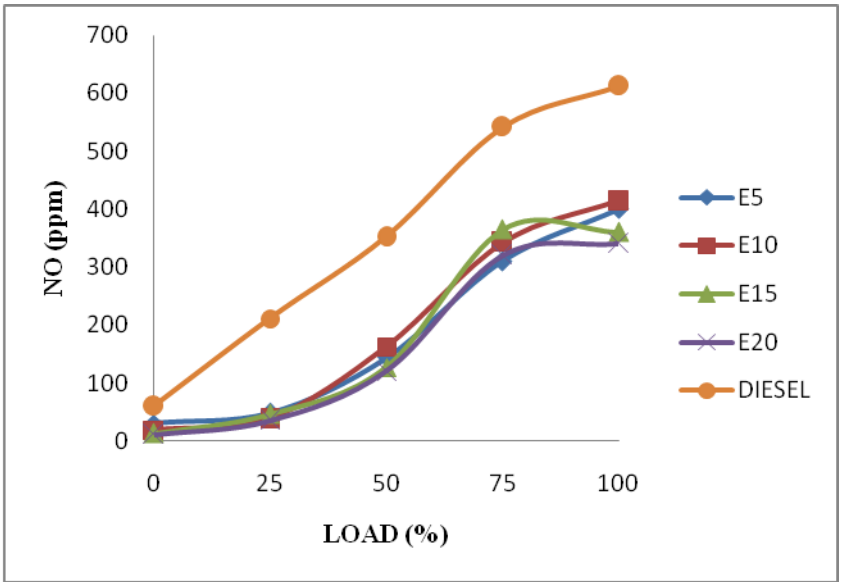


Fig. 3 Variation of NO_x emission with respect to change in load

The result shows that oxides of nitrogen emission level is very low compare to conventional diesel and also increase in percentage of ethanol drags the emission level to bottom. The reason for blending low reactive fuel like ethanol was to reduce the in-cylinder temperature by absorb the latent heat of surrounding air which cases low temperature combustion. This mechanism reduces the reaction nitrogen with oxygen to form oxides of nitrogen. At full load condition, nearly 45% of reductions in oxides of nitrogen emission for E20 blend.

B. *Smoke Emission*

Effect of blend with diesel on smoke emission for various load condition is shown in a figure 4.

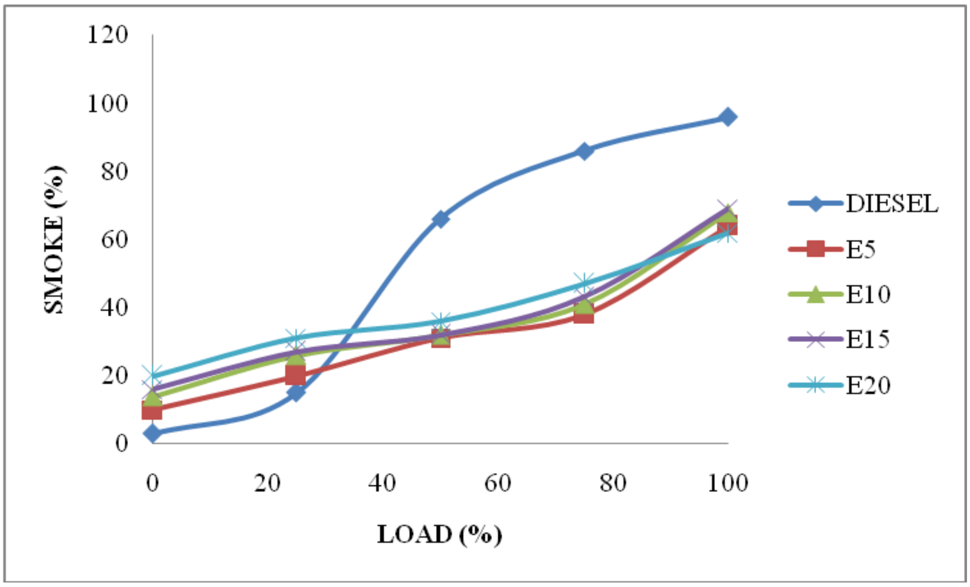


Fig. 4 Variation of Smoke emission with respect to change in load

Smoke form during combustion is mainly due to improper mixing of fuel and air, low in-cylinder temperature with less oxygen concentration. Ethanol is a high volatile fuel and it easily vaporize by absorbing heat from surrounding air during suction stroke itself. It also has oxygen content by own and produce pre-cooling which increase the density of air for fuel utilization. The surfactant used to increases the delay period for peter mixing. This causes increases in delay period for quicker combustion. At full load condition, nearly 27% of reductions in smoke emission for E20 blend.

C. *Hydro Carbon Emission*

Effect of ethanol blend with diesel on unburnt hydrocarbon emission for various load condition is shown in a figure 3.

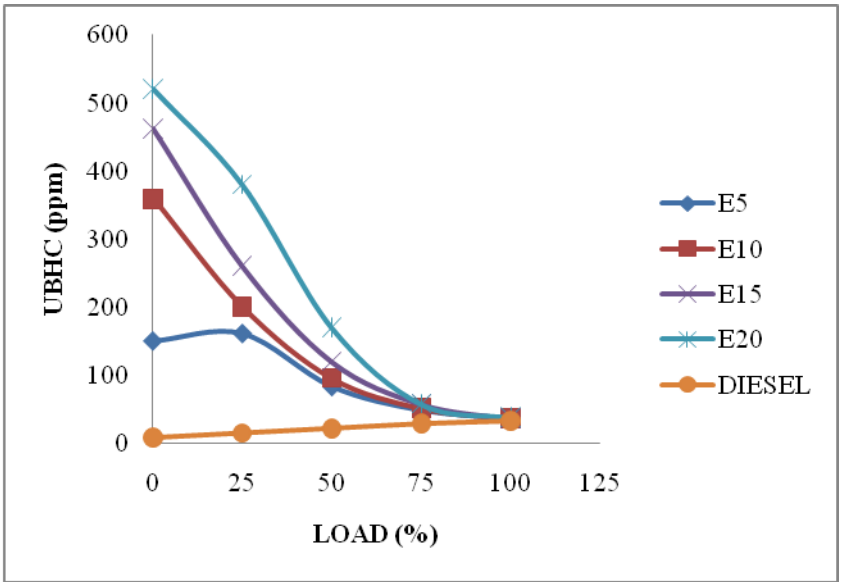


Fig. 5 Variation of hydro carbon emission with respect to change in load

Hydrocarbon emissions level was higher in ethanol-diesel blend combustion compare to conventional diesel operation. This was purely due to lower in-cylinder temperature caused by high latent heat property of ethanol. HC level increases with increase in blending ratio at no load condition and gradually decrease with increase in load due to increase in temperature at high operating loads.

D. *Carbon Monoxide Emission*

Effect of ethanol blend with diesel on carbon monoxide emission for various load condition is shown in a figure 5.

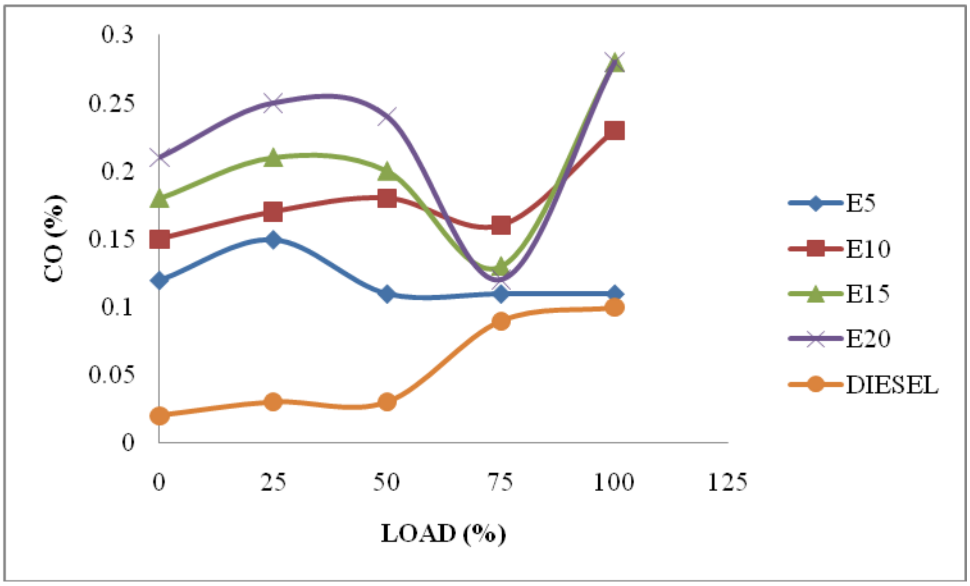
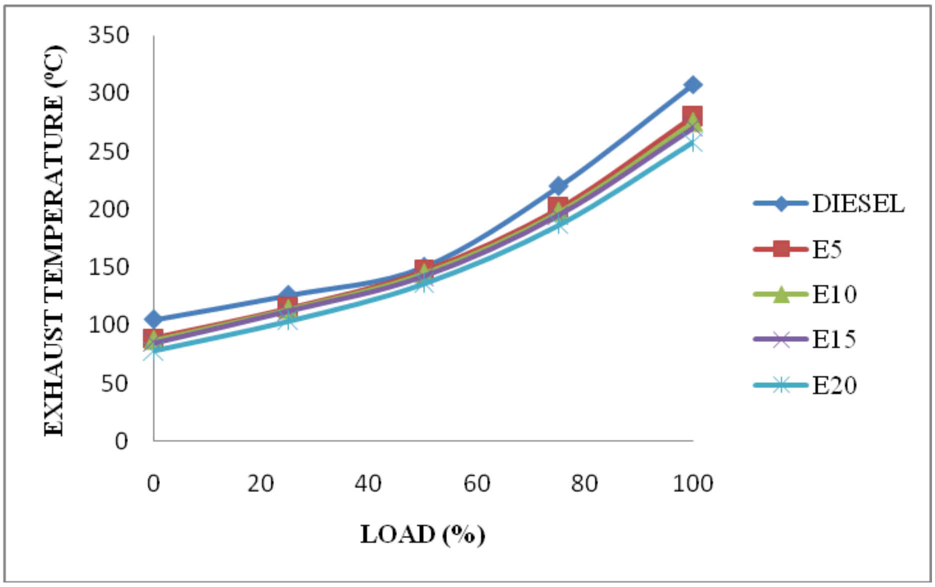


Fig. 5 Variation of carbon monoxide emission with respect to change in load

Carbon monoxide level was increases with increases in blending ratio irrespective of all load conditions due to lower in-cylinder temperature and less oxygen availability caused by ethanol.

E. *Exhaust Gas Temperature*

Effect of ethanol blend with diesel on carbon monoxide emission for various load condition is shown in a figure 5.



In this research work, it is noted that exhaust gas temperature was increases with increase in operating load condition and decreases with increase in ethanol blending ratio. High latent heat of vaporization of ethanol produce low temperature combustion which causes lower exhaust temperature compare to conventional diesel combustion.

IV. CONCLUSIONS

The emission characteristics of single cylinder four stroke water cooled direct injection compression ignition engine for various ethanol-diesel with surfactant blends were studied. The salient points of this experimental work are listed below.

- The oxide of nitrogen (NO_x) emission was lower for E20 compared to conventional diesel and others blends. This was due to high latent of vaporization ethanol which pre-cooled surrounding air.
- The smoke density also low for E20 compared with other blends due to increase in ignition delay and better mixing.
- Hydrocarbon (HC) and Carbon Monoxide (CO) emissions were higher for E20 compared with all blends due to low temperature combustion.
- Exhaust gas temperature decreases with increase in ethanol blend due to low temperature combustion.

This experimental results show that E20 blend with surfactant can be effectively used as an alternate fuel for direct injection diesel engine.

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