Hexanol-Ethanol Diesel Blends on DI-Diesel Engine to Study the Combustion and Emission

A.P. Sathiyagnanam, C.G. Saravanan and M. Gopalakrishnan

Abstract -- **Hexanol was added in ethanol – diesel fuel to prevent separation of ethanol from diesel in this study. The ethanol blend proportion can be increased upto 45% in volume by adding the Hexanol. Engine performance and emissions characteristics of the fuel blends were investigated on a diesel engine and compared with diesel fuel. Experimental results show smoke emission decreases significantly with the increase of oxygen content in the fuel. When blended fuels are used, nitrogen oxides (NOx) emission is almost the same as or slightly higher than the NOx emission when diesel fuel is used. Cylinder pressure and Heat release are slightly increased when the engine was fueled with ethanol – Hexanol – diesel blends. Hexanol – ethanol diesel blended fuel slightly improves the performance of the engine.**

Key words: Hexanol, Ethanol, smoke density, NOx – Oxides of nitrogen.

I INTRODUCTION

Direct injection diesel engines are still fuel-efficient driving power plants for automotive applications because of their superior fuel economy relative to spark ignition and indirect injection engines of comparable capacity. The problem of environmental pollution in urban area is mainly caused by NOx and smoke emission which are emitted from the diesel engine [1]. However, the increase in the price of diesel fuel, stringent emission regulations and foreseeable future depletion of petroleum reserves force us to research new technologies to meet human developments to reduce emission. Many investigations of improvement of combustion characteristics and exhaust gas emission of diesel engine, such as high pressure fuel injection, fuel modifications, alcohol fuels, Exhaust Gas Re-circulation (EGR) and the aftertreatment technology have been conducted [1]. Among various developments to reduce emission, the application of oxygenated fuels to diesel engines is an effective way to reduce pollution without any modification of the engine.

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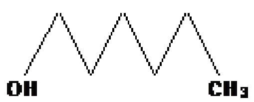
In the past decades, many investigations were carried out to apply ethanol to diesel engines. According to these researches, there are mainly three methods of application. One is that pure ethanol is used on the diesel engine [2, 3], which is the commonly used method. The engine should be modified or redesigned because of the large differences between ethanol and diesel. Furthermore, additives which enhance ignition should be added to ethanol so it can be compression ignited. The second technology is duel-fuel system [4,5]. Besides the original diesel injection system, another injection system must be adopted to inject the ethanol fuel and the ethanol can be injected into the intake port or directly into the cylinder. The third method is blend fuel [6,7]. In this method diesel engines need little or no modification. Therefore, it's most feasible to run blend fuel on existing engines.

The ethanol can be produced from crops, like corn, vegetables etc. Research continues on the development of high efficient, low cost processes for producing ethanol from other feed stocks such as waste from agricultural crops, food and beverage processing, wood and paper processing, and municipal refuse [8], In addition to this, application of ethanol on diesel engines can reduce environmental pollution, strengthen agricultural economy, create job opportunities and reduce diesel fuel requirements.

The major problem associated with use of alcohol in diesel engine is, the limited miscibility at lower temperature and the required minor variations in fuel delivery systems restrict the use of ethanol in diesel. One of the effective approaches is adding oxygenated fuel to solve the above problem without any modification of the engine. The selections of oxygenated fuels is based on economic viability, toxicity and fuel blending properties [9,10].

Ethanol (97 to 99%) is highly soluble in diesel fuel at contents of approximately 0-20% and 80-100% within this region of miscibility; we observed cloudiness in the mixture followed by separation. When the water content of the ethanol exceeded 1% the occurrence of this phenomena will prevented by using additives.[11,12]

Literary survey revealed that several oxygenated organic compounds (ether, aminoalcohols, surfactants etc….) acted as additives when the ethanol concentration increases beyond 20% high concentrations of additives needed to stabilize the mixture. Choosing in suitable additive meets with several difficulties viz; immiscible fuel-alcohol blends, difficult to handle, very expensive etc., Hence, we decided to find out an additives to eradicate the above problem. We find hexanol suitable oxygenated fuel to fulfill all qualities of good additive hexanol is miscible in ethanol from 0-100% and in diesel 0-15%. The hydrocarbon moieties of these molecules constitute the hydrophobic portion of the structure due to their strong affinity over diesel fuel while the one oxygen in hexanol forms very strong hydrogen bond with ethanol. Figure 1 shows the molecular structure of hexanol.



In this study, Hexanol was added to the ethanol-diesel blend fuels to prevent separation of ethanol from diesel. The test of different blend ratios of ethanol like 20%, 25%, 35% and 45% in volume were compared on the same engine. The performance and emissions characteristics were investigated with different fuels. The effects of ethanol content on torque output of the engine, fuel consumption (FC), emission, including smoke, NOx and HC, were studied and discussed.

II EXPERIMENTAL

A. Equipment and method

The engine kirloskar TV1 was used, its main parameters are shown in Table 1.

The engine bench is shown in Figure 2. An eddy dynamometer was connected with the engine and used to measure the engine power. An exhaust gas analyzer (AVL Di-gas analyser) was employed to measure NOx, HC, CO, and CO_2 emission on line, The AVL smoke meter was measured the smoke density. The AVL combustion analyser is used to measure the combustion characteristics of the engine.

The commercial diesel fuel employed in the tests was obtained locally. The Hexanol (99.7% purity) was supplied from Merck India pvt Ltd. The ethanol was an analysis-grade anhydrous ethanol (99.7% purity). Table 2 gives the properties of the diesel, ethanol and the hexanol. The similarities of hexanol to petroleum diesels allow the use of hexanol-diesel blend on transportation engines at any blend ratio. But sometimes, the poor cold flow characteristic of the hexanol is a barrier to the use on engines in cold weather. If the barriers of hexanol and ethanol using on engines are taken into account, it's a better way to blend ethanol, hexanol, and diesel together for applications.

Table 1 Specification of the test engine

Type	:	Vertical, Water cooled, Four stroke
Number of cylinder	:	One
Bore	:	87.5 mm
Stroke	:	110 mm
Compression ratio	:	17.5:1
Maximum power	:	5.2 kW
Speed	:	1500 rev/min
Dynamometer	:	Eddy current
Injection timing	:	23° before TDC
Injection pressure	:	220 kgf/cm^2

First, the hexanol is one of the co-solvents that allow more ethanol in the blend fuel, improve blend tolerance for water, keep the blend fuel stable. With the hexanol, blend fuels can also be stored for longer time. Secondly, high cetane number of hexanol can compensate for the reduction of cetane number by blending ethanol with diesel fuels.

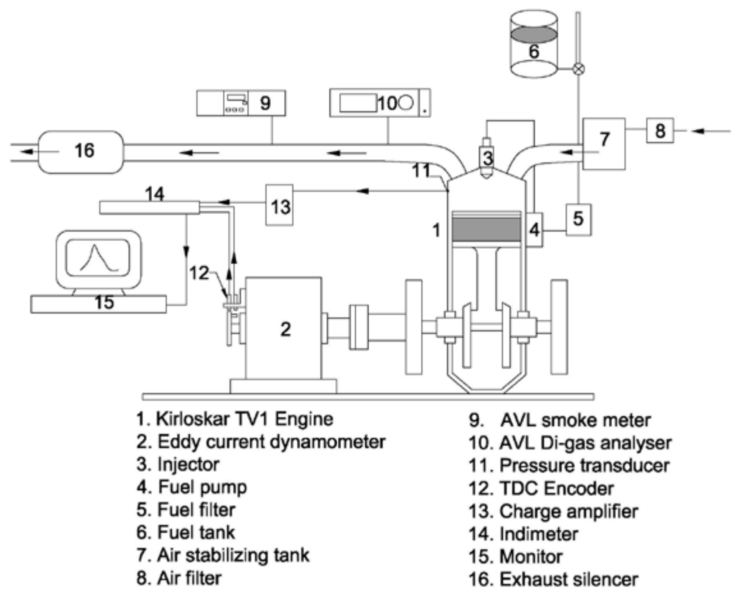


Figure 2. The layout of the engine test bench

In fact, hexanol is also used as one ignition improver. Thirdly, hexanol have good lubrication properties and are therefore beneficial to the engine when firing with ethanol-diesel blends. Lastly, hexanol is good oxygenating fuel to increase oxygen content of the ethanol-diesel blends.

In current study, five kinds of fuels were prepared: diesel (D0) as the baseline fuel, 20% ethanol blending with 10% hexanol and 70% diesel (denoted as D20E), 25% ethanol blending with 10% hexanol and 65% diesel (denoted as D25E), 35% ethanol blending with 10% hexanol and 55% diesel (denoted as D35E) and 45% ethanol blending with 10% hexanol and 45% diesel (denoted as D45E). Properties of the blend fuels are listed in table 2. Increasing the ethanol percentage in blend fuels also increases the oxygen content of the fuel and decreases the heat value of the fuel.

Table 2 Properties of diesel and additive blended fuel (Source: Laboratory evaluation at Italab –Chennai)

Property	Diesel	D 35E
Density @ 15 °C in gm/cc	0.8291	0.8136
Specific gravity @ 15° /15°C	0.8298	0.8145
Kinematic viscosity @ 40 °C in CST	2.57	1.8
Flash point by PMCC (°C)	37	10
Fire Point by PMCC	40	13
Calorific value (kJ/kg)	44000	40838.616

When the ethanol content is more than 45%, misfire is normally observed under some conditions, because the ignition delay is prolonged due to the low cetane number of ethanol in the blend fuels. The ignition occurs well after the top dead center (TDC), especially at high speed. In order to avoid this, four types of fuels mentioned above were used in the experiments.

III RESULT AND DISCUSSION

The performance and emission characteristics of the test engine were evaluated for the blended ethanol with diesel. The engine started without any problem and it was running smooth, but there was an increase in engine noise when 50% or more of ethanol was blended to diesel. Hence the blending was restricted.

A. Performance

The variation of brake thermal efficiency against brake power of the engine is shown in figure 3. It was observed the brake thermal efficiency increases with increasing brake power. Among the blends the D 25E concentration shows higher thermal efficiency than other blends. Regarding the brake thermal efficiency for the blends there is no appreciable changes up to part load and beyond that there is slight increase in thermal efficiency than that of diesel were noticed. The presence of oxygen concentration aids improvement in combustion especially diffusion combustion that contributes higher thermal efficiency. The increase in brake thermal efficiency for D 25E is 1.89 % when compared to other concentrations.

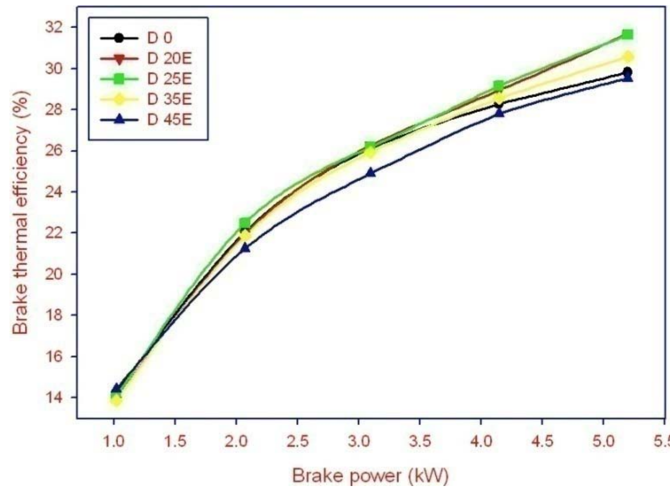


Figure 3. Brake Thermal Efficiency

B. Emission

The variation of smoke density with brake power of the engine for D 0, D 20E, D 25E, D 35E and D 45E by volume of concentrations are shown in figure 4. It is seen from graph upto 70% of load smoke level increases after that gradually decrease for all the concentrations. It was observed that the smoke density of all the blends is lower than that of diesel at maximum load. The smoke density is lower for

D 35E compared to other concentrations. The maximum smoke density recorded for the diesel was 73 HSU and 45.3 HSU for D 35E at maximum brake power. Because of the oxygen enrichment contained by D 35E improves fuel evaporation during diffusion combustion which subsequently reduces the smoke density.

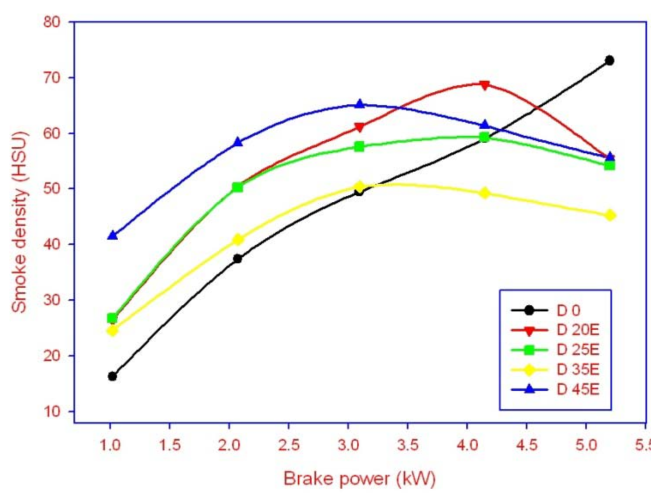


Figure 4. Smoke density

Figure 5 shows NOx emission with different blends of ethanol. It can be seen that NOx emission increases with addition of ethanol blends than diesel. However the blends marginally increase the NOx emission in the entire range of test conditions. All concentrations are increasing the NOx emission due to high temperature promoted by combustion and oxygen enrichment. It is clearly evident from the heat release results graph. Stage de Caro, et al., [9] found that same observation.

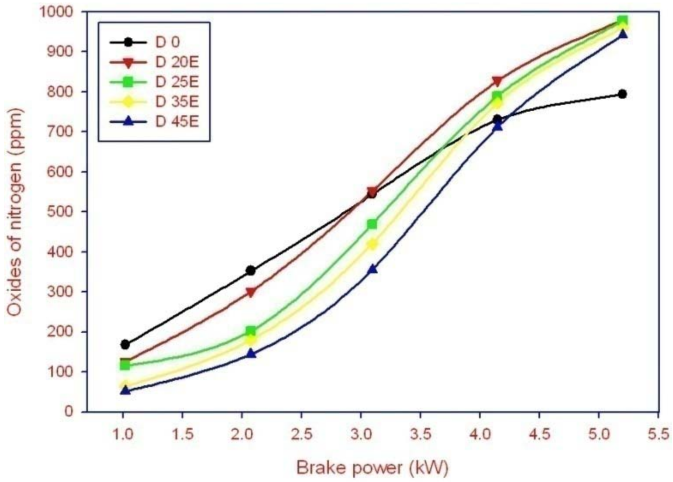


Figure 5. Oxides of nitrogen

The variation of cylinder pressure for different crank angle with different concentration of ethanol blend is shown in figure 6. The general trend of the blends was higher cylinder pressure when compared to diesel. It can be seen that cylinder pressure 1.26 bar is higher for D 20E than that of diesel. It was observed that the cylinder pressure curves of the blends and diesel shows similar pattern. This is due to shorter delay period of fuel blends. The shorter delay period is mainly due to higher cetane number and better vaporization of fuel additives hence this duel effect helps to improve combustion temperature.

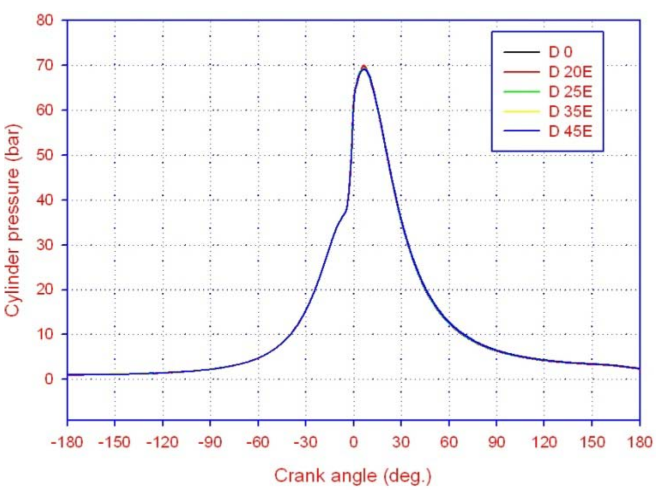


Figure 6. Cylinder pressure

A comparison of heat release between various ethanol blends and sole fuel is made in figure 7. Among the fuel blends the D 25E shows higher heat release rate than other blends and diesel. The increase in heat release rate is due to enhanced combustion and higher rate flame propagation because of high cetane number. This is evident from the brake thermal efficiency of D 25E at maximum brake power. The other blends followed the same curve pattern but well above that of the sole fuel. The peak of the heat release rate D 25E blend slightly shifted from top dead center due to reduced premixed combustion.

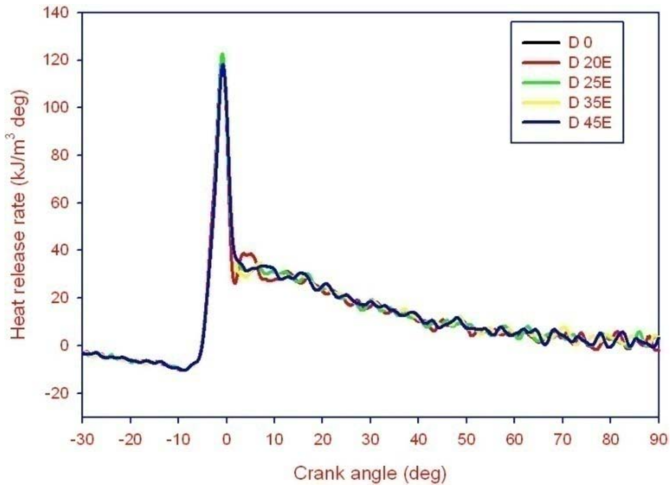


Figure 7. Heat release rate

Figure 8 give the HC emission with different ethanol and hexanol additions. It is observed that HC emission for hexanol blend slightly higher than neat diesel fuel. This is due to higher heat of evaporation ethanol that caused slower evaporating it leads to increase the HC emission. Stage de Caro, et al., [9] found that same observation.

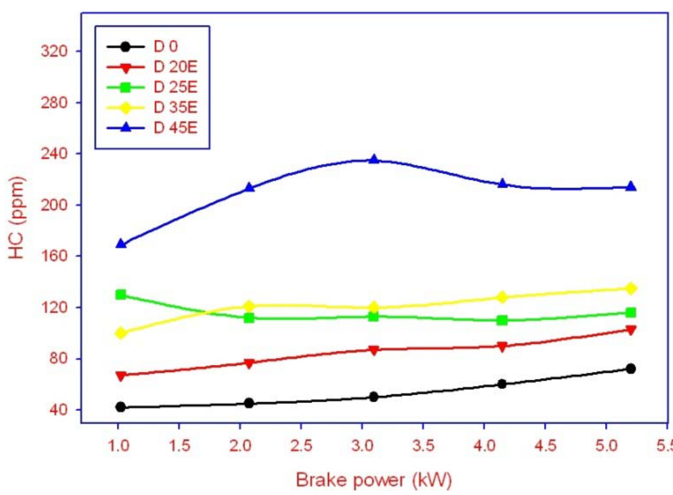


Figure 8. HC emission

IV CONCLUSION

From the experimental investigations the following conclusions are arrived at

From the experimental procedure the best ethanol blend could be identified based on the performance, emission and combustion characteristics by conducting the load test on the DI diesel engine.

Among the four blends, the D 20E shows higher brake thermal efficiency than the other blends and diesel. The brake thermal efficiency improves by 1.89%.

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The D 35E concentration shows better smoke reduction than the other blends and diesel. The smoke density is reduced by 45.3 HSU than the diesel at maximum brake power.

All the blends slightly increase the NOx emission beyond 75% load than that of diesel.

The cylinder pressure is higher for all the blends. But D 20E concentration show significant increase in the cylinder pressure.

Heat release rate for all the blends is higher than that of diesel. In the D 25E concentration shows maximum heat release rate.

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