PERFORMANCE TEST AND EMISSION CHARACTERISTICS OF DIESEL FUEL BLENDED WITH N-HEXANOL

by

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The interest of using alternative fuels in Diesel engines has been accelerated exponentially due to a foreseen scarcity in world petroleum reserves and restrictions on exhaust emissions. Alcohol which is bio-based renewable and oxygenated fuel provides a suitable alternate fuel for internal combustion engines. In this regard, exploration of potential for higher alcohols in automotive application is needed. Long chain alcohols such as pentanol and hexanol despite their analogous properties have rarely been inspected. The n-hexanol, the longer chain alcohol is used to be fueled with diesel. These oxygenated additives allow the fuel to increase combustion efficiency due to the presence of oxygen. In the present investigation, two blends of hexanol and diesel were prepared. All the blends were found to be homogenous and stable. The brake thermal efficiency for all the blends was observed to be slightly higher in comparison to neat diesel. The maximum brake thermal efficiency was obtained with B20 blend. Similarly, minimum total fuel consumption was obtained for B20 blend while rest of the blend showed a reduction in total fuel consumption. The CO emissions were found to get reduced with increase in hexanol percentage in the blends. The HC emissions were observed to increase as the percentage of hexanol increases on the blend. The NO_x emissions increased with increase in engine load for all test fuels. Finally, concluded that a blend of B20% hexanol in diesel will result in better engine performance and emissions of CO_2, CO, and NO_x.

Key words: *hexanol, oxygenated fuel, brake thermal efficiency, emission, engine performance*

Introduction

Diesel engines are the backbone of Indian economy. In India, the consumption of diesel fuel is nearly five times higher as consumption of gasoline. Diesel engines due to its higher efficiency and ruggedness play a very significant role in Indian economy as these are used in agriculture, transport and industrial sectors. However, Diesel engines also emit harm-

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ful emissions and pollute environment [1]. In the financial year 2012-13 the consumption of diesel in India was 69.17 million tones and the consumption of petroleum in India was 15.74 million tones [2]. The world is by and by gone up against with the twin emergencies of petroleum product consumption and natural degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction of underground based carbon resources. The increasing industrialization and motorization of the world has led to a steep rise for the demand of the petroleum based fuels. Petroleum based fuels are obtained from limited reserves. These finite reserves are highly concentrated in certain region of the world. Therefore, those countries not having these resources are facing energy as well as economic crisis, mainly due to import of crude petroleum. Hence it is necessary to look for alternative fuels which can be produced from sources available locally within the country. The search for alternative fuel should be in correlation with sustainable development, energy conservation, efficiency and environmental preservation [3]. Before the introduction of gasoline as an engine fuel, in the late 1800's, the vehicles were often powered by what are now considered as alternative fuels. The first internal combustion (IC) engine, designed built and demonstrated by Rudolf Diesel at the Paris World Fair ran on peanut oil.

Alcohols are made from renewable resources like biomass from locally grown crops and even waste products such as waste paper, grass, and tree trimmings, *etc.* Alcohols is an alternative transportation fuel since it has properties which would allow its use in existing engines with minor modifications. Indeed alcohols like ethanol and their blends with gasoline have shown that they can be burned in conventional unmodified gasoline engines with performance equivalent to that of premium unleaded petrol. As the experience with Brazil has shown, it is also technically and commercially feasible to manufacture vehicles capable of running on pure alcohols. Alcohols fuels are relatively benign environmentally, when compared to alternative liquid synthetic fuels. Because the production technologies are well understood, the pollution control technologies are also known, and the emissions and effluents are controllable. Alcohols burns cleaner in comparison to fossil based fuels and produces lesser CO, HC, and NO_x. The most significant advantage of these fuels compared to conventional ones is reduction of emission because of non-sulphur content and oxygen enrichment enhancement of premixed combustion phase and improvement of the diffusive combustion phase [3-6]. Lower viscosity, high evaporative cooling and high laminar flame propagation speed [7, 8] also add to their advantage. Alcohol has higher heat of vaporization, therefore, it reduces peak temperature inside the combustion chamber leading to lower NO_x emissions and increased engine power. However, the aldehyde emissions go up significantly. Aldehyde plays an important role in formation of photochemical smog. Alcohols have been attracting attention worldwide. Customer needs a cleaner fuel that can bring down the danger of harm to surroundings and human health. Government aim to reduce reliance on imported energy and promote domestic renewable energy programs, which could utilize domestic resources and create new economic activities. Though bio-fuels remain relatively small in use compared to more traditional energy forms, the scenario is changing rapidly when factors are coupled with vast agri-resources, new technologies that reduce cost. Emphasis on environment and pollution abatement and a strong will from both government and private entrepreneurs will provide an immense boost to the market of bio-fuels which is slowly but surely gaining momentum. While increases in oil prices are impossible to predict accurately under prudent assumptions about long term real oil price increases, search for an effective alternative fuel that can be cost competitive is gaining momentum.

Hexanol is a promising renewable long chain alcohol that can be used in conventional fuel blends or as a co solvent for biodiesel mixtures. It is an organic alcohol with a six carbon chain and a condensed structural formula of $CH_3(CH_2)_5OH$. It is produced industrially by the oligomerization of ethyl alcohol which can be produced from crops, corns, vegetables and other feedstock such as wastes from agricultural food and beverage processing and hence, a renewable oxygenated HC is investigated in this study. Hexanol can easily be blended with diesel by splash blending. It is immiscible with water and therefore, could be distributed in existing pipelines without the risk of water contamination. It is less volatile and has fewer evaporative emissions compared to n-Butanol. The cetane number and density of hexanol are very close to the properties of diesel fuel. Although the net heating value of hexanol is higher than that of ethanol and methanol, it is about 16.5% lower than that of diesel fuel. Higher net heating value of hexanol is an important advantage for the engine performance and fuel consumption. Hexanol is an oxygenated fuel like other alcohols and has an oxygen content of about 15.7%, which may significantly promote the combustion process. Excellent cold flow properties of hexanol also add to its advantages and make it applicable as a fuel in various regions were the temperature drops below 0 °C. The main obstacle of hexanol for a direct replacement of diesel fuel is its high viscosity, which may deteriorate amount of the fuel injected. However, the use of hexanol as blends with diesel fuel up to 20% may be regarded as a possible solution when earlier studies performed with ethanol and methanol are taken into consideration.

Emulsion of methanol and diesel prepared using a rotating packed bed was suitable to overcome the homogeneity concerns while making diesel methanol blend. The viscosity of the emulsified fuel appeared similar to Newton fluids. A reduction in surface tension was noticed with increase in surfactant concentration in the emulsion whereas the stability of the fuel was found to be high with higher rate of agitation, additive amount and higher liquid-flow rate [9]. Tests were carried out with methanol-diesel blend and ethanol-diesel blend on single cylinder, four-stroke, direct injection, naturally aspirated Diesel engine. He observed a decrease in smoke opacity, CO, HC, and total HC. However, NO_x emissions increased with the use of blends. Brake specific fuel consumption (BSFC) with all the fuel blends was found to increase mainly due to the lower heating value of methanol and ethanol [10]. Further testing at different proportions of ethanol-diesel fuel blends in a constant speed Diesel engine was carried out. They observed that a 9% increase occurred in the BSFC with the blends up to 20% as compared to diesel fuel, while emissions of CO and NO_x were lower with the use of blends [11]. It was found that HC and CO emission increase with decrease in speed and load while NO_x and smoke opacity decreased at 81 kPa pressure. Increase in pressure had insignificant effect on engine performance [12]. At no load condition, NO_x emissions are nearly same for all the test fuels while at full load the NO_x emissions increased [13].

The brake thermal efficiency increased (BTE) slightly for 15% and 20% blend. At lower loads, an increase in BSFC was observed. However, at peak loads, variation in BSFC was insignificant. The unburned BHC emissions were higher and CO_2 was found to decrease with increased percentage of isopropyl alcohol. At peak load, CO emission increased for all the blends and 20% blend showed lower smoke opacity at peak load. Compared with the neat diesel, all blends earned an increase in BSFC. Among the blends tested, the highest BTE was obtained with ISB10. The use of isobutanol-diesel fuel blends caused a decrease in CO and NO_x emissions. However, HC emissions increased with the use blends. The formation of exhaust emissions was heavily affected by the isobutanol content of the blend.10% isobutanol-diesel blend was found to be an optimum in terms of performance and exhaust emissions [14]. The butanol-diesels blending ratios was varied from 0 vol.% to 40 vol.% with a step of 10 vol.%, and for each blended fuel the influence of exhaust gas re-circulation (EGR) and injection timing were studied [15]. He found that butanol diesel blends with low blending ratios serve to decrease NO_x emissions compared to pure diesel fuel under light load operation without EGR [16, 17]. Not much difference in NO_x production levels was observed from medium load tests across different blending ratios. Soot emission detected from exhaust gas was substantially reduced with the addition of butanol to the engine fuel, especially with high butanol-diesel blending ratios [18-20]. Thus the objective of this study is to investigate the effects hexanol-diesel fuel blend on the performance characteristics and exhaust emissions of a Diesel engine

Experimental set-up and method

Testing

The performance of the direct injection Diesel engine with the blending of hexanol fuel in the different proportion were carried out. The emission analysis for the different blends of hexanol to diesel such as 10% and 20% were examined and then finally compared with the base diesel fuel and blended hexanol fuel.

Preparation of fuel blends

Normally the making of blended fuel would be done by various processes and would take more time to form a perfect blended fuel due to its various compositions. But the diesel and hexanol blended fuel making process is very easier by using splash blending. The diesel and hexanol fuels have been taken at different ratios in different flasks and shaken well for getting homogeneity. For these blends the performance are calculated and compared with the base diesel fuel and the emission test carried out to evaluate the reduction in the level of emission of the engine exhaust. The engine was started at no load by pressing the exhaust valve with decompression lever and it was released suddenly when the engine was hand cranked at sufficient speed. After feed control was adjusted so that engine attains rated speed and was allowed to run (about 30 minutes) till the steady-state condition was reached. With the fuel measuring unit and stop watch, the time elapsed for the consumption 10 cc of fuel was measured and average of them was taken. Fuel consumption, CO, NO_x, HC, CO_2, and power output were also measured. The engine was loaded gradually keeping the speed with in the permissible range and the observations of different parameters were evaluated. The performance and emission characteristics of various blends of hexanol and diesel were evaluated and compared with baseline diesel fuel. All the performance and emission were evaluated at each load thoroughly. Every time the engine was started with diesel and stopped after running at least 20 minutes on diesel.

Results and discussion

Performance tests

The performance tests were conducted with the various blend proportions of the diesel-hexanol fuels. The performance parameter such as brake power, BTE, total fuel consumption (TFC), and mechanical efficiency were calculated. These results compared with the base diesel fuel and performance of the blended hexanol-diesel fuel was analyzed.

Brake thermal efficiency

The range of BTE against brake power of the engine is shown in fig. 1. It was found that the BTE raises with rising brake power. Among the mixture the B20 combination indicates higher thermal efficiency than other different mixtures. Respecting the BTE for the blends there is no measurable difference up to part load and above that there is slight raise in thermal efficiency than that of diesel were noticed. The existence of oxygen combination helps increase in combustion particularly diffusion combustion which contributes greater thermal efficiency. The increment in BTE for B20 is 0.49% in comparison to other mixtures.

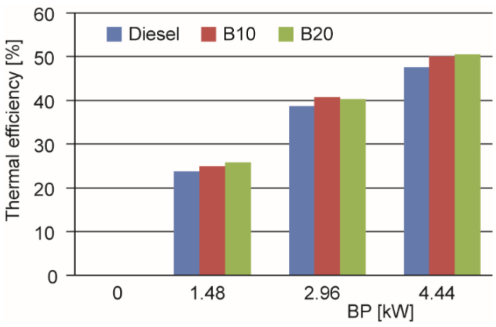

Figure 1. Brake power *vs.* BTE

Mechanical efficiency

The mechanical efficiency of the diesel-hexanol blends was calculated by relating the brake power (output) to heat input (fuel power). The output power is calculated with the current given to the field for stator of the electromagnets. The fuel power was determined by the time of consumption of fuel for 10 cc. Figure 2 shows the variation in the mechanical efficiency for the different proportion of diesel-hexanol blends in a direct injection Diesel engine. It clearly shows that the brake power increases mechanical efficiency also rises for all combination. Among all the blends B20 were higher values than other in all respective brake power.

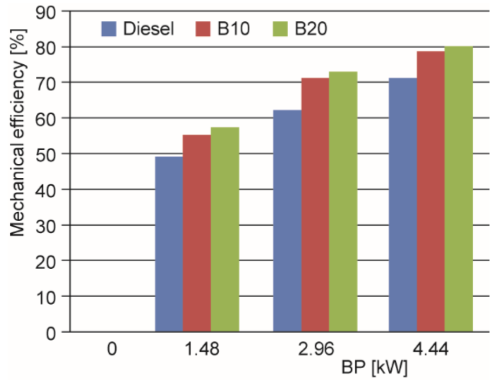

Figure 2. Brake power *vs.* mechanical efficiency

Total fuel consumption

The TFC for all combination of blends along with diesel shown in fig. 3. The TFC is considerably decreased up to 0.025 kg/kW per hour at 4.44 kW of brake power. At null load, the variation of TFC of blends is not high compare to diesel, but that variation is slightly get increased when rise in brake power and finally B20 had a less TFC compare to diesel.

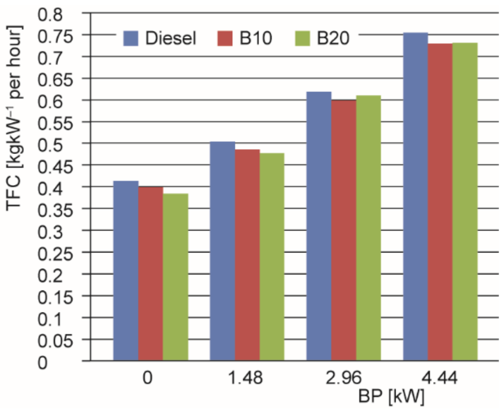

Figure 3. Brake power *vs.* TFC

Emission characteristics

The exhaust gas emission test at different loading condition for the various blending ratio diesel-hexanol fuels are examined with the help of AVL DI gas analyzer.

Carbon monoxide

When there is not enough oxygen to convert all carbon to CO_2, some fuels does not get burned and some carbon ends up as CO. Because of using oxygenated fuel like hexanol, it reduces the CO emissions in the blending. Figure 4 shows the variation in CO emissions for dif-

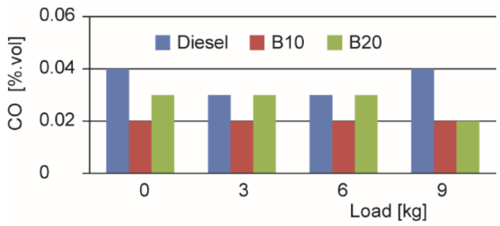

Figure 4. The CO emissions for various load

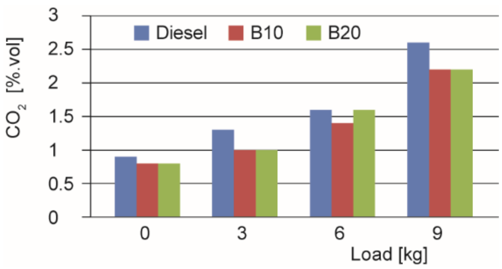

Figure 5. The CO_2 emissions for various load

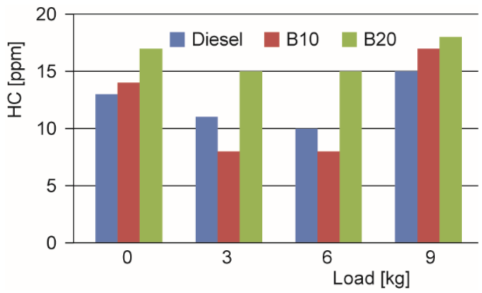

Figure 6. The HC emissions for various load

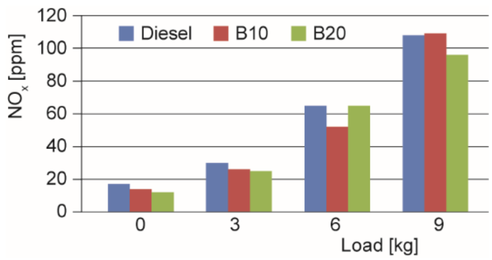

Figure 7. The NO_x emissions for various load

ferent blends along with the base fuel. Here in this present study, CO emissions value marginally decreased at peak loads and both the blend values are less compare to neat diesel value.

Carbon dioxide

Figure 5 shows the variation in CO_2 emissions for different blends along with the base fuel. Here in this case, CO_2 emissions values were drastically increased at peak loads and B10, B20 had a little amount of lesser values than base fuel.

Hydrocarbon

The HC emissions of the different blends were tested with various load condition of the engine. Figure 6 give the HC emission with various hexanol additions. It is found that HC emissions for different blends were marginally higher than base fuel. The HC emissions for B20 were slightly higher than B10 with all loads and pretty much higher to neat diesel fuel. At peak load, the blend was too rich causing incomplete combustion and higher HC emission.

Oxides of nitrogen

The NO_x are exhausted due to the presence of nitrogen in the air used for the combustion. Figure 7 clearly shows NO_x emissions were increased for different load conditions of all the blends and diesel fuel. It can be seen that NO_x emission decreases with addition of hexanol blends than diesel. However the blends marginally increase the NO_x emission in the entire range of test conditions. This may be attributed to the fact that increase in engine loading leads to increase in-cylinder pressure and bulk gas temperature.

Conclusions

In the present case, performance and emission studies were carried out for blends of hexanol (B10, B20) and diesel. Depends on the experimental results, the following conclusions have been written:

- It was observed that peak load BTE was found to increase with increase in hexanol percentage in the blend. This might be clarified by a better combustion due to the raise in the presence of oxygen inside the combustion chamber. Full load BTE of B20 was found to be the maximum which was approximately 0.49% higher than the base fuel at maximum load.

- The mechanical efficiency was little bit higher than neat diesel at peak load for the blend B20 and the variation occurs gradually for all load condition.
- The TFC is considerably less when the addition of hexanol to diesel, At peak load it increased up to 0.7 kg/kW per hour when compare to null load where only 0.4 kg/kW per hour range for all combination.
- The CO was found to get reduced with increase in hexanol percentage in the blends. At part loads, CO emission was found to be low for all the test fuels, however, substantial increase was observed after 60% load. Reduction in CO emissions for higher blends may be attributed to improved combustion of oxygenated fuel hexanol blends.
- The HC emissions were observed to increase as the percentage of hexanol increases on the blend.
- The NO_x emissions increased with increase in engine load for all test fuels. At full load conditions higher percentage of hexanol blend B20 showed an decrease in NO_x emissions as compared to the neat diesel. This may be attributed to a rise in in cylinder mean gas temperature due to proper combustion. The NO_x emission of 108 ppm was observed for diesel at full load. For B10 NO_x was 109 ppm whereas for B20 NO_x was 89 ppm. From the above engine trial, it can be clearly concluded that a blending of B20% hexanol in diesel will result in better engine performance and emissions of CO2, CO, and NO_x.

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