Print ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Comparison of Blends of Diesel with 1, 4 Dioxane with Thermal Barrier Coating, Exhaust Gas Recirculation and Fumigation Processes

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ABSTRACT

Experiments have been conducted to analyse emission performance of different rate of fumigation of two different light fuels. To implement better method to reduce the diesel emission using various methods like thermal barrier coating along with exhaust gas recirculation and with fumigation with diesel blends with 1,4 dioxane. Base data is recorded with base diesel fuel with and without PSZ Zirconium thermal coating. NO_x emissions can be substantially reduced in fumigation with both the fuels. Carbon monoxide emission increased in fumigation mode. Smoke emission is considerably reduced at high loading conditions for fumigated fuel and the reduction is high for MEK fumigation compared with methanol the performance, emissions and combustion characteristics of the engine under variable load conditions have been compared for the optimum blends with diesel, for the engine with PSZ Zirconium coating and with EGR. Results shows that improved performance with blends compared to base diesel fuel for all loading conditions. However, 70% diesel, 20% ethanol and 10% dioxane blends show 36.4% of brake thermal efficiency without coating and 38.5% with PSZ Zirconium coating compared with 31% for the base diesel fuel.

KEY WORDS: Diesel Blends, 1, 4 Dioxane, Thermal Barrier Coating, EGR.

1. INTRODUCTION

Diesel engines have been used for better thermal efficiency with low emissions, however diesel engine have disadvantage of producing smoke, Smoke density and NO_x and it is difficult to simultaneously to reduces NOx, and smoke density diesel engine due to trade of between Oxides of nitrogen and smoke density (Ying, 2006). Many methods available to reduce smoke density and NOx emission by EGR, deNOx catalytic converter, high pressure injection and oxygenated fuels (Agarwal & Dhar 2010). The use of alcohol to replace diesel in diesel engine is the miscibility at low temperature and fuel injection variations major problem associated with in diesel engine while attending to use of alcohol (Balamurugan & Nalini 2014). The effective approach adding oxygenated fuel to solve the above problem without any modification of a diesel engine (Wang, 2009). The ethanol is favourably soluble in diesel fuel at the blends of upto 20% in the miscibility region (Kumar, 2013), it is observed the lack of transparency in the blend of fuel liquids followed by separation. When the water content of the ethanol exceeded 1% the occurrence of this phenomena will be prevented by using additives (Yin, 2016).

When the ethanol concentration increases beyond 20% additives needed to stabiles the mixture (Yin, 2016). It is found 1,4 dioxane (1,4-dioxacyclohexane) suitable oxygenated fuel with all qualities of good additive dioxane is miscible in ethanol from 0-100% and in diesel 0-15% (Sundar Raj, 2010). The hydrocarbon molecules constitute the hydrophobic portion of the structure due to their strong affinity over diesel fuel while two oxygen in dioxane forms very strong hydrogen bond with ethanol (Shahir, 2015).

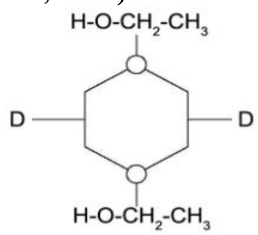

Figure.1. Representation of a Micelle between the Dioxane, Diesel (D) and Ethanol (E)

These surfactants are therefore non-ionic and to the form a stable, homogenous emulsion as shown in Figure.1. The use of EGR causes a greater reduction of NOx and an increase of smoke density emissions (Hussain, 2012). It is reported that the exhaust gas recirculation keeps the temperature of the recirculated exhaust gases at a very high level, not only helps reduce NOx but also contributes distinctly to achieving lower hydrocarbon (HC) and smoke emissions (Sendilvelan, 2016). In addition, there is no adverse effect of EGR on the fuel economy.

Fumigation is a process by which alcohol is injected in to the intake manifold by a simple carburettor and vaporizing it in the air stream (Tsang, 2010). Alcohols are examples of the desired alternative non-petroleum fuels used in internal-combustion engines (Kohse-Hinghaus, 2010). Researchers concentrated more on the use of alcohols in spark ignition engines, less interest has been given to the use of alcohols in diesel engines (Agarwal, 2007).

Although completely removing the diesel fuel by the alcohols is not possible at present, particularly the alcohols such as methanol and ethanol. The simplest one of these techniques we are concerned with in this experimental analysis is alcohol fumigation for diesel engines. Most of these studies are focused on to calculate the dimensions of carburettor for fumigation (Ghadikolaei 2016). In this work the performance and emissions are studied by adapting a microprocessor controlled electronic pump with injector to control the flow rate. Experiments were conducted for various fumigation rates of methanol and methyl ethyl ketone and the results were compared.

2. MATERIALS AND METHODS

The purpose of this work is to evaluate through experiments, different methods of usage of alcohol and its derivatives effectively on a diesel engine with improved performance and reduced emission levels. To achieve the aim, the following objectives have been set.

Alcohol as blends with dioxane as additive:

- To create a stable ethanol-diesel blended fuel with 10% dioxane additive.
- Systematic engine study and assess performance, for different ethanol contents on a Zirconia Alumina (thin layer of 200 microns) coated engine with exhaust gas recirculation and assess performance for different ethanol content and to analysis the results with that on a normal engine.

Dioxane – Diesel blends: Systematic engine study and assess performance, for different ethanol contents on a Zirconia Alumina (thin layer of 200 microns) coated engine with and without recirculated exhaust gas and assess performance for different dioxane content and to analysis the results with that on a normal engine.

Alcohol in dual fuel mode: Fumigating small quantities of methanol/methyl ethyl ketone while diesel is the injected fuel using electronic fuel injection kit.

Description of the research work: Ceramic coatings have been used as a thermal barrier to improve the efficiency of the engines, with acceptable reductions in emissions except NOx. Use of recirculated gas causes a sharp reduction of NOx and smoke simultaneously on the oxygenated fuels. On the other hand, exhaust gas recirculation reduces the efficiency and pressure which changes the benefits obtained from the oxygenated fuel. 1, 4 dioxane, normally called as dioxane is an ether, miscible in diesel has favorable properties as an alternative or additive for diesel fuels. This work presents a comparative evaluation of dioxane as an alternate fuel and an additive with ethanol on a standard diesel engine, Zirconia Alumina (PSZ) coated engine, and coated engine with EGR regarding engine performance characteristics and environmental repercussions. The engine is modified as a dual engine by adopting an electronic fuel injector at the inlet manifold and other light alcohol fuels namely methanol and methyl ethyl ketone are fumigated in to the combustion chamber as secondary fuel and the performance and emissions were analyzed. Results have been compared with the base engine to analysis performance and emission characteristic for all loading conditions of the engine on all fuel cases.

Experimental setup: An experimental set up was made with necessary instruments to evaluate the performance, emission and combustion parameters of the compression ignition engine at different operating conditions. The overall view of the experimental setup is shown in Figure.2. Experiment were conducted on kirloskar TV1, four stroke, single cylinder, air cooled diesel engine. The rated power of the engine was 4.4kw at 1500 rpm. The engine was operated at a constant speed of 1500 rpm and standard injection pressure of 200 bar pressure. K-type thermocouple was used to measure exhaust gas temperature. Hartridge smoke meter was used for measurement of smoke density. NOx emission was measured by AVL five gas analyzer. Gas analyzer was used to measure NOx, smoke, CO and HC. In cylinder pressure was measured with help of AVL combustion analyzer. The experiment was carryout the different blends of fuel were prepared with ethanol 20 to 30%and 10% dioxane by volume to sole fuel.

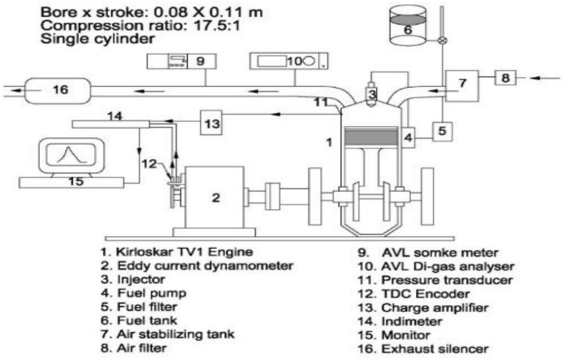

Figure.2. Experimental setup

Readings were taken, when the engine was operated at a constant speed of 1500 rpm for all loads. Parameter like engine speed, fuel flow and the emission characteristic like NOx and smoke were recorded. The performance of the engine was evaluated in terms of brake thermal efficiency, brake power, specific fuel consumption from the above parameters. The combustion characteristics like cylinder pressure and heat release rate noted for different blends.

3. RESULTS AND DISCUSSION

The results obtained with different methods that were tried to improve the performance of a CI engine using diesel as the main fuel. Figure 3 shows the SFC for different oxygenation of diesel fuel for all loading conditions of the engine. Among the blends 70D: 20E: 10Dy ratio shows minimum specific fuel consumption to other blends and sole fuel. Slight increase in BSFC is observed for EGR as some of the intake air is replaced with hot exhaust gases. As some of the air is replaced by the secondary fuel in the dual fuel mode the BSFC for fumigation is less compared to the normal diesel operation. Methanol shows lower BSFC than MEK.

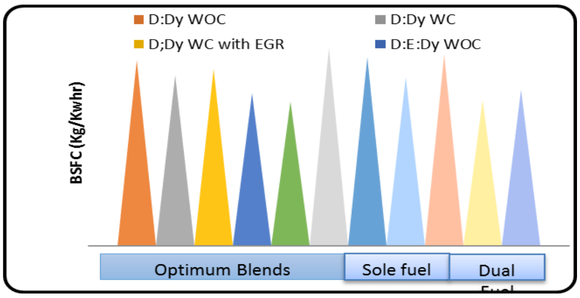

Figure.3. Comparison of BSFC for different blends and dual fuel at peak load

Figure.4, compares the effect of oxygenated fuel blend on the brake thermal efficiency for different blends of dioxane with diesel and dioxane with ethanol and diesel. D: E: Dy blends contain excess oxygen than D: Dy blends and this excess oxygen helps in oxidation of carbonaceous soot matter and associated hydrocarbons resulting in improvement in efficiency for higher blends. TBC engine improved the efficiency of sole fuel by 2% in each case of the oxygenated fuels when compared to the standard engine due to the in cylinder heat transfer reduction and increase in combustion duration. 25% EGR slightly reduces the efficiency as the oxygen availability is reduced due to the exhaust gas. Highest brake thermal efficiency is obtained in Diesel, Ethanol and 1,4 dioxane blend with TBC as compared to other methods. Brake thermal efficiencies are 36.42% for D: E: Dy blend, 38.5% for D:E:Dy blends for TBC conditions and 37.2% for the same blend for TBC condition with 25% EGR and the values are 29.6%, 31.8% and 30.95% for the respective conditions for D: Dy blends. For dual fuel mode methanol fumigation results in highest efficiency 37.34% and it is 34.4% for MEK fumigation.

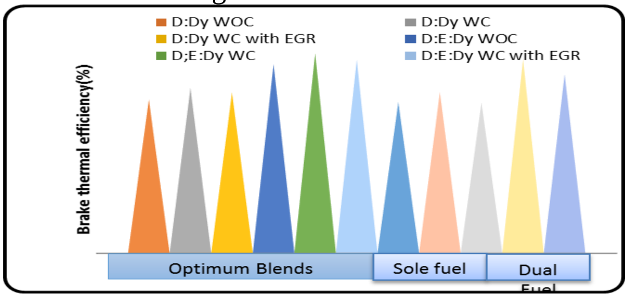

Figure.4. Comparison of brake thermal efficiency for different blends and dual fuel at peak load

The addition of oxygenates, decreasing the smoke density due to increased heat release rate and more complete combustion of the oxygenated fuel by acting as an ignition improver. Further reduction was observed for the engine with barrier coating because of the decreased quenching distance and the increased lean flammability limit. A maximum of 15 HSU reductions was observed for 70D: 20E: 10Dy blend ratio on TBC engine against sole fuel at normal conditions. The fuel rich region increases smoke density, but ethanol addition decreases the smoke density. EGR increase the smoke density for sole fuel and D:Dy blends due to deterioration in diffusion combustion, but decrease in smoke density was observed for D:E:Dy due to the presence of excess oxygen. The smoke level for the sole fuel and the blended fuels at different engine conditions along with dual fuel mode of operation is shown in Figure 5. The smoke is less than diesel for D: Dy blends at all loading of the engine. However, its value is slightly higher for D: E: Dy blends and is reduced by TBC and with EGR techniques. Fumigation reduces the smoke drastically and methanol is having higher capacity to reduce smoke than MEK.

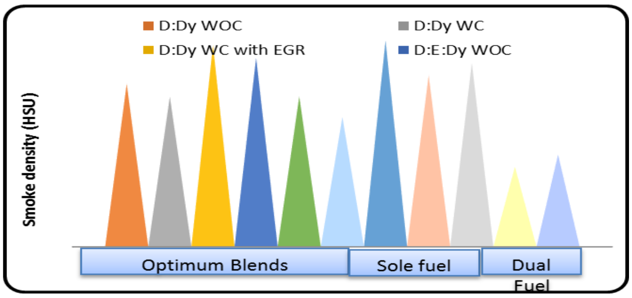

Figure.5. Comparison of smoke density for different blends and dual fuel at peak load

Nitrogen oxides emissions are predominately temperature phenomena. The availability of oxygen increases the heat release rate for the fuel and hence the NOx emission will be high. Late combustion due to change in the delay period lower the peak pressure in TBC engines for the sole fuel and low oxygenated fuels. Since the high-pressure rise is lower, for the same value of mass, the peak gas temperature may also be lower, resulting reduced NOx emissions for base diesel fuel and low oxygenated fuels. However, the availability of excess oxygen increase the heat release rate and maximum pressure rise for the D:E:Dy blends and hence the NOx emission is high for TBC engine than the standard engine. When exhaust gas re-inducted in the combustion chamber it dilutes the fuel mixture and also reduces the oxygen availability in the cylinder. Exhaust gas specific het is more than the intake air, so that the heat capacity of the incoming fuel mixture, which decreases the temperature inside the combustion chamber and hence, reduces the NOx emissions drastically. The variation of NOx emissions at peak power output is shown in Figure 6. It is seen that the blended fuels increased the NOx emissions at normal and TBC conditions, but it is drastically reduced with 25% EGR. The maximum value is 710 ppm for D: E: Dy blends at TBC conditions and is reduced to 285ppm by EGR. Dual fuel operation reduces NOx emission as the inducted light fuel reduces the combustion temperature. Among the tested fuels methanol emits 430 ppm and MEK 535ppm of NOx at peak load.

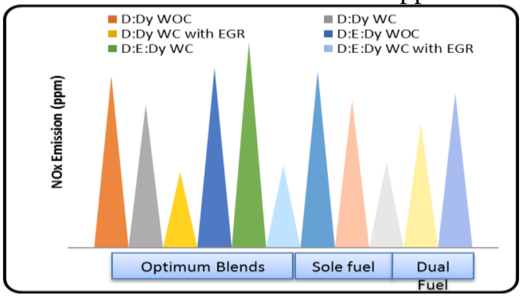

Figure.6. Comparison of NOx emissions for different blends and dual fuel at peak load

4. CONCLUSION

From the above result analysis, it was concluded that alcoholic fuels can effectively be used in diesel engines with dual fuel operation i.e fumigation using EFI kit in an engine that normally operates at high power outputs. Ethanol blends with diesel along with 1,4 dioxane also performs well and it was further improved by TBC condition with high NOx emissions. The NOx value may be effectively controlled by EGR without much change in the performance. The new oxygenate 1,4 dioxane a derivative from alcohol may be considered as an alternate fuel with better performance and emission in Zirconia Alumina (PSZ) coated engines with EGR. Lower blends can be used in normal conditions also with improved performance than neat diesel.

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