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Reducing oxides of nitrogen (NO_X) emission of DI diesel engine using refrigerated methanol blend as a fuel

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Abstract: Faster exhaustion of fossil fuel, day to day increase of automotive vehicles and stringent emission norms force the researchers to find out an alternative fuel that can be used in diesel engines with less modification or without any modification. The present experiment investigates the effect of using refrigerated methanol-diesel blend as a fuel in DI diesel engine. In this investigation, two blends of methanol and diesel were selected. One was 10% methanol and 90% diesel and another one was 20% methanol and 80% diesel. The data of pure petroleum diesel fuel operation was taken as a base line configuration to examine the effectiveness of the two blends.The results show that the use of refrigerated methanol-diesel blend, keep the combustion temperature low and increases the ignition delay. It also showed better reduction in NO_X and visible smoke. It may be concluded that refrigerated methanol blend can be readily used in diesel engine without significant modification of engine and fuel system.
Keywords: refrigerated methanol blend; cloud point; insulation;DI diesel engine.

Introduction

The diesel engine has been in service as a reliable and efficient prime mover for a long time. From the beginning of the diesel era, the diesel engines are mostly used in heavy duty field because of their superior fuel economy. Due to their high efficiency and comparatively low pollutant formation characteristics, their application to lighter duty vehicles, like small goods carriers and passenger cars have drawn much attention in recent years. This development was accelerated by the energy crisis in 1973. Also in recent years, the prominence to conserve petroleum based fuels has provided the motivation for several studies on the development and testing of alternate fuels in diesel engine. Among these substitutes, the blends of alcohols have been found to yield some beneficial effects in spray combustion. Significant beneficial results have been achieved by the use of alcohol as fuel blend with petrol and diesel [1-4]. But the blending of diesel with alcohol was not an easier one. It is a complex phenomenon. Periodically alcohols, particularly methanol and ethanol attracted the attention of researchers as engine fuels [5]. When Rudolph Diesel patented his thermodynamic cycle, the socalled diesel cycle in 1892, he presumed that any fuel would be suitable for an engine operating in the manner he described. Diesel established the perception that his engine could adopt to a wide variety of fuels. Development of this engine over the years has confirmed this. However, it can be fueled most effectively, with diesel oil. Nowadays methanol is frequently used in racing cars.The blend of methanol and diesel exhibits somewhat different physical and chemical properties than pure diesel fuel. There is an effect on cetane rating and energy content of blends, which decrease, with the addition of methanol. The blends of these fuels give smoke free operation and reduction in oxides of nitrogen (NO_X), carbon monoxide (CO) and unburned hydrocarbons (UBHC). Hence this study was conducted to compare the effects of methanol blended diesel fuel on the performance and emission characteristics of a diesel engine.For comparing the results, the sole petroleum diesel operation was chosen as a base line operation. In this study 10% and 20% blend of methanol was made with diesel on volume basis.

Experimental Details

The present experimental investigation was carried in a single cylinder, water-cooled, four-stroke cycle, and direct injection diesel engine. The engine was rated as 4.8kW at 1500 rpm. For loading the engine, the engine was coupled to aneddy current dynamometer. The rotational speed of the engine was measured using digital tachometer. The temperature of the exhaust gas was measured by a K type thermocouple. The NO_X, CO and CO_2concentrations were measured using Crypton five gas analyzer.All the data were collected after the engine reached the steady state.The basic concept behind this experiment was "Anhydrous alcohols can combine with hydrocarbon fuels in any proportion" [6]. But such solutions have very very low water tolerance. The diesel fuel blends upto 40% anhydrous methanol by volume are stable at 0^{o}C. But due to the restriction of cloud point of the diesel, the blend cannot be maintained at 0^{o}C. Hence in the present study the blend was kept at 7^{o}C by insulating the fuel tank and the fuel injection line. To ensure homogeneous mixture formation, motorized stirrer was also used.

Results and Discussions

The significant breakthrough found in this investigation was that there was no change in the engine operating mode while refrigerated blend was used as a fuel and also there was an increase in smoothness in operation of the engine.

Brake specific fuel consumption

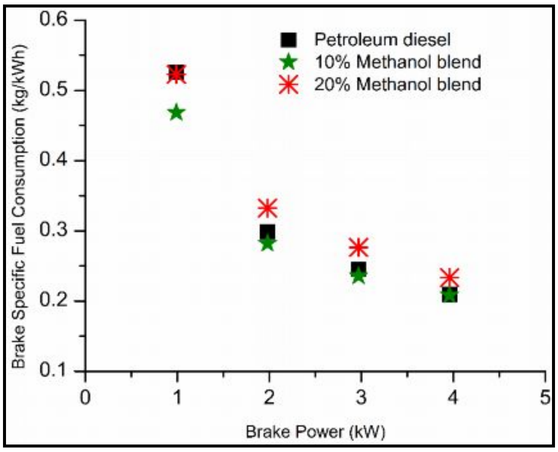

Figure 1. Variation of Brake specific fuel consumption with Brake power for different percentage of methanol fuel blend

Figure 1 shows the comparison of brake specific fuel consumption when the test engine used petroleum diesel as a sole fuel and refrigerated methanol blend in the ratio of 10% and 20% with diesel as a fuel. The figure indicates that at low loads, the BSFC was high. This is because of the higher percentage of heat loss [7] and lower mechanical efficiency at low load conditions. However, over a range of 70% to 80% of full rated load of the engine, BSFC was low. This range can be considered as economical operating power range of the engine. When comparing with 10% refrigerated blend and petroleum diesel, the 20% refrigerated blend operation consumes more amount of fuel. This is because of the low heat content of the fuel at 20% blend [8].

Brake thermal efficiency

Figure 2 compares of the brake thermal efficiency of the test engine when the engine was operated with petroleum diesel and refrigerated methanol blend in the ratio of 10% and 20% with diesel.It is evident from the graph that the brake thermal efficiency got increased when the refrigerated methanol blend was used as a fuel in diesel engine. This is because of the higher volumetric efficiency resulting while the refrigerated methanol blend was used as fuel.

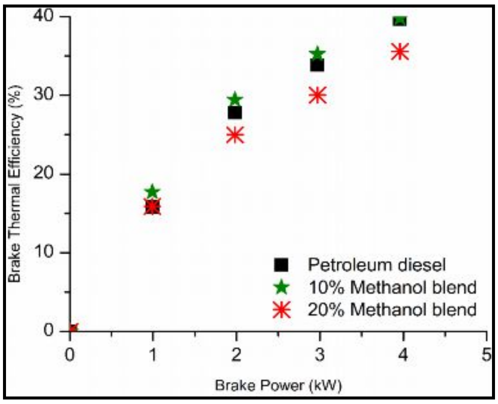

Figure 2. Variation of Brake thermal efficiency with Brake power for different percentage of methanol fuel blend

NO_Xemission

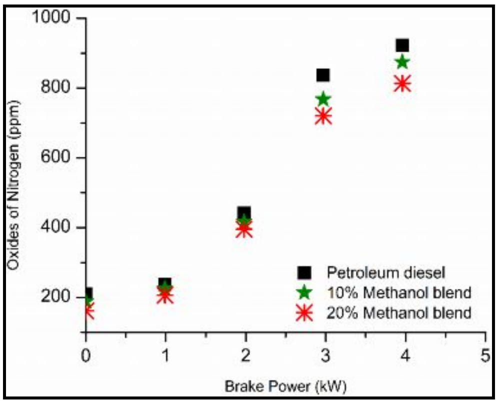

Figure 3. Variation of Oxides of nitrogen (NO_X) emission with Brake power for different percentage of methanol fuel blend

The principle factors dominating the NO_Xformation are combustion temperature, oxygen concentration in the combustion region and residence time of high temperature gas in the cylinder [9]. Therefore, it appears that, when these factors are controlled, the concentrations of oxides of nitrogen exhausted can be reduced. **Figure 3** shows the comparison of NO_X emission when refrigerated methanol is used in the ratio of 10% and 20% with petroleum diesel operation. The figure shows that when the blend percentage was 20%, the amount of NO_Xemission was less. This is because of the low temperature developed inside the cylinder due to the higher latent heat of vaporization of methanol [10]. This eventually lessens the combustion temperature and also resulted in higher unburned hydrocarbon emission.

$CO_2$and CO emission

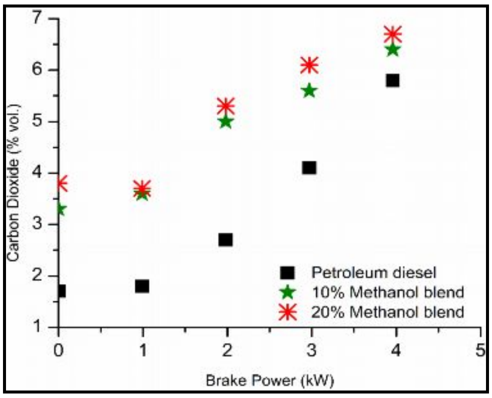

Figure 4. Variation of Carbon dioxide (CO_2) emission with Brake power for different percentage of methanol fuel blend

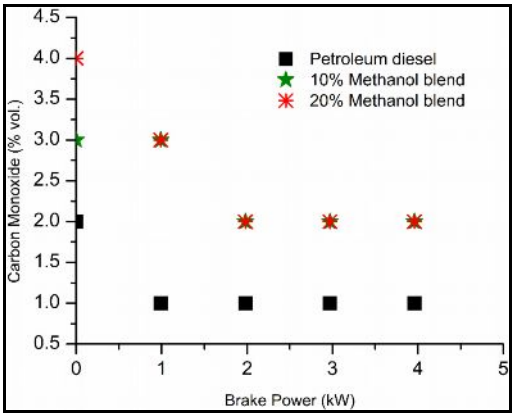

Figure 5. Variation of Carbon monoxide (CO) emission with Brake power for different percentage of methanol fuel blend

Figure 4 and 5depict the comparison of emission of $CO_2$and CO emission when refrigerated methanol blend was used in 10% and 20% ratio and petroleum diesel operation.It is clear from the figure that the emission of CO_2 was less when the engine was loaded more than 60% of its rated load using 20% blend of refrigerated methanol as a fuel. At the same time CO got reduced because of the lesser dissociation reaction incurred during the combustion of 20% methanol blend compared to 10% blend of refrigerated methanol. This is because of the higher latent heat of vaporization of methanol leads to lower temperature development inside the cylinder.

Conclusions

The present experimental investigation carried out in a single cylinder DI diesel engine which used a refrigerated methanol blend as a fuel draws the following results.

- Refrigerated methanol can be used in an unmodified diesel engine as a fuel.
- Refrigerated methanol blend with diesel reduces BSFC.
- Blended methanol reduces NO_X emission considerably.
- CO_2& CO emission increases or decreases depends on the amount of percentage of fuel blend. If the percentage of blend is more CO_2 emission will be less and vice-versa.
- Visible smoke level gets reduced when refrigerated blend is used as a fuel.

Higher percentage of blend may not be useful since, increased delay period may increase fuel accumulation in ignition delay period. This may leads to violent rapid combustion.

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