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Research Article

The Effect of Injection Pressure on the Performance of Alcohol Fueled Insulated Diesel Engine

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Abstract

The continuing rise in prices, growing concern on environment from exhaust emissions, global warming and threat of supply instabilities have led for alternative fuel for diesel engines. The alcohols are considered to be as a favorable substitute as they are indigenously developed and are renewable. But due to the alcohols low cetane number, high self ignition temperature, high latent heat, low viscosity, it is difficult to start the diesel engine at the available combustion chamber temperatures. So in the present work an insulated engine (IE) is developed by insulating the engine components that retains higher temperatures in the combustion chamber and further condenses the ignition delay and improves the efficiency. But the main shortcoming of alcohol is its lower viscosity, which makes the fuel injection pump to inject additional quantity of fuel into the combustion chamber. This reduces the temperature of the chamber and thus the beginning of the engine is difficult. So in the present work an attempt is made to find the suitable fuel injection pressure at which the performance of alcohol is near to diesel fuel. Further the performance parameters of the engine are studied with five injector opening pressures (180, 175, 170, 165 and 160 bar). From the experimental results, it is observed that at 165 bar fuel injector pressure the performance results best and is in close agreement with diesel fuel.

Keywords: *Insulated engine, injection pressures, ceramics and emissions*

1. Introduction

Within the recent years high activities can be observed in the field of Alternative fuels, due to the scarcity of the petroleum fuels. This intensified the research to ascertain the new type of engine design and alternative fuels for better control over pollution. Alcohols are being considered to be supplementary fuels to the petroleum fuels in India because these are derived from indigenous sources and are renewable. But due to its properties it requires higher compression ratios in diesel engines which further makes the engine bulky [Huang Z.H et al 1999]. The skinny heat barrier ceramic coatings in a DI diesel engine results [Roy Kamo et al 1999, S.Nagesh et al 1999]results that the fuel economy at full load is 6% higher and 3.5% higher at low loads when put next to normal diesel engine. Further the investigations [Lioyd S Kamo et al 2000] with LHR engine concluded that there's a reduction in ignition delay, premixed combustion, and combustion period associated a rise in diffusion combustion compared to a normal engine, but it requires modification to the fuel injection system. The low heat rejection engine is developed with insulated piston and liner coated with PSZ. At higher chamber temperatures [Varaprasad et al 1986] with variable injection pressure, injection timings the emissions are drastically reduced with alcohol. Ozer will et al (Ozer will et al, 2004) conducted the experiments with ethanol–diesel blends with different injection pressures (150, 200 and 250 bar) with none modifications to the engine. One percent isopropanol is added to the mixtures to satisfy homogeneity and stop section separation. Experimental results showed that the alcohol addition reduces CO; Soot and SO_2 emissions however will increase NO_x emissions. Similarly Rakopoulos et al (Rakopoulos et al 2008) developed a theoretical two dimensional multi-zone model for a direct injection (DI) diesel engine. This deals with the spray characteristics and this is further compared with the experimental results with 5, 10 and 15 percent alcohol. He concluded that 15 % alcohol mix is best and is nearer to the theoretical one. Shipinski et al (Shipinski et al, 2007) have highlighted the fuel handling problems which may affect the performance of the fuel injection system and also the fuel properties like spray characteristics, ignition delay and rate and duration of the combustion. Finally he suggested that a VCR engine system holds out most promise for multi-fuel use. Wang W G et al (Wang W G et al 2003) argued that in low heat rejection engines with ceramic insulation there is a decrease in premixed

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combustion by 75% and increase in the BSFC by 9%. Myung Yoon Kim et al (Myung Yoon Kim et al, 2008) have reported the use of a thermal barrier piston in the adiabatic engine and developed the temperature distribution analysis and reported that the piston top temperature were higher by around 400^0C for the thermal barrier pistons. These higher temperatures (Abdullah Uzum, 2010 and Shrirao P N et al 2011) are observed in the exhaust and can be recovered with turbocharging. However, the problems associated for using alcohols in diesel engines are its high latent heat of vaporization, high self ignition temperature and low viscosity. So for the burning of alcohols in the combustion chamber insulated engine is developed. In the present work the fuel injection pressure is varied (180, 175,170,165 and 160 bar) and the effect of that is studied.

2. Objective

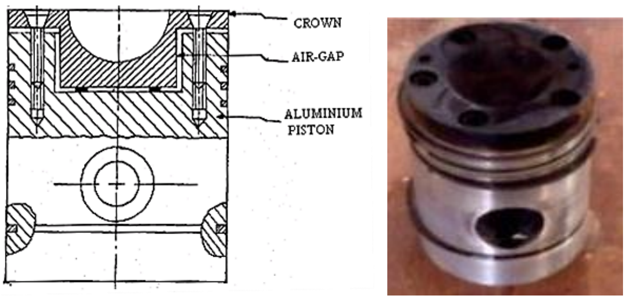
The main objective of this investigation is to experimentally determine effect of fuel injection pressure variation on the performance of the insulated diesel engine. The total experiment consists of the following phases

- Preparation of the Insulated engine
- Materials and Methods
- Results with different injection pressures

2.1 Preparation of Insulated Engine

2.1.1 *Air Gap Insulated Piston*

As per the literature 2 mm air-gap between the aluminum piston crown and skirt is used . The piston crown and skirt were separated by copper and steel gaskets. Figure.1 shows the air gap insulated aluminum piston.



(a) (b)

Figure 1: Air gap insulated Aluminum crown (a) Line diagram (b) Photographic view of aluminum crown

2.1.2 *Insulated Cylinder Head and valves*

The combustion chamber area of the cylinder head exposed to the combustion and the bottom surfaces of the inlet and exhaust valves are machined to a depth of 0.5 mm and are coated with Partially Stabilized Zirconium (PSZ) material for the same depth. The Photographic views of cylinder head and valves are as shown in the figure. 2.

Figure 2 Cylinder head and valves coated PSZ

2.1.3 Insulated Cylinder Liner

The reciprocating movement of the piston within the bore is an obstruction for the insulation of the liner on its inner surface. So it is to be insulted from outside. In this case air with its low thermal conductivity is used as the insulating medium. A thin mild steel sleeve is circumscribed over the cast iron liner maintaining a 2mm layer of air in the annular space between the liner and the sleeve. The joints of the sleeve are sealed to prevent seepage of cooling water into the air-gap region.

2.2 Materials and Methods

A stationary, four stroke, 3.68 kW DI diesel engine is used for the experimentation. The concentrations of smoke (Bosch smoke meter); CO, UHC and NOx are measured using on-line non-dispersive infrared (NDIR) AVL exhaust gas analyzer. With alcohol operation, the major pollutant emitted from the engine is aldehydes. The well-known DNPH method (2, 4 dinitrophenyl hydrazine) is employed for measuring aldehydes in the experimentation.

Figure3. Experimental set up of Insulated Engine Test Rig

Air suction rate and exhaust air flow rates were measured with the help of an air box method. Temperatures are monitored using Nickel-Nickel Chromium thermocouple. Engine RPM is measured using an electro-magnetic pick up in conjunction with a digital indicator of AQUTAH make. The experimental set up used is as shown the following Figure.3. In the present experiment, the performance parameters of alcohol are tested at various injection pressures (180, 175,170,165 and 160 bar) and the same thing is compared with normal diesel engine (NE) which operates at 180 bar injection pressure.

2.3 Results and Discussion

2.3.1 Pressure

The pressure developed in the combustion chamber depends on the latent heat of vaporization, viscosity and fuel injection pressure. At higher injection pressures more alcohol is injected due to its low viscosity. Though more

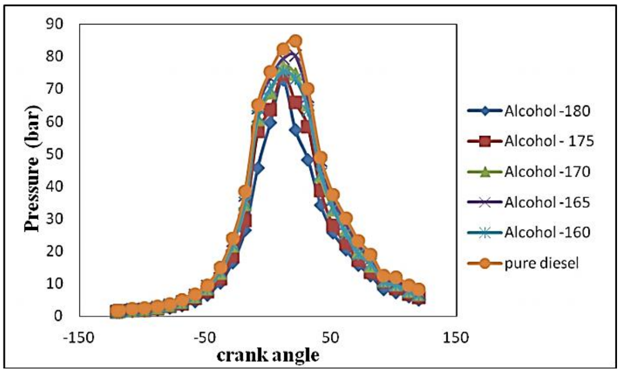


Exhibit 1 Variation of Pressure with Crank angle

Oxygen is available with alcohol; the latent heat dominates and further reduces the peak pressures in the chamber. The exhibit 1 shows the variation of pressure in the combustion chamber with the crank angle at different fuel injection pressures. From the above figure it is observed that with the reduction in the injection pressure the peak pressure increases. At 165 bar pressure it is 80.22 bar which is in close with diesel pressure 83.4 bar. But with 160 bar fuel injection pressure less amount of fuel is injected and causes for the insufficient combustion. So the pressure dropped.

2.3.2 Brake Thermal Efficiency

The variation of Brake Thermal Efficiency with power output is shown in exhibit.2 It is evident from the graph

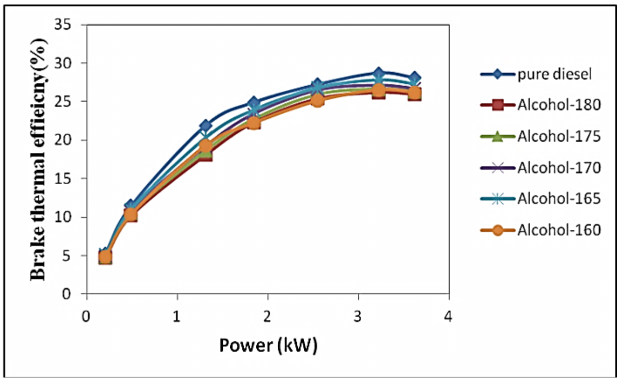


Exhibit 2 Comparison of Brake Thermal Efficiency with Power Output with different Injection Pressures

That diesel has the highest Brake Thermal Efficiency. Brake Thermal Efficiency depends on combustion process and further depends on chamber design, viscosity, latent heat of vaporization and the fuel injection pressure. It is concluded that at 165 bar injection pressure, the brake thermal efficiency is slightly better than the other and is in close agreement with diesel fuel. The left over values of Efficiency of alcohol are in between 180 bar and 165 bar pressure.

2.3.3 Ignition Delay

In diesel engine, the ignition delay decreases with rise in temperature i.e., with load. It is seen from Exhibit: 3 that the ignition delay of an insulated engine varies from 25^0CA at no load to about 21.7^0CA at full load.

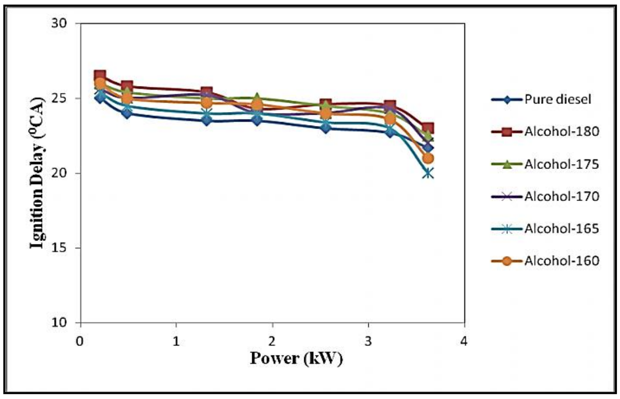


Exhibit 3 Comparison of Ignition delay with Power Output for different Injection Pressures

The exhaust gas temperatures are lower with the alcohol operation in the insulated engine compared to pure diesel operation. With the insulation the higher temperatures in the chamber reduces the delays along with the load, further expands in the engine cylinder with lower heat rejection. At 180 bar pressure, the alcohol injected is more and this increases the delay period but this is compensated marginally with the oxygen in the alcohol.

2.3.4 Smoke Density

The variation of smoke levels with power output at different fuel injection pressures are shown in the exhibit 4. Smoke in diesel engines may be results of density, Unburnt liquid particles of fuel or lubricating oil and due to this carbon particle (soot) seem on combustion chamber walls. The oxygen gift within the alcohol acts as a combustion promoter and reduces the smoke and soot chemical reaction. But with the increase of fuel injection pressure more amount of alcohol will be injected and makes the combustion chamber cool. Further this increases the smoke emissions at 180 bar injection pressure. But with the reduction of fuel injection pressure, the smoke emissions increase due to the less availability of oxygen content. At 165 bar injection pressure, the latent heat of fuel and the oxygen availability is compensated. So smoke levels are less at 165 bar pressure and all other emissions are in between 180 bar and 165 bar.

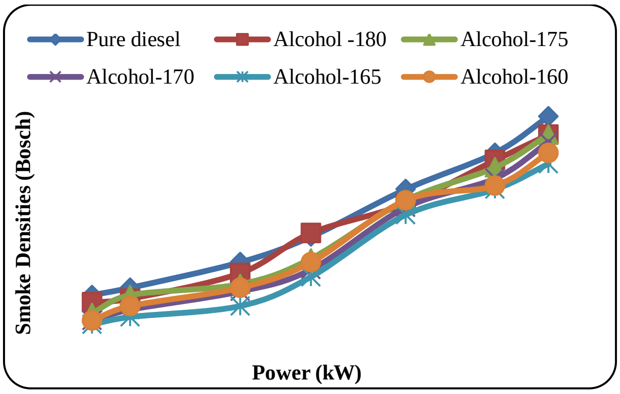


Exhibit 4 Comparison of smoke densities with Power Output for different Injection Pressures

2.3.5 Carbon Monoxide Gas Emissions (CO Emissions)

The deviation of carbon monoxide gas emissions for different injection pressures of the insulated engine is illustrated in exhibit 5. With the elevated combustion chamber temperatures, oxygen in the alcohol the chemical reaction of the carbon monoxide is complete. Hence the CO emissions in the exhaust due to the incomplete combustion reduce significantly. But with higher injection pressures and loads the combustion is incomplete and thus increases the emissions. At 180 bar pressure the emissions are 0.18 %volume and at 160 bar pressure the emissions are 0.15 % vol. The emissions at other different pressures are in between these two extremes.

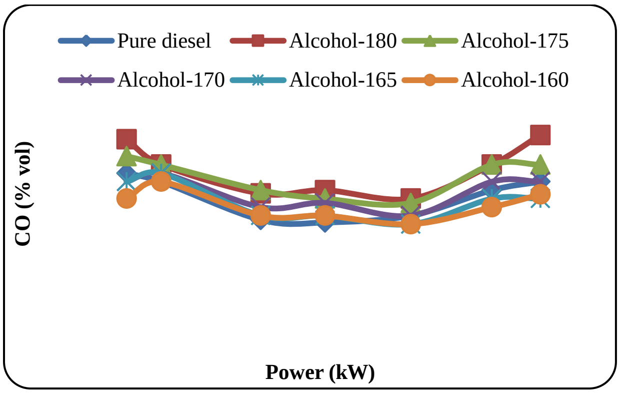


Exhibit 5 Comparison of CO emissions with Power Output for different Injection Pressures

2.3.6 Nitrogen Emissions (NO_X Emissions)

In diesel engine the Nitrogen oxide emission is susceptible to Oxygen present in the fuel, combustion chamber temperatures and spray characteristics. As alcohol itself consists of oxygen, the formation of NO_x emissions within the insulated engine additionally will increase, but it is compensated by the latent heat of vaporization. With the higher injection pressures, the temperature in the chamber is less and this makes the nitrogen inactive and reduces the NOx emissions. These emissions drop with the reduction in the injection pressure. Though the fuel injection pump injects less amount of alcohol at an injection pressure of

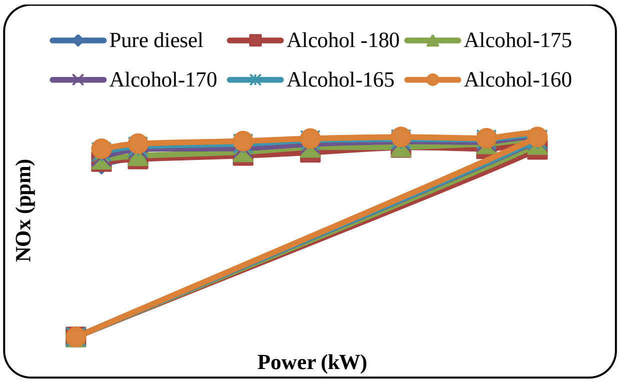


Exhibit 6 Comparison of NOx emissions with Power Output for different Injection Pressures

160 bar, the NOx emissions are higher due to the higher prevailing temperatures in the combustion chamber. The emissions at the remaining injection pressures are in between this two extremes. This is evident from exhibit 6.

2.3.7 Aldehyde Emissions

The aldehydes are the most important pollutants emitted from the alcoholic engine. These aldehydes (if more than 170 ppm) irritate the secretion membranes within the eyes and also the respiratory system of the human beings. The aldehydes form not only in the quench zone but also in the expansion and exhaust process. With the higher prevailing temperatures in the chamber the unburnt hydrocarbons oxidized in to aldehydes. The above exhibit 7 illustrates the variation of aldehyde emissions with power output for varied fuel injection pressures. It's discovered that for the diesel fuel, the aldehydes are less. With the rise of load within the insulated engine, the quantity of alcohol induction is additionally magnified and the aldehydes are exaggerated. This formation will further increase with the amount of fuel injection pressure.

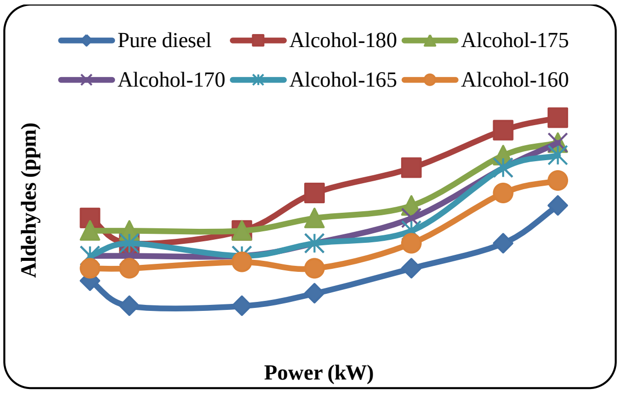


Exhibit 7 Comparison of NOx emissions with Power Output for different Injection Pressures

Conclusions

Based on the above experiment the following conclusions are drawn:

- The pressure developed in the chamber depends on the latent heat, viscosity and fuel injection pressure of the alcohol. At 165 bar fuel injection pressure the pressure developed in the chamber is less than diesel fuel, but is in close agreement with diesel fuel in the insulated engine.
- The thermal efficiency of the engine mainly depends upon the chamber design, viscosity, latent heat of the fuel, injection pressure. At 165 bar injection pressure of alcohol the viscosity and latent heat is compensated and is near to the diesel.
- With the higher loads higher amount of fuel will be injected. But the alcohol absorbs more heat from the chamber and increases the delay and this is compensated by the insulation of the chamber and oxygen content in the fuel.
- The higher prevailing temperature in the combustion chamber increases the combustion rate and reduces the smoke levels.
- Though the oxygen in the fuel acts as a combustion promoter, the CO emissions increases with the injection pressures due to the high latent heat of the fuel.
- The higher temperatures in the insulated engine and the oxygen content in the fuel increases the NOx emissions.
- At higher temperatures the hydrocarbon oxides converts into aldehydes. In this insulated engine the aldehyde emissions increases with the amount of fuel injection pressures.

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