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Investigations on the Performance of Ceramic Insulated Diesel Engine with Diesohol as a Fuel

Dr. S Sunil Kumar Reddy, Dr. V. Pandurangadu, Dr. V. Pratibha

***Abstract*— The global fuel crisis triggered awareness among many countries of their vulnerability to oil embargoes and shortages. Considerable attention was focused on the development of alternative fuel, particularly in terms of emissions and efficiency. With the major advances in the engine technology, the reduction of emissions from engines has become major factor as specified by EPA. Among all the fuels tested more attention is given to the alcohols because these are renewable, ecofriendly and produce less pollutant. But with its high self ignition temperature and low latent heat, the burning of alcohol in the diesel engines at the available compression ratios is difficult. Hence in these substitute fuels, the emulsions of diesel fuel with alcohols have been found to yield some beneficial effects with particular emphasis on emission reductions. So in the present work, a low heat rejection engine is developed which retains heat in the combustion chamber and makes the combustion complete. To explore these benefits of emulsions of diesel and alcohol blends, several experiments are performed with different proportions of ethanol in diesel. Among all the blends 20% ethanol-diesel blends shows best performance in all respects with the insulated engine.**

***Index Terms*— Ceramic engines, Air gap insulation, Low heat rejection engine, PSZ, Alcohol-blends.**

I. INTRODUCTION

The applications of diesel engine are enormous in different sectors and play a key role in the country's economy. In the context of depletion of fossil fuels, ever increase of pollution levels with fossils fuels and increase of economic burden on developing countries like INDIA in importing crude oil, the search for alternate and renewable fuels has become pertinent. The reduction of emissions from the engines has become a major factor in the development of new engines as per the EU. The alternative fuel selected must be replenishable, cheap and easily available. Among many fuels considerable attention was given to alcohol due to its renewable nature. Our country is one of the good producers of sugarcane which is a major one in the production of alcohol. Implementation of alcohol as a fuel in I.C. Engines in INDIA will lead to many advantages like green cover to waste land, support to agricultural sector, rural economy, and reduction in dependence on import crude oil and fall in pollutions. But the alcohols have high self ignition temperature and low latent heat which makes the burning of alcohols in diesel engines difficult at the available compression ratios. So, these fuels can be used in the form of alcohol-diesel fuel blend in the C.I engines. Based on the available literature it is observed that much amount of work has been done on the utilization of alcohol with diesel in the form of blend.

Li et al [1] evaluated the performance of ethanol-diesel fuel blend experimentally by varying the ethanol percentage and concluded that brake specific fuel consumption and brake thermal efficiency increases and smoke emissions reduces with ethanol content in the blend.

Hasimoglu et al [2] concluded from their experiments that due to high operating temperatures in the low heat rejection engines for the blends the brake thermal efficiency, brake specific fuel consumption and exhaust gas temperatures are increased.

Parlak et al [3] showed that in comparison with standard diesel engine, specific fuel consumption was decreased by 6% and brake thermal efficiency was increased by 2%. Further the exhaust gas energy of low heat rejection engine was 3-10% higher than normal diesel engine. Lyne et al [4] reviewed the issues of alcohol-diesel blends with particular reference to safety and distribution, integrity of the fuel delivery, emissions, engine performance and durability. It is concluded that with the oxygenated alcohol the emissions are reduced. Hashimoto et al [8] reported a 5% drop in the maximum fuel delivery with 30% ethanol-diesel blend. Moses et al [9] and Hornbaker et al [5] observed 2-3% improvement in brake thermal efficiency with 10% of alcohol-diesel blend. But from the above experiments it is concluded that the performance of the diesel engine is better with the alcohol-diesel blend.

Lioyd S Kamo et al [6] used porous iron oxide and molybdenum based composite thermal coatings to improve coating strength and tribological properties. This further improves the coating wear resistance. K.A. Khor et.al [11] reported 4 to 7 % improvement in fuel consumption in single cylinder DI diesel engine. This was accomplished by using constant air flow rate with boosting pressure with 1 mm thick PSZ coating to the cylinder head face and the valve heads by placing a short solid PSZ cylinder liner in the area above the piston rings and heat insulated steel piston.

Form above literature it is concluded that the blend performance mainly depend on the combustion chamber temperatures. Due to the high latent heat and self ignition temperature, complete combustion of the fuel is not possible. But combustion can be done at the elevated temperatures in the combustion chamber. So in the present work, a ceramic engine is developed with the insulation of the combustion chamber [2, 3 and 4] with ceramics. The concept of ceramic engine is to provide thermal insulation in the path of heat flow to coolant. This will increase the in-cylinder work and

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Dr.S.Sunil Kumar reddy Associate Professor, Department of Mechanical Engineering, NBKRIST, Vidyanagar, Nellore, Andhra Pradesh
Dr.V.Pandurangadu Professor, Department of Mechanical Engineering, JNT University, Anantapur, Andhra Pradesh
Dr.V.Pratibha, Associate Professor, Department of mechanical engineering, Mallareddy College of engineering, Hyderabad, Andhra Pradesh

the amount of energy carried by the exhaust gases, which could also be recovered.

II. DETAILS OF THE PRESENT INVESTIGATIONS

Diesohol is a mixture of diesel and alcohol (ethanol) in which diesel is present in major portion. Generally ethanol can be blended with diesel; however as the ethanol is water based, in the blend ethanol is immiscible in diesel fuel over a wide range of temperature. This is because of their difference in chemical structure and characteristics. Due to this the fuel is unstable with the phase separation. This can be avoided with the addition of emulsifier.

The main purpose of the investigation is to find the suitability of the insulated engine for alcohol-diesel blends with and without emulsifier. The experiment has the following phases.

1. Production of ethanol
2. Preparation of diesohol
3. Properties of diesohol
4. Preparation of ceramic engine components
5. Results and discussions

III. PRODUCTION OF ETHANOL

INDIA is an agricultural country which has for about 100 million hectares of waste land. These waste lands can be used for the production of sugarcane. Now-a-days farmers are producing sugarcane which is used for the production of sugar. Ethanol has traditionally been produced from molasses, a by-product in the sugar industry. The overall process of producing ethanol consists of the following steps. 1. Crushing 2. Extraction of sugar 3. Fermentation of molasses 4. Distillation 5. Dehydration 6. Denaturing

IV. PREPARATION OF DIESOHOL

Generally, ethanol can be blended with diesel fuel without modifying the engine. Diesohol is a fuel containing alcohol that comprises of blend of diesel fuel and hydrated ethanol. As the ethanol is hydrated, both these are immiscible and results instability in the fuel due to phase separation. So, this separation can be prevented by adding emulsifier. An emulsion is a system of two immiscible liquids, one of which is dispersed throughout the other in small drops. Emulsifying agents include not only soaps, which reduce surface tensions. Emulsions are made by shaking together two liquid phases in the presence of emulsifying agents to form homogeneous mixture. In this present work mechanical homogenizers are used to mix two immiscible liquids to produce very fine droplets of one in the other. In an emulsion, the surfactant serves as an interface between the ethanol-water solution and the diesel fuel. The surfactant used in this work to stabilize ethanol-diesel fuel emulsion is TWEEN 80 LR (poly oxy ethylene sorbitan mono-oleate) Non-ionic surfactant.

V. PROPERTIES OF DIESOHOL

The main important properties of diesohol which affect the combustion are Stability, Viscosity, Density and Cetane number.

A. Stability:

The stability and solubility of ethanol in diesel mainly depends on temperature and water content in the blend. At the higher temperatures these will readily blend and will separate if temperature changes. This separation can be prevented by adding emulsifier or by adding a co-solvent that acts as a bridging agent. In the present experiment emulsifier is used. With the emulsifier the blend is thermodynamically stable with no separation.

B. Viscosity and lubricity

Fuel viscosity and lubricity plays a significant role in the lubrication of fuel injection systems. Lower fuel viscosities lead to greater pump and injector leakage reducing fuel delivery and hence power output. Generally an addition of ethanol to diesel lowers fuel viscosity and lubricity. Speidel and Ahmed et al [12] investigated the effect of blend on viscosity and concluded that the final blend viscosity depends on the amount of diesel fuel added. For the durability of the engine fuel injection system there should be minimum specifications for viscosity and lubricity. In the present experiment the viscosity of the blend is found with Saybolt viscometer.

C. Material compatibility

The amount of ethanol presents in the blend influences the corrosion of various components in the engine particularly fuel injection system, fuel tank and fuel line etc., According to Brick et al [13] the corrosion was divided into three categories i.e general corrosion, dry corrosion and wet corrosion. General corrosion is due to the chloride ions, dry corrosion is due to the ethanol and wet corrosion is due to azeotropic water which oxidizes the metal components. So before the experiment the material compatibility is checked.

D. Calorific Value

The power output of the engine is mainly depending upon the energy content (Calorific Value) of the fuel. As per the Wrage et al [7] the calorific value of the blend should be sufficient enough to use them in the existing diesel engines at different loads and speeds. With the addition of ethanol in to diesel the calorific value of the diesel fuel is dropped. Further the ignition delay is increased which further affected the performance of the engine.

E. Cetane Number

The combustion characteristics of the blend mainly depend on the cetane number of the fuel. Lower cetane number fuel requires will have high self ignition temperatures further longer ignition delays, allowing more time for fuel to vaporize during combustion. morel et al [10] investigated on the isopropyl nitrate ignition improvers with ethanol blends and concluded that though the improver is efficient the improvement in the efficiency is not much. So for the burning of low cetane fuels it requires higher temperatures in the combustion chambers.

F. Safety and Biodegradability

The flammability of alternative fuels during handling and storage is a major concern for the present engines. Speidel and Ahmed et al [12] evaluated the biodegradability of alternative fuels, including a diesel blend with 15% ethanol and 5% additive. They concluded that this blend is more biodegradable than diesel fuel, further due to the sunlight the blend has not shown any residue.

VI. PREPARATION OF CERAMIC ENGINE COMPONETS

For the combustion of ethanol, higher compression ratios and temperatures are needed in the combustion chamber. For achieving elevated operating temperatures in the combustion chamber, the heat transfer from the engine components to the cooling system is to be reduced. So the important engine components are insulated. The detailed method of insulation is explained below.

A. Piston Insulation

In the present experiment 2 mm air gap is provided between piston crown and skirt. This act as an insulator for the heat transfers and retains the heat in the combustion chamber. The figure 1 shows the line diagram and photographic view of the piston crown used in the experiment.

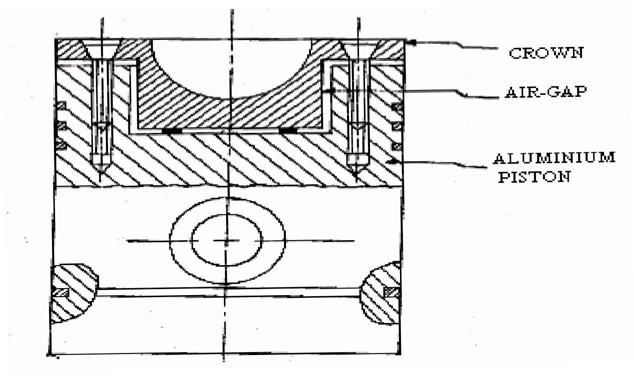

Fig 1: Air gap insulated Aluminum crown
(a) Line diagram (b) photo of Aluminum crown

B. Cylinder Liner Insulation

With the piston movement inside the cylinder an air gap of 2 mm is provided outside the liner. This insulation reduces the heat transfer to the cooling medium.

C. Cylinder Head and Valve Insulation

For the present experiment Ceramic is chosen as the insulating material because of its low density, high thermal stability, stability in severe chemical environment, low thermal conductivity, heat and wear resistant and favorable strength and creep behavior.

In the present work ceramic coating is done on cylinder head and valves. The process involves

1. Pre-cleaning and pre-machining of the cylinder head and valve surfaces to remove rust, scale, paint etc.
2. Ceramic Coating on the component surfaces with plasma spraying technique
3. Final finishing operations like grinding, lapping, polishing and cleaning.

With the above specified method, the cylinder head and valves bottom surfaces are machined to a depth of 0.5 mm and further insulated by coating the area exposed to the combustion with PSZ. The PSZ coated cylinder head and valves are as shown in the above figure 2. All these insulated parts described above are interchangeable with the standard engine parts.

Figure 2: PSZ coated cylinder head and valves

VII. RESULTS AND DISCUSSIONS

The present study was conducted on 5 Bhp single cylinder direct injection water cooled ceramic coated diesel engine.

The diesel and alcohol fuel emulsion was introduced into the fuel tank and was continuously stirred.

Fig. 3: Photo of Insulated Engine Experimental set up

A load test was conducted with emulsifier for different percentage of blends. The results are presented below. The experimental set up and the air gap insulated aluminum piston is shown in figure 3and figure 4. All the tests are conducted at the rated speed of 1500 rpm.

Fig 4: Photo of air gap Aluminum crown piston

A. *Brake Thermal Efficiency*

Exhibit 1 shows the variation of the Brake thermal efficiency with brake power for different ethanol-diesel blends. It is seen from the figure that an improvement in thermal efficiency at higher loads has been achieved during ethanol-diesel fuel operation. This may be attributed to better vaporization of emulsified fuel resulting from higher inlet charge temperatures. The longer delay period allows a larger premix of fuel vapour and air in the cylinder, hence once combustion commences there is large heat release at almost constant volume resulting in a more efficient conversion of heat energy into work. Thus with the complete combustion of the fuel the efficiency increases. This further enhances with the higher prevailing temperatures in the combustion chamber with the insulation of the components. The brake thermal Efficiency with 10% blend and 20% fuel blends are 1.2% and 4.63% higher than diesel fuel at the rated load. The efficiency for 30% blend is in between the efficiency of 10% blend and 20% blend.

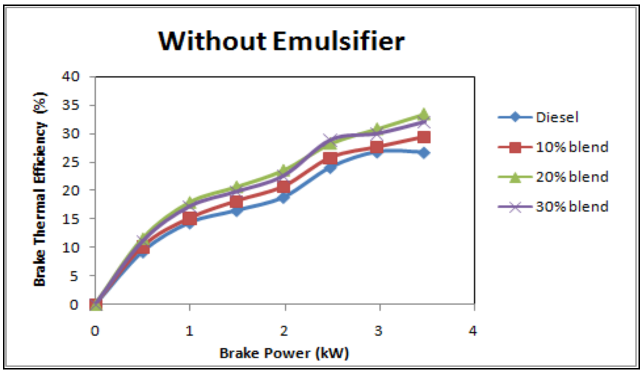

Exhibit 1 Variation of brake thermal efficiency with power output without emulsifier

B. *Specific fuel consumption*

The variation of Specific fuel consumption with brake power output for different ethanol-diesel blends is shown in the **Exhibit 2**. It is seen from the above graph that there is decrease in specific fuel consumption at higher loads. This may due to an increase in delay period due to low residual gas content in the cylinder and lower cooling water temperature resulting in complete combustion. It is observed that at 20 % of the fuel blend the SFC is 3.21% lower than diesel fuel.

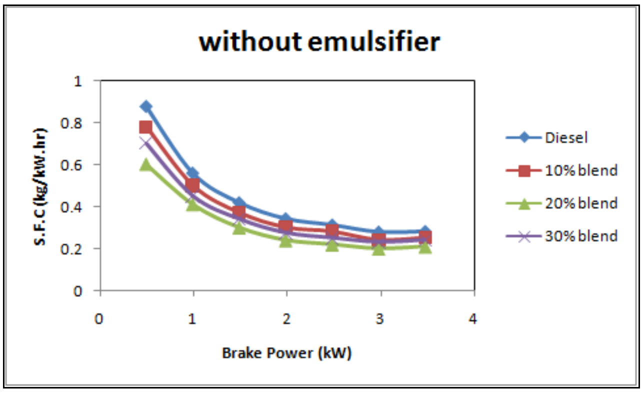

Exhibit 2.Variation of Specific fuel consumption with power output without emulsifier

The rate of decrease of specific fuel consumption is more at part loads than higher loads. This is further attributed to the complete combustion of the fuel blend at the higher prevailing temperatures in the combustion chamber. For 10% blend and 30% blend it is 2.76% and 2.32% lower than diesel fuel.

C. *Exhaust gas Temperature*

The amount of exhaust gas temperature depends on the complete combustion of the fuel in the combustion chamber. **Exhibit 3** shows the variation of the Exhaust gas temperature with brake power output for different ethanol-diesel blends. It is seen from the figure that there is a marginal decrease in the exhaust temperature with ethanol- diesel blends compared to diesel fuel. The reduction in the exhaust temperature is the indication of the advancement

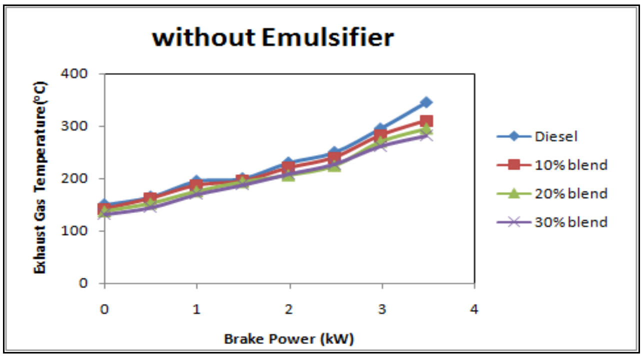

Exhibit 3 Variation of Exhaust gas temperature with power output without emulsifier

of heat release or an increase in the pressure expansion ratio as well as the combined effects of charge cooling and lower flame temperature of ethanol combustion. As all the components of the engine are insulated the heat energy results in the exhaust. This high heat in the exhaust can be recovered by the turbo compounding system. The maximum increase in temperature is with 20% fuel blend and is 5.9% compared to 10% fuel blend.

Exhibit 4, 5 and 6 show the variation of the Brake thermal efficiency, Specific fuel consumption and exhaust gas temperature with brake power output with the addition of emulsifier. From the above graphs, it is observed that

- The Brake thermal efficiency has been increased for all the emulsified blends due to better vaporization and proper mixing of fuels. With reference to the ethanol-diesel blend, brake thermal efficiency of the 20% emulsified ethanol-diesel blend increased from 25.93 % to 27.12 % compared to thermal efficiency without emulsifier.
- The specific fuel consumption of emulsified ethanol-diesel blend is less than that of the ethanol-diesel blend. This is possible due to high temperature prevailing in the cylinder, which increases the combustion efficiency and further leads to the instantaneous higher pressure in the chamber. With the using of emulsifier, the S.F.C has been decreased by 1.32 % with 20% ethanol-diesel blend when compared to the same counterpart without emulsifier.
- The exhaust gas temperature of ethanol-diesel blend has been increased with the complete combustion of the fuel. The rate of increase is 6.23 % for emulsified ethanol-diesel blend compared to the same counterpart

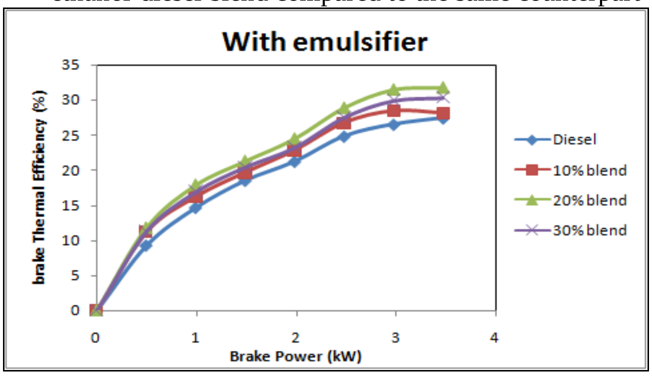

Exhibit 4 Variation of brake thermal efficiency with power output with emulsifier.

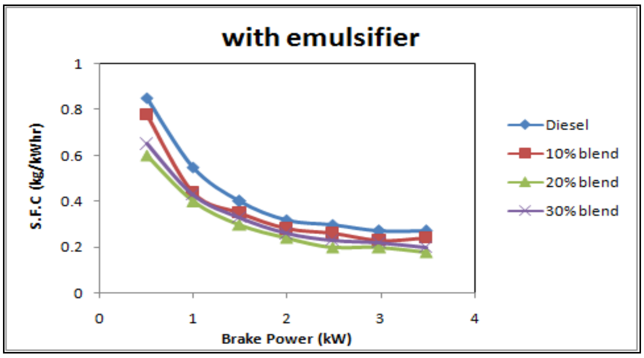

Exhibit 5 Variation of Specific fuel consumption with power output with emulsifier.

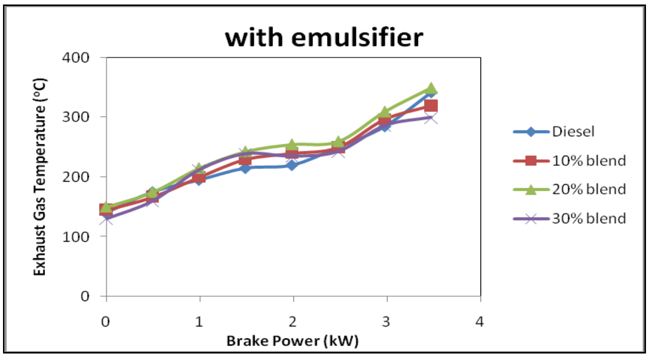

Exhibit 6 Variation of Exhaust gas temperature with power output with emulsifier

D. Exhaust Smoke:

With the inferior operating temperatures and due to the lack of oxygen, the combustion will be incomplete in the combustion chamber and this may cause for the smoke in the exhaust. Visual observation of engine exhaust shows reduced smoke with emulsified fuel. When ethanol is added in the diesel fuel it increases the ignition delay. Therefore, more fuel is burnt in second phase of combustion known as rapid combustion. Smoke being generated mainly in diffusive flames; evidently it will be less due to less fuel available for diffusive burning when ethanol is added to diesel fuel. Further with the inherent oxygen content in the ethanol; emulsifier and higher operating heat causes for the complete combustion and oxidation of the soot particles which reduce the smoke emissions.

VIII. CONCLUSIONS:

Following are the conclusions drawn based on the experimental results obtained while operating single cylinder ceramic insulated air gap diesel engine fuelled with ethanol and diesel blend.

- The experimental results show that it is possible to use an emulsion of hydrous ethanol and diesel fuel to operate diesel engine with a minimum modifications of the engine.
- Ethanol can be used as power booster by making higher degree of air utilization.
- Use of ethanol-diesel fuel emulsion results in a clean exhaust.

- The exhaust gas temperatures are lower with ethanol-diesel fuel emulsion.
- From the above results it can be concluded that it is advantageous to use 20% ethanol- diesel blend at present without any modifications of the engine.
- The effect of high self ignition temperature and latent heat of ethanol-diesel fuel blend are compensated with higher prevailing temperatures in the combustion chamber.

With the burning of alcohol in diesel engine, it can be considered as a preferable replacement for diesel fuel thereby promoting our economy and makes the farmers self sufficient.

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I am **Dr. S.Sunil Kumar Reddy**, working as an Associate professor in the department of Mechanical Engineering, NBKR Institute of science & Technology, Vidyanagar, Nellore , Andhra Pradesh, INDIA. I completed my M.Tech in thermal Engineering and P.hD in the area of alternate fuels from JNT University, Anantapur, Andhra Pradesh. I published 10 articles in various national and international conferences and 19 research papers in various national and international journals.