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Effects Of Additives On The Performance And Emission Characteristics Of A Alcohol Fuelled C.I Engine Using Glow Plug

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Abstract : Alcohols posses low cetane numbers as compared to diesel fuel. Low cetane fuels delay the combustion. Conventional diesel engines with alcohol as fuel are associated with problems due to high self-ignition temperature of the fuel. The hot surface ignition method, where in a part of the injected fuel is made to touch an electrically heated hot surface (glow plug) for ignition, is an effective way of utilizing alcohol in conventional diesel engines. The purpose of the present study is to investigate the effect of thermal insulation on methanol and ethanol fuelled compression ignition engine. One of the important alcohols properties to be considered in the high compression ratio engine is the long ignition delay of the fuel, normally characterized by lower cetane number. In the present study, the ignition delay was controlled by partial insulation of the combustion chamber (low heat rejection engine) by plasma spray coating of yttria stabilized zirconia. Additives play a major role in improving the performance and emission characteristics of a compression ignition (C.I) engine fuelled with alcohols. It is known that operating C.I engines with 100% alcohols. Innovative research revealed that certain additives have to be added to the alcohol fuels by carrying out combustion process in a combustion chamber using glow plug. Traditionally compression ignition combustion chambers were designed using cast irons. Cast iron combustion chambers are bulky so much of the heat generated by the combustion will be absorbed by the cylinder block. Cold start becomes difficult. In the present investigation a detailed literature review results have been presented, A four stroke CI engine is converted into hot surface ignition engine using a glow plug hot surface and tested by providing different piston crown materials. Methanol and Ethanol fuels are selected with an objective to find the best one in terms of performance, emissions and combustion parameters. It is planned to use this best piston crown material for further investigations such as the effect of additives and other operating parameters. It is also planned to investigate the use of these alcohols as fuels in a LHR engine. And the fuels with best additives are planned based on locally available technology

Keywords: Methanol, Ethanol, Different Crown Materials, Surface ignition, Glow Plug, Low Heat Rejection Engine, Additives.

I. Introduction

Alcohols were quickly recognized as prime candidates to displace or replace high octane petroleum fuels. The scarcity of transportation petroleum fuels due to the fast depletion of the petroleum deposits and frequent rise in their costs in the international market have spurred many efforts to find alternatives. The concept of using alcohol fuels as alternative to diesel fuel in diesel engine is recent one. However, alternatives to the large demand for diesel fuel in many countries were not so evident. Innovative thinking led to find varies techniques by which alcohol can be used as fuel in diesel engine. Amongst the fuel alternative proposed, the most favourest ones are methanol and ethanol. So far no established method is available to run a normal diesel engine with a compression ratio from 14:1 to 20:1 by using alcohol as fuel. This is because, the properties of diesel engine fuels. The specific tendency of alcohols to ignite easily from a hot surface makes it suitable to ignite in a diesel engine by different methods. The advantage of this property of alcohols enables to design and construct a new type of engine called surface ignition engine.

Alcohols by virtue of own their very nature do not make good CI engine fuel. But they have peculiar property of igniting over a hot surface at a low temperature in spite of their high self – ignition temperature. It is this tendency of alcohol that has been exploited in developing the surface ignition Diesel engines, unlike gasoline engines, do not use spark plugs to induce combustion. Instead, they rely solely on compression to raise the temperature of the air to a point where the diesel will combust spontaneously when introduced to the hot high pressure air. The high pressure and spray pattern of the diesel ensures a controlled, complete burn. The piston rises, compressing the air in the cylinder; this causes the air's temperature to rise. By the time the piston reaches the top of its travel path, the temperature in the cylinder is very high. The fuel mist is then sprayed into the cylinder; it instantly combusts, forcing the piston downwards, thus generating power. The pressure required to heat the air to that temperature, however, necessitates the use of a large and very strong engine block. The temperature at the top of the compression stroke is dependent upon many factors, the most influential of which are the compression ratio of the cylinder and the starting temperature of the inducted air. When the engine is cold, the temperature of the inducted air is low and it receives little heat from the engine cylinder walls. In addition, as the air is compressed and becomes heated, some of this heat will be given up to the cold cylinder walls, further reducing the temperature at the top of the compression stroke. This problem is solved by the glow plug. Under these cold conditions, the glow plug is temporarily activated to add a hotspot within the combustion chamber until the residual temperature of the combustion chamber achieves the level required to support self-combustion. For that reason indirect injected diesel engines are manufactured with glow-plugs in each pre chamber, and direct injected diesel engines are manufactured with glow-plugs in each combustion chamber. The glow plugs used in model engines are significantly different from those used in full-size diesel engines. In full-size engines, the glow plug is used only for starting. In model engines, the glow plug is an integral part of the ignition system because of the catalytic effect of the platinum wire.

II. Alcohol as a fuel for IC Engine

Methyl alcohol (CH_3OH) and Ethyl alcohol (C_2H_2OH) are promising alternative fuels to liquid petroleum fuels for the following reasons.

1. They are both liquids at room temperature and hence as convenient to handle as petrol or diesel oil.

2. They can be produced from raw materials like coal, Natural gas and plant material like sugar cane, corn etc. These raw materials are either renewable or plentifully available as fossil fuels

3. Many of the properties of the two are similar to those of petrol or diesel oil.

1. Production

Because they are available plentifully in nature, the alcohols chosen as future alternative fuels for motor vehicles.

1.1 Methanol

Methanol was originally produced by the destructive distillation or wood alcohol. At present, most of Methanol is produced from Natural gas, whose main constituent is Methane. Methanol production offers a solution for utilizing plentiful natural gas sources, which are far away from industrial areas. Methanol can also be produced from bio mass.

1.2 Ethanol

Ethanol is the next higher member of the alcohol family to Methanol. It is produced mainly by the fermentation of plant derived materials. Its principal current uses are the production of alcoholic beverages and to a lesser extent in the chemical industries. It can also be produced by the synthesis of Ethylene and water gas Ethanol can be produced from the following different sources. Sugar containing materials like sugar cane, molasses, and sugar beet. Starch containing materials like corn, potatoes and cassava

2. Properties of Methyl and ethyl alcohols concerned to IC engine applications

Methyl and Ethyl alcohols have a hydroxyl major (OH) in their structure and hence are sometimes called as "oxygenated fuels" lists the important properties of the alcohols in comparison with those of typical samples of gasoline and diesel oil.

Table 1 Fuel properties of Methanol, Ethanol and Diesel fuels

CHEMICAL PROPERTY	Methanol	Ethanol	Diesel
Formula	CH_3OH	C_2H_5OH	$C_nH1.86_n$
Molecular weight (g/mol)	32	46	13.86n
Mainconstituents by weight: % Carbon	32	56	82
% hydrogen	12	13	13
%oxygen	50	35	---
% sulphur	---	---	0.8
PHYSICAL PROPERTIES			
Density (kg/m^3)	0.79	0.79	0.84
Viscosity at 20^0C mm^2/s	4	1.5	0.75
Boiling temperature	65	78	180-360
COMBUSTION PROPERTIES			
Lower calorific value(MJ/kg)	19.7	26.8	42.5
Specific latent heat of vaporisation (kj/kg)	1110	904	250
IGNITION PROPERTIES			
Auto ignition temperature	450^0C	420^0C	250^0C
Cetane number	3	8	50-55

The density of the two alcohols is in the same range as gasoline or diesel oil. The latent heat of vaporization is much higher for the alcohols, more so for Methanol. This has some significance when they are used as IC engine fuels. It makes the starting in SI engines more difficult, particularity in cold weather. The high self – ignition temperature of the alcohols (reflected in their low cetane numbers) and their high latent heat of evaporation make them poor fuels for diesel engines, which depend on self – ignition of the injected fuel. Hence it is impossible to use Methanol or Ethanol as CI engine fuels without either modifying the engine or the fuel. When the Ethanol is blended with gasoline, the octane rating can be improved. This is a possible way of retaining the knock resistance of present day gasoline, without using Tetra Ethyl lead (TEL) which leads to exhaust emissions of lead oxides. The behavior of Methyl alcohol and Ethyl alcohols as engine fuels is quite similar. However, from the safety angle, methyl alcohol has to be handled with much greater care. It is a deadly poison when consumed by human beings. In lower amounts of consumption it can lead to blindness and other types of health damage. Inhaling methanol vapour, physical contact of Methanol with eye, skin etc; have to be carefully avoided

III. Use of alcohols in diesel engines

Due to their high self- ignition temperature and high latent heat of vaporization, Methyl and Ethyl alcohols make poor CI engine fuels. Consequently either the engine has to be modified or the fuel has to be modified. The following methods are available for using alcohols as fuels in CI engines.

1. Use of very high compression ratios.
2. Use of ignition accelerating fuel additives.
3. Alcohol – diesel emulsion.
4. Dual fuel system.
5. Surface ignition system.

3.1 Use of very high compression ratios

The normal compression ratio used in CI engines 16-20, us insufficient to self – ignite alcohols. It is necessary to raise it to 25-27 to achieve compression ignition of Methanol or Ethanol. Such a high compression ratio makes the engine very heavy and hence this solution is not generally favoured.

3.2 Use of ignition accelerating fuel additives.

Additives play a major role in improving the performance and emission characteristics of a compression ignition (C.I) engine fuelled with alcohols. It is known that operating C.I engines with 100% alcohols. Innovative research reveld that certain additives have to be added to the alcohol fuels by carrying out combustion process in a combustion chamber using glow plug. Traditionally compression ignition combustion chambers were designed using grey cast irons, cast iron combustion chambers are bulky and have poor thermal conductivities. Much of the heat generated by the combustion will be absorbed by the cylinder block. Cold start becomes difficult.

Additives can enhance the cetane number of the alcohols and make them suitable for operation in normal diesel engine. By adding 15-20% by volume of Cyclohexyl nitrate to Methanol or Ethanol brings the cetane number to 40-50 range which is acceptable for commercial diesel engines. The addition of hexyl nitrate as an additive to alcohols, reduces the ignition delay, which must be low for a diesel fuel.

Iso – amyl nitrate, kerobrizol, Ethylene glycol etc., have been identified as good ignition improving additives. Angsar J.Schaefer et al have concluded form their tests that there is no definite correlation between the cetane number and ignition quality in engine tests for the additive added alcohol. Though additives are generally nitrogen – bound compounds, they have not been found to produce high No_x levels.

The advantage of these additives is that no engine modification is necessary to use the alcohols. However, they are quite expensive and have to be added in fairly large proportions. 3.3 **Alcohol – Diesel Emulsion**

Another solution which has been investigated is the use of alcohol- diesel oil emulsions, produced by chemical or mechanical mixing in the performance of this system, when the proportion of Methanol in the emulsion increases, the thermal efficiency fails, more prominently at low speeds, but at full output the efficiency increase. The same tendency is noticed with Ethanol. Pischinger has found that for operation without additional ignition aids the maximum diesel substitution could be 30%.

3.4 Dual Fuel System

Dual fuelling is another solution to use alcohol in diesel engines. Here alcohol is mixed with the air inducted into the diesel engine, compressed and then ignited by a spray of diesel oil. A minimum amount of diesel oil is necessary to sustain ignition. J.B. Heisey et al found significant differences between the performance of methanol and Ethanol and also with increase in water content in these alcohols. Panchapakesan et al have found that up to 70-80% alcohol substitution is possible. Govindarajan et al have conducted dynamometer and road tests on an automobile diesel engine using novel device to control the alcohol to diesel ratio and have been able to substitute as much as 48% diesel.This method can also be used for reduction of smoke emissions. When alcohols or gaseous fuels like LPG are inducted into the diesel engine, the smoke emissions immediately go down.

3.5 Surface ignition system

Methyl alcohol and Ethyl alcohols can also be ignited in a diesel in a diesel engine with the help of surface ignition. In this type of ignition, the injected fuel ignites not by compression ignition but by contact with the hot surface maintained within the engine. Since Methanol and Ethanol are very susceptible to surface ignition {pre-ignition in SI engines), this method is suitable to these fuels. The hot surface ignition engine is reported to have better multi fuel capability than its spark assisted counterpart.

3.5 Modification of test engines

Use of ethanol in diesel engines is associated with problems on account of their low cetane numbers, low viscosity and poor miscibility with diesel, higher latent heat of evaporation and also need a compression ratio of 23:1 for starting and 20:1 for normal running. To use ethanol in diesel engine assistance in the form of a timed spark or a hot surface is needed. In the present investigation, glowplug was used for ignition assistance. Ethanol was used as a sole fuel in the normal and LHR engine to study the characteristics of glowplug assisted ceramic coated engine.

Plasma spray process

Material in the form of powder is injected into very high temperature plasma flame, where it is rapidly heated and accelerated to a high velocity. The hot material impacts on the substrate surface and rapidly cools forming a coating. Plasma gun comprises a copper anode and tungsten cathode, both of which are water cooled. Plasma gas (argon, helium, nitrogen, hydrogen) flows around the cathode and through the anode which is shaped as a constricting nozzle. Atmospheric plasma spray coating method was used to coat the combustion chamber components. As for plasma gas, a mixture of argon (Ar) and nitrogen (N2) was used. The coating materials and the parameters of plasma spray are given in Table 2. The conventional combustion chamber of a diesel engine was insulated with yttria stabilized zirconia of 0.3 mm thickness. Thermal insulation of the combustion chamber was provided to have a hotter environment for the combustion of ethanol in order to avoid the problems that will occur due to the low ignition quality of ethanol and its latent heat of vaporization. Figure 1 shows the photographic view of insulated engine components. Cylinder head, piston, exhaust and inlet valves of the diesel engine used in the tests were coated with yttria stabilized zirconia (Y_2O_3–ZrO_2). Engine piston, cylinder head and valves were coated by plasma spraying technique. The thickness of coating was selected as 0.3 mm, within the optimum range of thickness 0.1–1.5 mm. Cylinder liner was

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not coated because of very negligible area. Combustion chamber geometry was maintained by machining the components before ceramic coating. In the conventional diesel engine the hot air that prevails at the end of compression stroke is sufficient for igniting the diesel fuel. But due to higher self-ignition temperature of ethanol (695 K) ignition assistance must be provided. In the present work, a glowplug of MICO 12 V single pole sheathed type has been installed in the cylinder, so as to increase the temperature in the cylinder by passing electric current through the glow plug, thereby improving starting characteristic of the engine. A helical heating wire is embedded in a powder of heat resistant electric insulation packed tubular sheath made of heat resistant metal in the glowplug. The glowplug is screwed into the combustion chamber to supply additional heat to air during compression stroke and to vaporize the fuel which impinges on it. The protrusion of the standard glowplug into the combustion chamber is not sufficient for the fuel spray to impinge on the glow plug. So, the glow plug was machined in such a way that the protruding part of the glow plug could be increased for better impingement of the fuel spray. Fig. 2 shows the location of the glow plug in the cylinder head and the combustion chamber configurations.

Figure 1: Zirconium Oxide coated piston and head

Key Properties of Zirconium Oxide:

- Use temperatures up to 2400°C
- High density
- Low thermal conductivity (20% that of alumina)
- Chemical inertness
- Resistance to molten metals
- Ionic electrical conduction
- Wear resistance
- High fracture toughness and high hardness.

Table 2: Engineering Properties:

Density	6	gm/cc
Elastic Modulus	200	GPa
Hardness	1300	Kg/ mm^2
Thermal Conductivity	2	W/m°K
Coefficient of Thermal Expansion	10.3	10^{-6}/°C

3.8 Glow plug: Glow plug is a heating device used for aid starting the diesel engines. The other names for glow plug are glow-plug and glow plug. High speed diesel engines are difficult to start in cold weather because the mass of the cylinder block and the cylinder head absorbed the heat of compression thereby preventing the ignition which relies on the heat. Pre- chambered engines make use of small electric heaters inside the pre-chamber where as the the direct-injected engines have these glow plugs in the combustion chamber itself. the glow plug is pencil-shaped piece of metal with a heating element at the tip. This heating element, when electrified, heats due to its electrical resistance and begins to emit light in the visible spectrum, hence the term glow plug. The visual effect is very similar to that of a toaster. The fuel injector spray pattern then impinges directly upon the hot tip of the glow plug during the injection of fuel at top dead centre. This enables the fuel to ignite even when the engine is insufficiently hot for normal operation. this reduces the cracking time needed to start the diesel engine.

The engine is fitted with glow plug, details of which are described in the subsequent sections.

3.6 Modification to accommodate glow plug

A conventional glow plug is fixed on the normal engine cylinder head on the down streamside of one of the fuel sprays as close to the nozzle as possible.

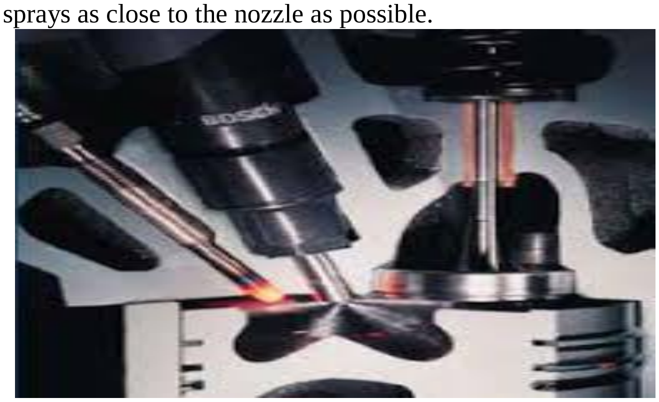

Figure 2. Sectional view of piston cylinder assembly showing the glow plug and fuel injector arrengements.

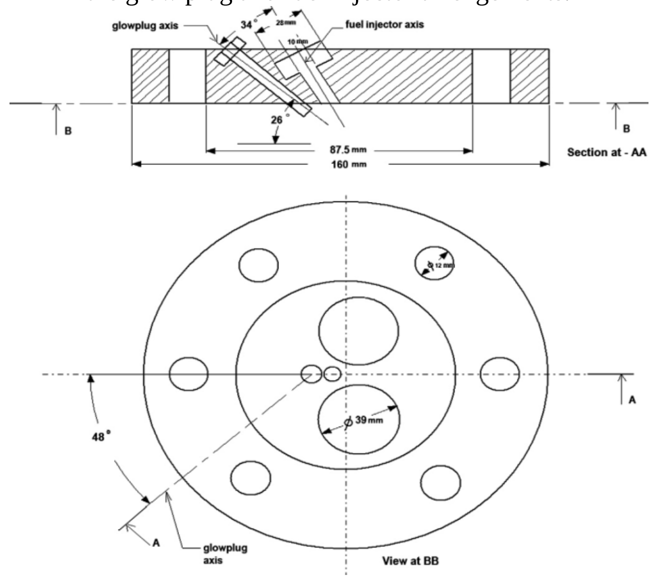

Figure 3: shows the location of glow plug on the cylinder head with respect to the injector and combustion chamber.

3.9 Low Heat Rejection (LHR) Engine: Energy conservation and emissions have become of increasing concern over the past few decades. As automobiles are one of the major sources of energy consumption and urban

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emissions, engineers concerned are under significant pressure to improve their energy efficiency and reduce exhaust emission levels. While tremendous effort has been devoted in improving performance and reducing emissions of current engines, new technologies are also getting attention. One example is the Low Heat Rejection Engine (LHRE). A technological thrust is currently in progress to develop insulated, low heat rejection engines which exhibit higher thermal efficiency and improved exhaust emissions. The low heat rejection engine concept is not new. For the past two decades many have conducted experiments on low heat rejection engines. Although promising, the results of the experimental investigations have been somewhat mixed.

The concept of low heat rejection (LHR) engine aims to reduce the heat transferred to cooling system. So this energy can be converted to useful work. Some of the major advantages of LHR engines are as follows: Better fuel economy, increased engine life, reduction in HC, CO and PM emissions, and lower combustion noise due to reduced pressure increasing rate, increased exhaust gases energy and ability of operating low Cetane fuels.

Various forms of LHR:

- Ceramic coated piston- low degree of insulation.
- Ceramic coated piston, cylinder head and liner.
- Air gap insulated piston engine.
- Air gap insulated piston, air gap insulated liner engine.
- Air gap insulated piston, air gap insulated liner and ceramic coated cylinder head engine- high degree of insulation.

Alcohols in LHR engine

The plain engine is modified by fitting with a PSZ coated cylinder head and liner. Then the existing aluminum piston is replace by a cast iron piston with an air gap. These air gap surface are coated with PSZ. Also the crown of the piston is coated with PSZ. These tests are conducted with Methanol and ethanol as fuels in GHSI engines as usual.

IV. Experimental analysis

Experiments were conducted on the standard Diesel engine in various combinations of piston crown material .

The engine was operated under no load for the first 20 minutes and for each load the engine was operated long enough to stabilize the condition.

All the tests were conduct at the rated speed of 1500 rpm. From the observed readings, the parameters of brake power, brake thermal efficiency, brake specific consumption, peak pressure, rate of pressure rise and ignition delay and emission parameter were evaluate.

The Aluminium piston engine is chosen as a base engine. Then four piston crown material (**Bronze, T**itanium**, Copper, Nimonic alloy**) are tried by changing different pistons. In all these engines **alcohols are use** as fuel in order to evaluate the performance characteristics.

The Experiments are Carrying out in the Following Types.

1. With Different Piston Crown Materials.
   - Normal Aluminium piston
   - Bronze Crown Aluminium Piston
   - Copper Crown Aluminium Piston
   - Nimonic alloy Crown Aluminium Piston
   - Titanium Crown Aluminium Piston
2. Five fuel additives used in the best performed **(Glow Plug Surface Ignition)** GHSI engine
3. Conversion of best performed GHSI test engine in to LHR Engine With best additive

Piston: The total height of the standard piston was 110 mm and this height had to be maintained in the insulated piston. The height of the standard piston was reduced by 7mm in order that the total height of the modified piston including the crown (7 mm).

Figure 4: Photographic view of Normal Aluminium piston

Different Types of Piston Crown materials

Figure5: Photographic view of Bronze crown

Figure 6: Photographic view of copper alloy crown

Figure 7: Photographic view of Titanium crown

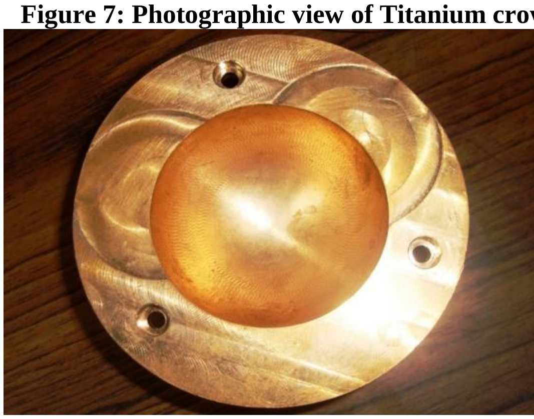

Figure 8: Photographic view of Nimonic alloy crown

Properties of Deferent Piston Crown Materials

Materials	Density Kg/m^3	Thermal conductivity (k) W/mk	Melting point ^{0}C	Specific heat kj/kg.k	Coefficient of thermal expansion 10^{-6} m/m/k
Bronze	3.93	34	660	0.9	7.4
Copper	8.94	339	900-950	0.395	17.7
Titaniumalloys	8.33	11.2	1390-1423	0.445	12.7
Nimonic alloys	8.52	121	900-950	0.38	20.1

V. Conclusion

1. After a careful review of literature, the present work is planned with the following objectives. A four stroke CI engine is converted into hot surface ignition engine using a glow plug hot surface and tested by providing different piston crown materials. Methanol and Ethanol fuels are selected with an objective to find the best one in terms of performance, emissions and combustion parameters. It is planned to use this best piston crown material for further investigations such as the effect of additives and other operating parameters. It is also planned to investigate the use of these alcohols as fuels in a LHR engine. And the fuels with best additives are planned based on locally available technology.

2. Among the various modes of operation, it is inferred that, alcohols with copper crown plasma sprayed glow plug assistance in LHR mode has better performance characteristics as compared to other crown piston materials.

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