Experimental Investigation on Diesel Engine Using Alcohol Based Fuel with Piston Modification

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Abstract- **The world-wide search for the alternative fuels has simulated in the recent years due to the petroleum crisis and also emphasized the need for using petroleum fuels with utmost economy. This recognizes the alcohols as a preferable replacement because these are derived from renewable indigenous sources. As our India is an agricultural country, the production of sugar cane is more which further used for the production of alcohols. However, with its low cetane number and high latent heat of vaporization, the burning of alcohols in diesel engines is difficult. But they can be ignited in the high temperature combustion chambers. This tendency of alcohols is being used for the development of the insulated engine (IE) which reduces the ignition delay and aids combustion. In this, the combustion chamber surfaces are thermally insulated for improving fuel efficiency and to reduce the emissions. With the low viscosity of alcohols more fuel will be injected in to combustion chamber at the available fuel injection pressure which leads to the problem of injection and equipment wear and tear. So, for evaluating the performance parameters and to find the fuel injection pressure at which the normal diesel engine has better performance characteristics, a comprehensive simulation model for the diesel engine is developed. This fuel injection pressure is further used for the experimental investigations. In the present work the following modifications are done to the engine for improving the performance. The piston of the test engine is insulated by incorporating an air-gap between the crown and the piston body. The cylinder liner is provided with an air-gap all around its outer surface with the help of a cylindrical sleeve. Alcohol (Ethanol) is used as fuel in all these configurations to find out the performance.**

I. INTRODUCTION

Few years ago, the energy crisis was merely a gloomy prediction for the future and a topic of casual discussion. But to-day it is a palpable and fear some reality and for the people all over the world very much a subject of grave concern. The world over to-day research is in progress to find new, easily available, abundant, less pollutant and renewable energy resources which will hopefully supplement and satisfies emission standards and finally replace our conventional energy supplies. It would, however, take a few decades of intensive research work to find a satisfactory alternative for petroleum and in the mean while it is necessary to use the available energy prudently. Another possible way of energy conservation would be to limit the use of petroleum by substituting other fuels like hydrogen, alcohol, bio-gas etc. This chapter presents a discussion of fuel characteristics, both favorable and unfavorable that must be considered in making long-range decisions about alternatives to petroleum fuels.

Alcohols- Suitableness as Alternate fuel

Of the four suitable alternate fuels, the alcohols are one of the fuel which exists as liquids under atmospheric conditions and can also be produced from raw materials like coal, natural gas and sugar cane etc. These raw materials are either renewable or plentifully available as fossil fuels. Many of the properties of alcohols are similar to that of petrol and diesel fuel. These alcohol fuels can used conveniently for the automotive applications and can also be easily transportable. As the alcohols doesn't have sulphur, the exhaust is also free from sulphur dioxide. The accidental fire can be easily put out with alcohol and water mixture, as they are readily dissolve rather than spreading as an insoluble layer or film. The alcohols have great potentiality as an alternative energy source, particularly in countries like India which are rich in coal and have fertile soil, abundant sunlight and good rain fall. Among all, alcohol is quickly recognized as prime to replace petroleum fuels.

II. EXPERIMENTAL INVESTIGATIONS

A detailed study is carried out as a preliminary to the design of the insulated components. The choice of materials and the design are influenced by the following factors.

- The material chosen for insulation should be a good insulating medium with a low thermal conductivity.
- Insulation of combustion chamber surfaces would increase the operating temperature of the engine and the material has to be capable of withstanding high temperatures.
- Higher pressures within the combustion chamber demand a material with good mechanical strength.
- Under operating conditions the material would be directly exposed to the high temperature combustion gases and the material has to be chemically stable under these conditions i.e. it has to offer resistance to oxidation and corrosion.
- The material chosen has to be easily machinable using available technology thus eliminating the need for complicated and expensive machining techniques.
- Availability of the material within India would facilitate implementation of low costs.

III. DEVELOPMENT OF INSULATED ENGINE.

The following are the three methods adopted for the insulation of diesel engine to reduce the heat losses.

1. Air Insulation 2. Ceramic Coatings 3. Piston inserts

CYLINDER LINER INSULATION

As the piston is reciprocating inside the engine cylinder, it is difficult to insulate the cylinder liner on its inner surface. Hence, it is decided to insulate the outer surface of the liner by coating with PSZ and by providing air-gap.

CYLINDER HEAD INSULATION

The area exposed to the combustion (80 mm diameter) in the Combustion chamber area to be coated is machined to a depth of 0.5mm and coated with an equally thick layer of PSZ as explained previously. It requires exceptionally good adherence of PSZ coating because of the high gas pressures acting on the cylinder head during the combustion process. The adherence qualities of PSZ layer over cast iron surface deteriorates with increasing the thickness. So the thickness of the PSZ layer could not be increased further. The cylinder head surfaces are then blasted with sand to form innumerable pores.

The valves and the hole for injector nozzle occupied about 35% of the total area of the combustion chamber surface and the remaining area is coated with PSZ. The formation of deposits (soot & carbon) on the head insulated with PSZ is lower the standard head due to increased operating temperatures in the combustion chamber.

Fig. Photograph Graphic Read of PSZ Coated plate

IV. PISTON INSERT

In the combustion chamber, maximum heat transfer is through the piston. So for increasing the thermal efficiency this loss is to be reduced. As higher temperatures are generating in the combustion chamber, the piston crown is to operate at high temperatures and high pressures. Further the fabricated piston is to be similar to the original piston with respect to dimensions and the shape of combustion chamber. The selection of the metal for the crown should be such that the metal is able to withstand for high temperature, high pressure and offer resistance to oxidation and corrosion. For this, various piston materials like Nimonic alloy, Copper alloy, Brass, Cast Iron are taken and made them as piston inserts. The above metals possess good thermal conductivity and thermal capacity so that they act as good heat regenerators.

Fig. Photograph Graphic read of Aluminum Piston with Brass Crow

All the insulated parts described above are interchangeable with the standard engine. The various results of these investigations are presented in the following chapters.

EXPERIMENTAL SETUP AND MEASUREMENT

The information regarding various components of the engine, modifications carried on them, the instrumentation used for experimentation is discussed in this chapter. The experimental set-up is designed to suit the requirements of the present investigations. Transducers like needle lift pick up, optical pick up and necessary electronic devices are used during the course of experimental work. The layout of the experimental setup is shown in Fig. The main components of the system are explained below.

ENGINE

The test engine used is a single cylinder, water cooled, vertical, direct injection compression ignition engine of Kirloskar make.

Reasons for Selecting the Engine

This engine can with stand for higher pressures encountered and also used extensively in agricultural and industrial sectors. Therefore this engine is selected for carrying experiments. Moreover necessary modifications on the piston and the cylinder head can easily be made.

Modification of Test Engine

The diesel engine is converted into an Insulated engine by applying PSZ coating on the cylinder head, Valves and Liner. Five different pistons (aluminum, Nimonic alloy, Copper alloy, Brass and Cast Iron) are used along with PSZ coated cylinder head, Valves and cylinder liner.

Dynamometer

The engine is connected to a swinging – field electrical dynamo meter with Ward – Leonard control which allowed the engine to be started and motored as well. The load is controlled by changing the field current. The load is read from the dynamo meter scale and the power absorbed is calculated.

Speed Measurement

The speed is measured using an electro-magnetic pick up in conjunction with a digital indicator of AQUTAH make. A magnetic pickup is fitted close to the flywheel with pins fixed on the periphery. The signals generated are fed to the display unit, which is calibrated to indicate the speed directly in number of revolutions per minute (rpm).

Measurement of Fuel Consumption

Fuel is supplied to the engine from the fuel tank through the burette. The rate of the fuel flow is measured by timing the consumption for a known quantity of fuel i.e. 20 cc from the burette.

Air Flow Measurement

The air flow rate is measured by observing the time taken for consumption of a known volume (0.5 cu.m) of air using an air flow meter working on the reversed roots blower principle. This meter is of Elster AG make and has a maximum flow rate of $25m^3/hr$. The inlet of the air flow meter is fitted with an air filter.

Exhaust Gas Temperature Measurement

A Nickel-Nickel Chromium thermocouple fitted to the exhaust pipe of the engine close to the cylinder head is used for measurement of exhaust gas temperature.

Smoke Density Measurement

The smoke density is measured with a Bosch Smoke meter. A known quantity of exhaust gas (330 ml) is drawn into the pump through a white filter paper. The carbon in the exhaust gas darkens the filter paper. The stain made on the filter paper is evaluated by means of a photo-cell reflectometer unit to give a precise assessment of the intensity of the stain. The intensity of the stain is measured on a scale of ten arbitrary units (0-10) with 0 signifying pure white smoke and 10 indicating pure black smoke.

General Working of the Setup

An inductive pickup is used to get a TDC signal from a disc mounted on the engine camshaft extension. Metallic protrusion is made on the disc corresponding to the TDC mark. By triggering inductive pickup, the data recording can be started. The inductive pickup is attenuated appropriately to a level compatible with the recording instrument.

Measurement of Combustion Characteristics

A KISTLER make quartz piezo electric pickup unit is fitted to the cylinder head by means of a suitable adaptor. The pickup communicates to the combustion chamber by means of a 1mm diameter hole drilled on the cylinder head, and is constantly cooled by a stream of fresh water. The signals sensed by the pickup are sent to a charge amplifier of KISTLER make. The pressure pulses after amplification are fed to the signal analyzer and this is used for analyzing the various combustion parameters such as peak cylinder pressure, occurrence of peak pressure, start of the combustion and ignition delay.

Lubricating Oil Temperature Measurement

Lubricating oil temperature is measured by Nickel-Nickel Chromium thermocouple. The engine sump is of 3.5 liters capacity. The level of lubricating oil in the sump is checked periodically.

Exhaust Gas Analyzer

A gas analyzer (Delta 1600S), for evaluation of the pollutants in the exhaust gas is attached to the engine. This analyzer is used to measure three important pollutants i.e. Carbon Monoxide (CO), Nitric Oxide (NOx) and unburnt Hydrocarbons (HC).

With alcohol operation, the major pollutant emitted from the engine is aldehydes. The aldehydes irritate the mucous membranes in the eyes and the respiratory system and participate in the formation of photochemical smog. The aldehyde levels more than 170 ppm creates problem for the human beings. Therefore their prevention and suppression are considered to be desirable. The well-known DNPH method (2, 4 dinitrophenyl hydrazine) is employed for measuring aldehydes in the experimentation . It is a very sensitive method and reproducibility of the results is found to be good.

The experimentation is carried out for measurement of aldehydes in the IE engine with alcohol as fuel. The exhaust of the engine is bubbled through 2, 4 dinitrophenyl hydrazine (2, 4 DNPH) solution. The hydrazones formed are extracted into chloroform and are analyzed by employing high performance liquid.chromatography (HPLC) to find the percentage concentration of acetaldehyde in the exhaust of the engine.

Coolant Water Measurement

Coolant water flow is measured by collecting the water in a pail for two minutes and weighing it in a spring balance. The flow of water is measured in Kg/min. The inlet and outlet temperature of the cooling water is measured using a temperature gauge. From the above the amount of heat lost to the cooling water is calculated. Constant water flow is maintained through the engine to prevent overheating.

Injection Timing Measurement

The injection timing is measured by the spill method. The delivery valve in the pump is removed and a goose neck tube is connected to the pump. The flywheel is rotated slowly to find out the point at which the port closes by observing the stoppage of dripping of fuel from the goose neck tube. The angular displacement of this point from the TDC gives the injection timing. The timing is altered by inserting thin shims between the pump base and the crankcase.

Fig.Photograph Graphic read of Experimental Set up of Insulated Engine Test Rig

V. RESULS AND GRAPHS

Fig. Picture Graphic Read of Plain Brass Crown Piston

Fig. Picture Graphic Read of Brass Crown Piston with six Groov

Fig. Picture Graphic Read of Brass Crown Piston with nine Grooves

Fig. *Picture Graphic Read of Brass Crown Piston with twelve Grooves*

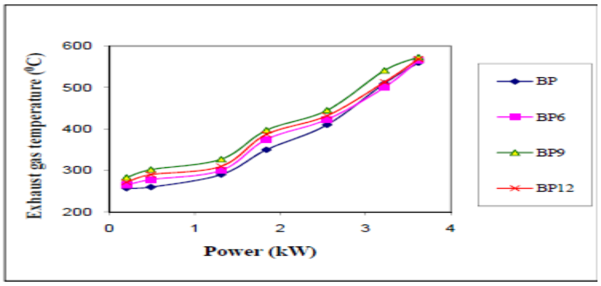

Fig. Comparison of Exhaust Gas Temperatures with totally different range of Grooves on the Brass Piston

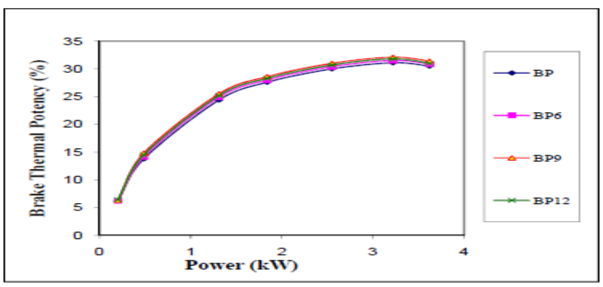

Fig. Comparison of Brake Thermal Efficiency with totally different range of Grooves on the Brass Piston

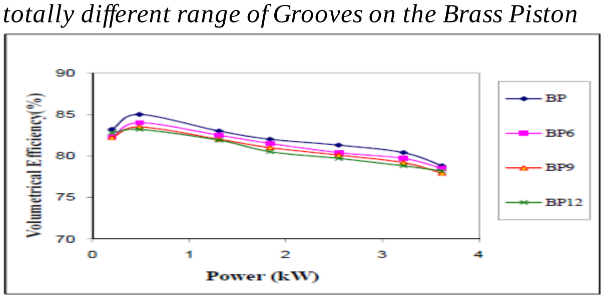

Fig. Comparison of Volumetric Efficiency with totally different range of Grooves on the Brass Piston

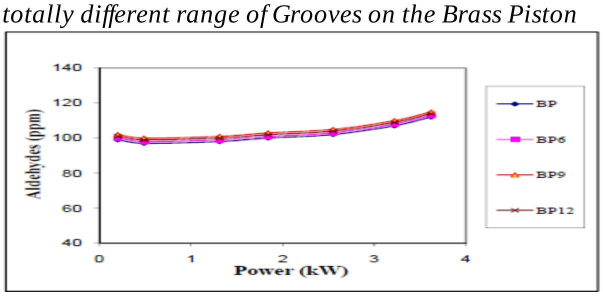

Fig. Comparison of Aldehyde Emissions with totally different Range of Grooves on the Brass Piston

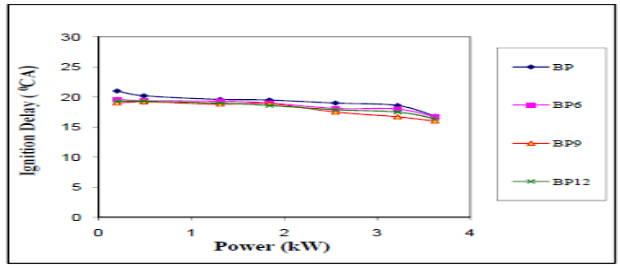

Fig. Comparison of Ignition Delay with totally different range of pressure rise with totally different of Grooves on the Brass Piston

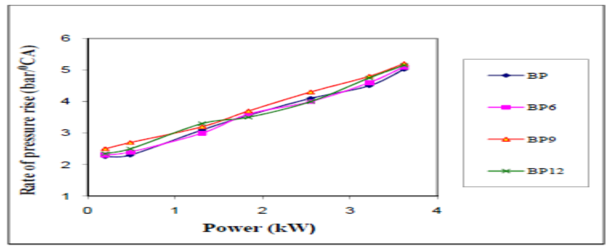

Fig. Comparison of Rate of range of Grooves on the Brass Piston

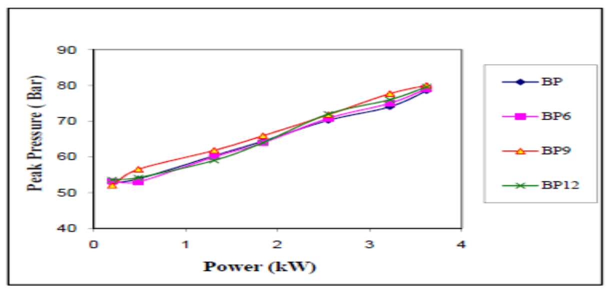

Fig. Comparison of Peak Pressure with totally different range of Grooves on the Brass Piston

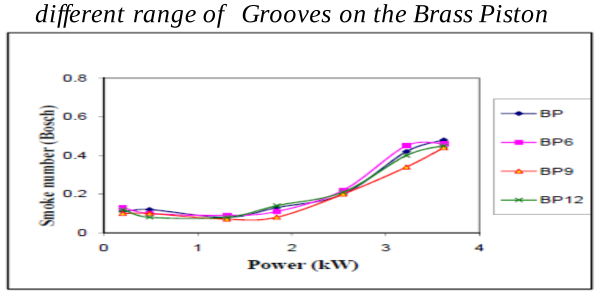

Fig. Comparison of Smoke Densities with totally different range of Grooves on the Brass Piston

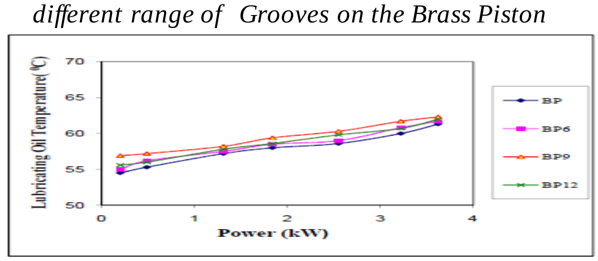

Fig. Comparison of Lubricating Oil Temperatures with totally different range of Grooves on the Brass Piston

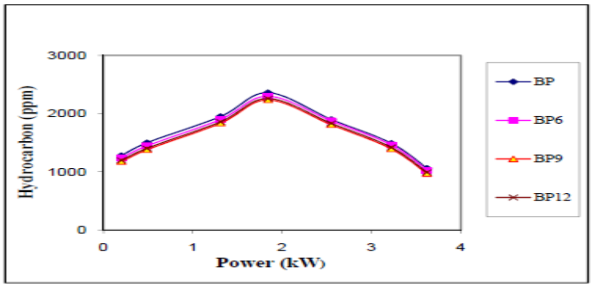

Fig. Comparison of Hydrocarbon Emissions with totally different range of Grooves on the Brass Piston

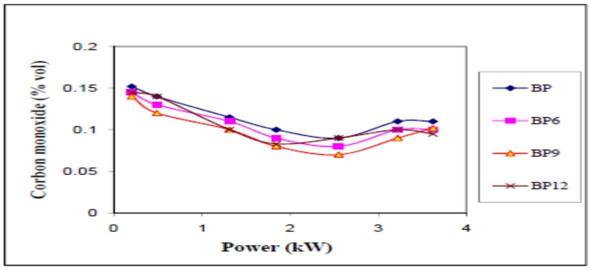

Fig. Comparison of Carbon Monoxide Emissions with totally different range of Grooves on the Brass Piston

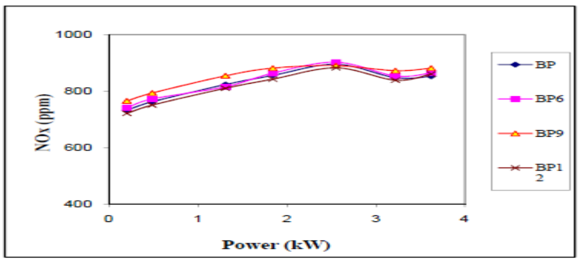

Fig. Comparison of Nitrogen Oxide Emissions with totally different range of Grooves on the Brass Piston

VI. CONCLUSION

The salient conclusions based on the experimental investigations on insulated engines with different piston inserts, different number of grooves on the piston, supercharging and turbo charging and new lubricating oils with alcohol as fuel is presented below:The overall improvement in the brake thermal efficiency of the insulated engine is 20.76% compared to normal engine.With the insulation to the combustion chamber, turbulence in the combustion chamber by grooves on the brass piston and turbo charging increases the exhaust gas temperature by about 30.3% compared to the normal engine.The volumetric efficiency is dropped by the higher temperatures in the combustion chamber. The overall volumetric efficiency compensated is 11.68% for BP9 with NO2 oil with 1.5% T.B.A.The overall increase in the pressure of the insulated engine is 12.7% compared to normal engine due to the complete combustion of the fuel.

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