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Performance and Emissions Characteristics of C.I Enginewith Different Piston Crown Materialsfuelled with Methanol

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ABSTRACT: The concept of using alcohol fuels as alternative to diesel fuel in diesel engine is recent one. 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. Alcohols were quickly recognized as prime candidates to displace or replace high octane petroleum fuels. 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. 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. Methanol and ethanol are very susceptible to surface ignition, this method is very suitable for these fuels. The hot surfaces which, can be used in surface ignition engine are electrically heated glow plug with hot surface. Hence present research work carries the experimental investigation on glow plug hot surface ignition engineon different piston crown materials like Bronze Crown Aluminium, Piston Copper Crown Aluminium Piston, Nimonic alloy Crown Aluminium Piston,
and Titanium Crown Aluminium Pistonwith methanol as fuel, in this investigation the Normal Aluminium piston is consider as base engine, with an objective to find the best one performance, emission and compression parameters. From the present experimental investigation the copper crown material give the better performance and fewer emissions.

KEY WORDS: C.I Engine; Glow plug Hot Surface (GHS) Engine; Methanol; performance; emissions

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I. INTRODUCTION

The power used in the agricultural and transportation sector is based on diesel fuel and hence it is essential to develop alternatives for diesel. A number of steps have been taken for promoting the conservation of petroleum products. These include improving energy efficiency of refineries and increasing fuel efficiency in the transport sector. Moreover the engine exhausts accumulate the pollution into the atmosphere. Alternative fuels especially for diesel are needed to diminish the impacts of exhaust gas pollution on the environment and depleting fossil fuel reserves. Such alternatives should be compatible with existing engines, associated equipment like fuel injector etc. and fuel transportation, storage and delivery.

There are some important properties to be considered while deciding alternative fuel for the existing engines.

(i) Investment cost: Additional investment on existing engine must be small to ensure that the operation is competitive with petroleum fuel.

(ii) Modification of existing engines: Engine modification should be simple, inexpensive and easily reversible. Such modification should not affect the use of traditional diesel fuel in order to preserve engine compatibility for the use of two fuels. Switch over of operation from alternative fuel mode to diesel mode should be easy.

(iii) Environmental compatibility: While using alternative fuel the engine performance is expected to improve significantly with regard to regulated emissions and unregulated emissions.

(iv)Manufacturer’s warranty: The alternative fuel must guarantee that the lifetime of the equipment, its reliability and operational capability is not modified. Maintenance, repair and fuel costs must be similar to that of conventional fuel and the alternative fuel must be readily available.

A. 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.

Alcohol has been used as a fuel for internal combustion engines since their invention. Reports on the use of alcohol as a motor fuel were published in 1907 and detailed research was conducted in the 1920s and 1930s. In 1973 there was a severe energy crisis all over the world because the oil prices shot up four folds. Thus, 1973 is considered as the first oil shock. The world took this shock seriously and for the first time a need for developing alternative sources of energy was felt. Alternative energy sources were given serious consideration and huge founds are allocated for the development of these resources. The world faced two more oil shocks in 1979 and 1980.which further focused to the attention an alternative energy sources. The enormous increase in the number of vehicles has started dictating the demand for alternative fuels. With the increased use and depletion of fossil fuels alternative fuel technology may become more common in the coming decades. Day-to-day, fuel economy of engines is getting improved and may continue to improve. Because of high cost of petroleum products and emission problems some developing countries are trying to use the alternative fuels for their vehicles. Alcohols are attractive alternative fuels because they can be obtained from both manufacturing and natural sources. Methanol and ethanol are two kinds of alcohols that seam most promising.

II. EXPERIMENTAL WORK

The above engine is one of the extensively used engines in agricultural and industrial sectors in India. This engine can withstand the peak pressures encountered because of its original high compression ratio. Further, the necessary modifications on the cylinder head and piston crown can be easily carried out in this type of engine. Hence this engine is selected for the present research work.The single cylinder, four strokes 5.2kW Kirloskar, water-cooled DI diesel engine with a bore of 87.5 mm and stroke of 110 mm and a compression ratio of 17:1 is used for the experimental investigation for present proposal work. The engine load is applied with eddy current dynamometer. For the reduction of heat to the cooling water .the plain engine is modified by fitting with a PSZ coated cylinder head and liner. Then the existing aluminum piston is replaced by a copper piston crown with an air gap. These air gap surfaces are coated with PSZ. These tests are conducted with Methanol as fuel in GHSI engines as usual. The experiments are carried out on the plain engine with the copper piston crown material and other selected materials on GHSI engine using Methanol as fuel to determine the performance, emissions and the combustion parameters.

III. EXPERIMENTAL ANALYSIS

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

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 **Methanol is uses** as fuel in order to evaluate the performance characteristics.

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).

Fig 1: Photographic view of Normal Aluminium piston

A. Different Types of Piston Crown materials

Fig 2: Photographic view of Bronze crown

Fig 3: Photographic view of copper alloy crown

Fig 4: Photographic view of Titanium crown

Fig 5: Photographic view of Nimonic alloy crown

A. 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 whereas 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.

B. 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.

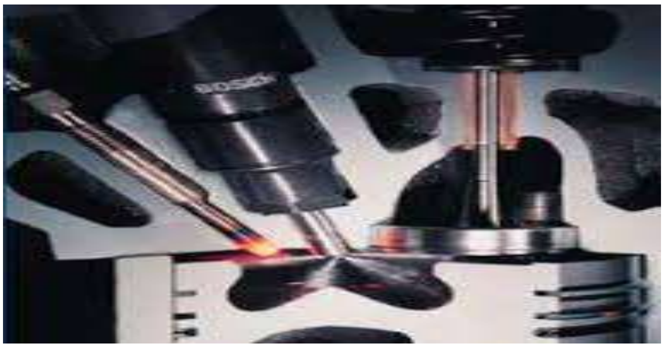

Fig 6: Sectional view of piston cylinder assembly showing the glow plug and fuel injector arrengements.

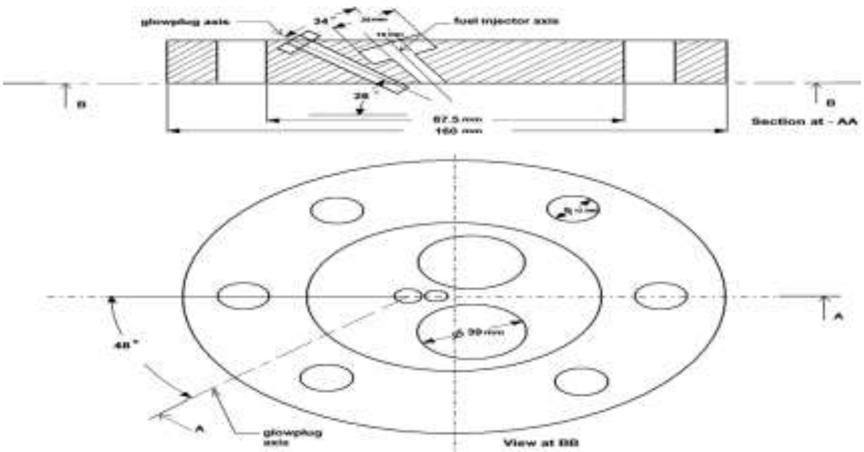

Fig 7: shows the location of glow plug on the cylinder head with respect to the injector and combustion chamber.

IV. RESULTS AND DISCUSSIONS

A. Methanol Operation in GHSI Engine with different piston crown materials

The experimental investigations are carried out with different piston crown materials on the Glow plug hot surface ignition engine with Methanol as fuel and the analysis of results are presented below.

3.1.1 Brake Thermal Efficiency

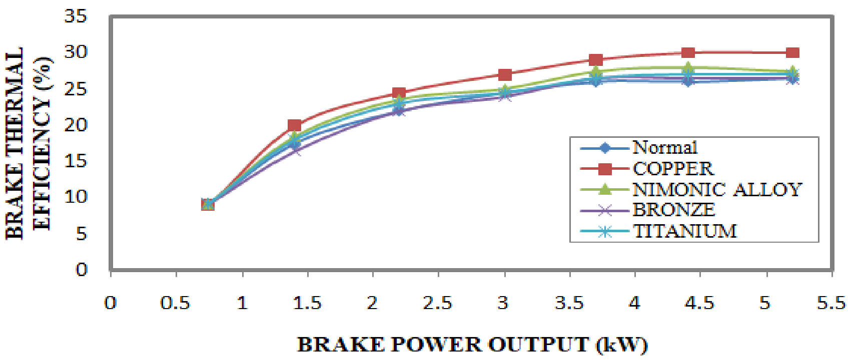

Figure 8: Variation of Brake Thermal Efficiency with power output for different piston crown materialsGlow plug hot surface ignition engine.

The brake thermal efficiency with power output as shown in figure 8 illustrates for four different piston crown materials with the normal Glow plug hot surface ignition engine. It is found that the brake thermal efficiency for all the piston crown materials Glow plug hot surface ignition engines is higher than normal Glow plug hot surface ignition engine, over a wide range of operation. The Glow plug hot surface ignition engine with copper piston crown material shows maximum efficiency over a wide range of operation. The Glow plug hot surface ignition engine with normal piston crown material indicates minimum efficiency as compared to other piston crown materials Glow plug hot surface ignition engines. The absolute improvement for the copper piston crown material Glow plug hot surface ignition engine over the normal Glow plug hot surface ignition engine is 4% at rated load. This is due to the positive ignition of the injected Methanol spray under all conditions by copper piston crown material Glow plug hot surface ignition engine.

4.1.2 Brake Specific Fuel Consumption

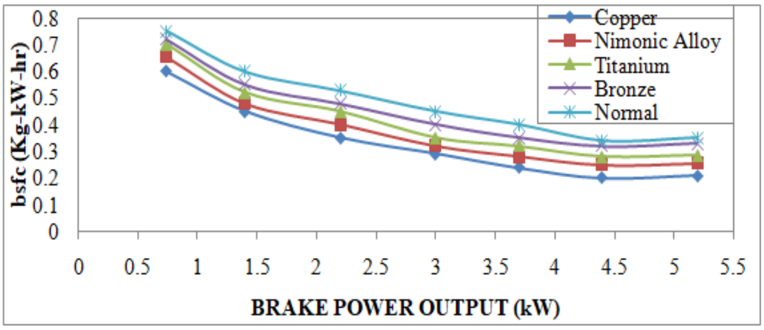

Figure 9: Variation of Brake Specific Fuel Consumption with power output fordifferent piston crown materialsGlow plug hot surface ignition engine.

The variation of brake specific fuel consumption with different piston crown materialsGlow plug hot surface ignition engine is shown in figure 9. All piston crown materials Glow plug hot surface ignition engines have lower brake specific fuel consumption compared to base engine. Copper piston crown materials Glow plug hot surface ignition engine gives lower bsfc (0.49 kg/kW-hr) over wide range of operation.

4.1.3 Volumetric Efficiency

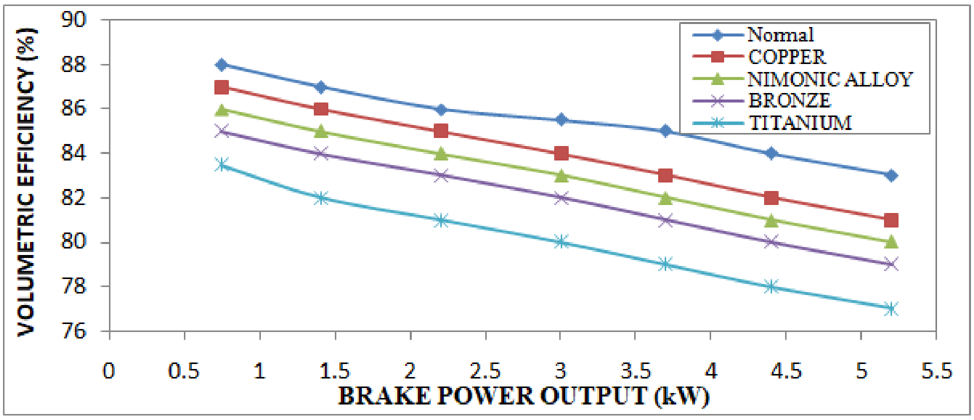

Figure 10: Variation of Volumetric Efficiency with power output for differentpiston crown materialsGlow plug hot surface ignition engine.

The variation of volumetric efficiency with power output is illustrated in figure 10. The general trend is that the volumetric efficiency drops with increase in power output. At standard condition, the volumetric efficiency varies from 88% at no load to 84% at full load. With copper configuration the volumetric efficiency comes to 83% at no load and to 75% at full load.

The volumetric efficiency has a bearing on power output. Because of insulation, the combustion chamber surface temperature increases, and there will be more heat loss to incoming air, resulting in a drop in volumetric efficiency. Since the incoming air density suffers, the combustion phenomenon is also affected. Therefore in insulated Engines, the drop in volumetric efficiency is a major problem. The drop in volumetric efficiency can be compensated by supercharging or by turbocharging.

4.1.4 Hydrocarbon emissions

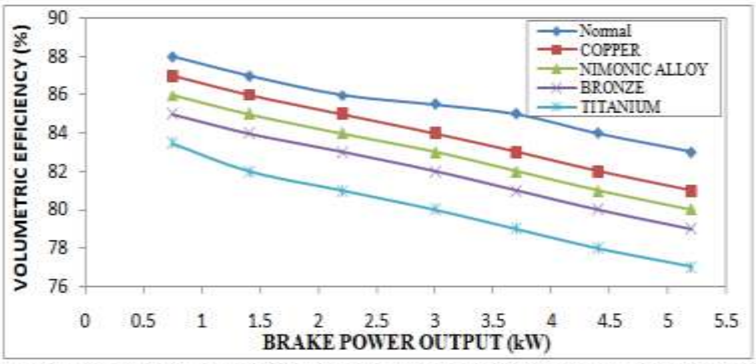

Figure 10: Variation of Volumetric Efficiency with power output for differentpiston crown materialsGlow plug hot surface ignition engine.

Figure 11: Illustrates the variation of hydrocarbon emission levels with power output. The copper piston crown material Glow plug hot surface ignition engine shows the lowest hydrocarbon emissions. The reduction in hydrocarbon emission level over the corresponding normal Glow plug hot surface ignition engine is about 120 ppm at rated load. The hydrocarbon emission level for all the other piston crown materials Glow plug hot surface ignition engines is higher. This is because the location of the ignition source with respect to fuel injector is optimized for the rated load operation. In case of Glow plug hot surface ignition engine. The hydro carbon emission levels for all the other piston crown materials Glow plug hot surface ignition engines are in between the normal Glow plug hot surface ignition engine and the copper piston crown materials Glow plug hot surface ignition engine.

4.1.5 Carbonmonoxide emissions

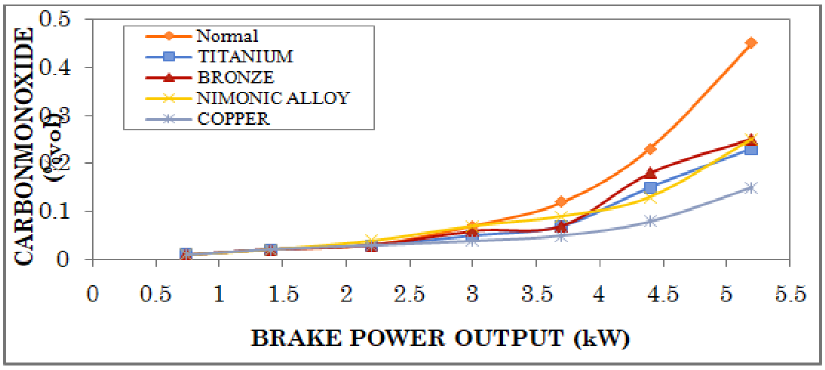

Figure 12: Variation of Carbon monoxide Emissions with power output for different piston crown materialsGlow plug hot surface ignition engine.

The variation of carbon monoxide with power output is depicted in figure 12. The copper piston crown materialsGlow plug hot surface ignition engine indicates lower level of carbon monoxide emissions when compared to the respective normalGlow plug hot surface ignition engine. However for Glow plug hot surface ignition engine, the variation of carbon monoxide emission at lower outputs is negligible. The reduction is about 12% by volume for Glow plug hot surface ignition engine at rated power output.

4.1.6 Carbon Dioxide Emission

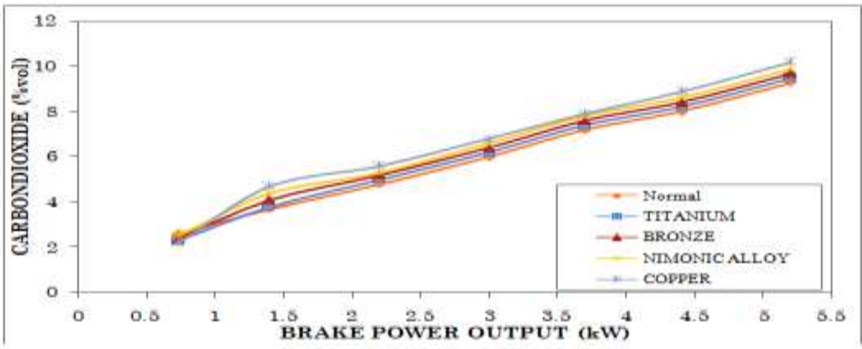

Figure 13: Variation of Carbon Dixode Emission output for differentpiston crown materialsGlow plug hot surface ignition engine.

with power Figure 13: Variation of Carbon Dixode Emission output for differentpiston crown materialsGlow plug hot surface ignition engine.

Carbon dioxide levels in the exhaust of base engine and different piston crown materialsGlow plug hot surface ignition engine are shown in figure 13. It is also evident from the graphs that the variation of Carbon dioxide (in the exhaust) with power output. Because of better and complete combustion in different piston crown materialsGlow plug hot surface ignition engine, Carbon dioxide levels are higher for different piston crown materialsGlow plug hot surface ignition engine. It indicates that the level of Carbon dioxide in the exhaust is highest (11%) for copper piston materialGlow plug hot surface ignition engine. Higher Carbon dioxide in the exhaust is an indication of complete or better combustion.

4.1.7 Nitrogen Oxide Emissions

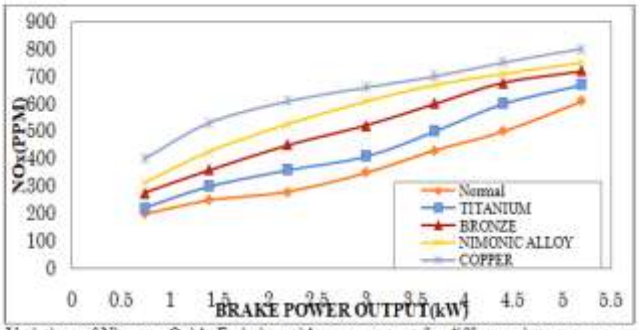

Figure 14: Variation of Nitrogen Oxide Emission with power output for different piston crown materialsGlow plug hot surface ignition engine.

NO_x levels in the exhaust of base engine and all different piston crown materialsGlow plug hot surface ignition engine with respect to brake power are shown in Figure 14. Because of better and complete combustion in the different piston crown materials, Nitrogen oxide levels are higher (780ppm) for different piston crown materials Glow plug hot surface ignition engines. It indicates that the level of nitrogen oxide is highest for copper Glow plug hot surface ignition engine. Higher nitrogen oxide in the exhaust is an indication of complete or better combustion.

4.1.8 Exhaust Gas Temperature

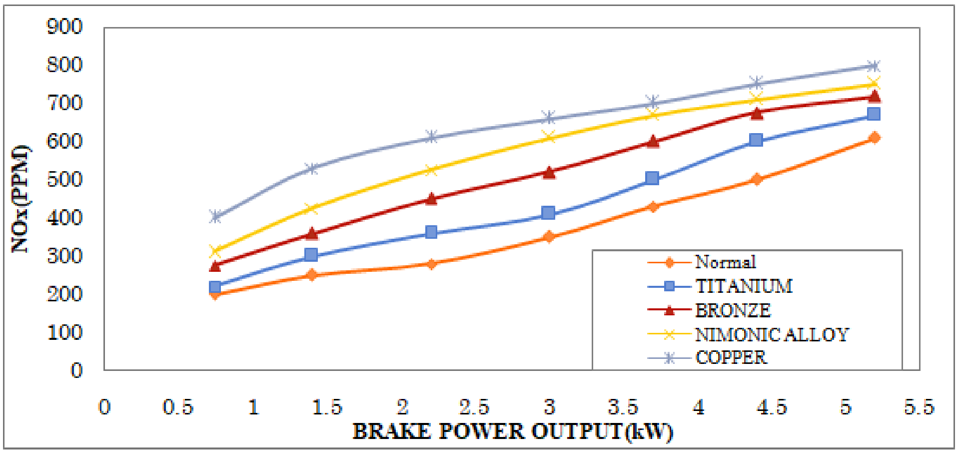

Figure 14: Variation of Nitrogen Oxide Emission with power output for different piston crown materialsGlow plug hot surface ignition engine.

The variation of exhaust temperature with power output is illustrated in figure 15. It clearly indicates that with the degree of insulation increasing the exhaust gas temperature progressively increases. Exhaust temperatures increase with the engine load. There is a 210^{0}C rise in the exhaust temperature for this configurations compared to base engine. It's found that the exhaust gas temperature of copper Glow plug hot surface ignition engine Configuration is higher than the other, which causes the gases to expand within the cylinder giving higher work output and lower heat exhaust.

4.1.9 Peak Pressure

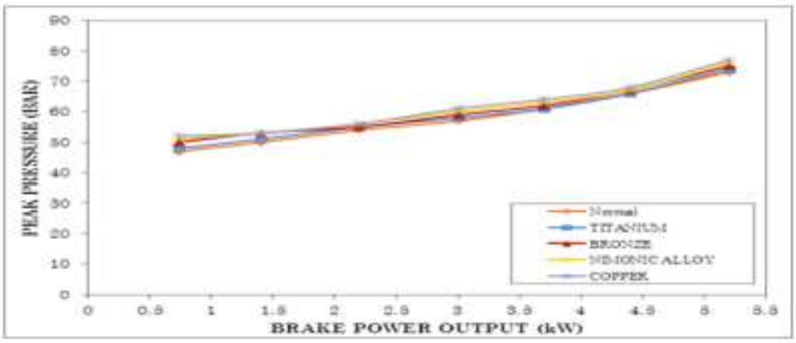

Figure 16: Variation of Peak Pressure with power output for different pistoncrown materialsGlow plug hot surface ignition engine.

The variation of peak pressure with power output is illustrated in figure 16. The peak pressure is higher with piston crown materials particularly at high outputs, where the gas temperatures accelerate the combustion process. It is observed that the peak pressure for all piston crown materials Glow plug hot surface ignition engine is higher than normal Glow plug hot surface ignition engine. The copper piston crown material Glow plug hot surface ignition engine shows higher peak pressure as compared to other coating Glow plug surface ignition engine and is about 54.75 bars.

4.1.10 Ignition delay

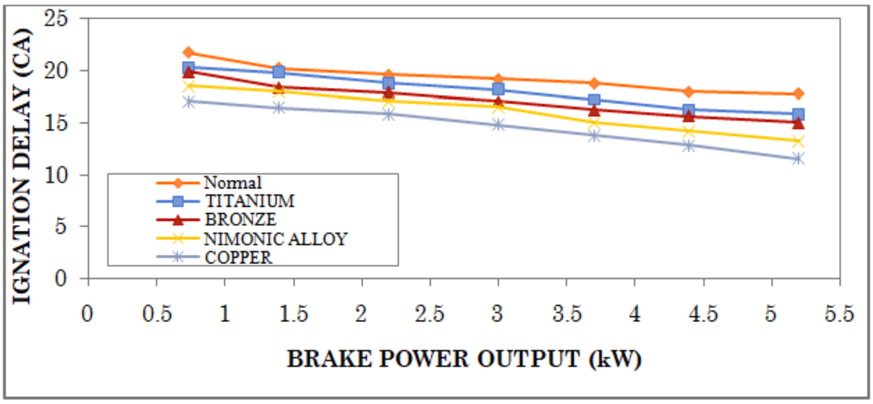

Figure 17: Variation of Ignation Delay with power output for different pistoncrown materialsGlow plug hot surface ignition engine.

The variation of ignition delay with power output is illustrated in figure 17. The copper piston crown material Glow plug hot surface ignition engine shows the lowest ignition delay. The normal Glow plug hot surface ignition engine shows highest ignition delay. The reduction in ignition delay for copper piston crown material Glow plug hot surface ignition engine over normal Glow plug hot surface ignition, the operation of piston crown material Glow plug hot surface ignition engine is smoother compared to normal Glow plug hot surface ignition engine.The reduction in ignition delay for copper piston crown material GHSI engine over the normal engine is about 4^0CA

4.1.11 Indicated Mean Effective Pressure

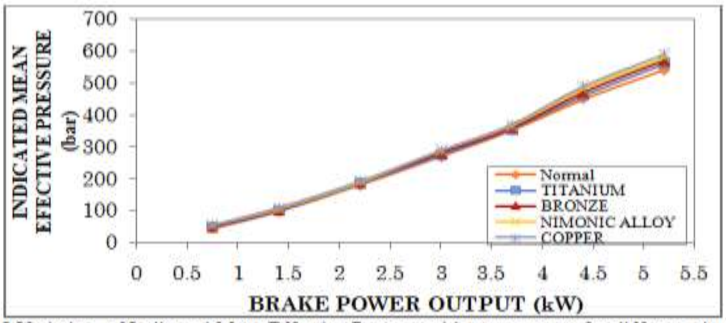

Figure 18 Variation of Indicated Mean Effective Pressure with power outputfor different piston crown materialsGlow plug hot surface ignition engine.

The variation of Indicated Mean Effective Pressure with power output is illustrated in figure 18. The increase in the Indicated mean effective pressure is normally expected because of higher temperatures in these configurations. Highest Indicated mean effective pressure (580 bar) is obtained for the copper compared to other configurations.The increase in the Indicated mean effective pressure depends upon the level of insulation applied.

4.1.12 Maximum Rate of Pressure Rise

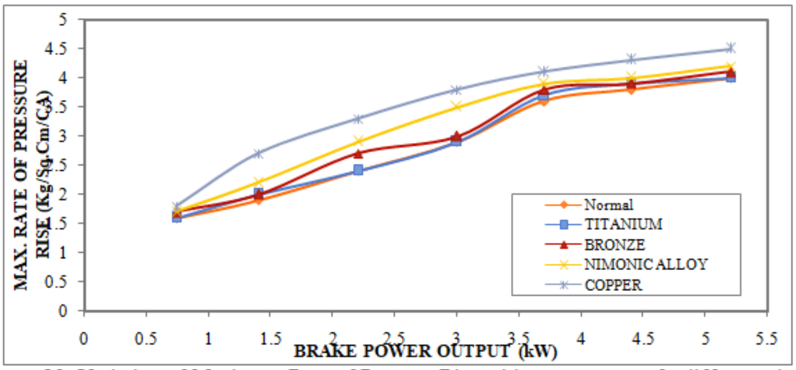

Figure 19: Variation of Maximum Rate of Pressure Rise with power output fordifferent piston crown materialsGlow plug hot surface ignition engine.

Figure 19 indicates the variation of maximum rate of pressure rise with power output for five different types of piston crown materials of a Glow plug hot surface ignition engine along with the normal Glow plug hot surface ignition engine. The maximum rate of pressure rise is maximum for copper piston crown material Glow plug hot surface ignition engine and is minimum for normal Glow plug hot surface ignition engine. The low ranges of pressure rise with alcohol as fuel in the low output ranges, is because of sluggish combustion. It can be seen that the maximum rate of pressure rise is higher with copper piston crown material Glow plug hot surface ignition engine and is about 25% by volume at rated load.

V. CONCLUSIONS

Out of four piston crown material are tested to the GHSI engine copper piston crown material GHSI engine gives the best results. The important results drawn from this work are given below. It is concluded that the copper piston crown material GHSI engine is proved to be the best among the four piston crown material given to the combustion chamber of GHSI engine.

- Brake thermal efficiency percentage improvement for the copper piston crown material GHSI engine over the normal GHSI engine is 4% at rated load. This is due to the positive ignition of the injected Methanol spray under all conditions.
- Copper piston crown materials Glow plug hot surface ignition engine gives lower bsfc (0.59 kg /kW-hr) over wide range of operation.
- The copper piston crown material GHSI engine, the volumetric efficiency comes to 83% at no load and to 75% at full load.
- The reduction in hydrocarbon emission level over the corresponding normal Glow plug hot surface ignition engine is about 120 ppm at rated load.
- The copper piston crown material GHSI engine gives the lowest level of CO emissions as compared to other coatings and is about 12% by volume.
- It indicates that the level of Carbon dioxide in the exhaust is highest (11%) for copper piston materialGlow plug hot surface ignition engine.
- Nitrogen oxide levels are higher(780ppm) for different piston crown materials Glow plug hot surface ignition engines.
- Exhaust temperatures increase with the engine load. There is a 210^0C rise in the exhaust temperature for this configurations compared to base engine.
- The copper piston crown material GHSI engine shows high peak pressure as compared to other piston crown material GHSI engines and is about 54.75 bar.
- The reduction in ignition delay for copper piston crown material GHSI engine over the normal engine is about 4^0CA.
- Highest Indicated mean effective pressure (580bar) is obtained for the copper compared to other configurations.
- The maximum rate of pressure rise is higher with copper piston crown material Glow plug hot surface ignition engine and is about 25% by volume at rated load.

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