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EXPERIMENTAL STUDY OF PERFORMANCE AND EMISSION CHARACTERISTICS OF THERMAL BARRIER COATED DIESEL ENGINE

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Abstract: Depleting Petroleum reserves on the earth and increasing concerns about the environment leads to the question for fuels which are ecofirendly safer for human beings. The objective of present work is to investigate the effect of coating on piston crown of diesel engine on Performance and emission characteristic of exhaust gasses using diesel, Ethanol blended with diesel(10% & 20%), Ethanol & Pongamia oil blend with Diesel (E-5%,P5% & E10%, P-10%) as a fuel.

In this study the effect of YSZ(60%)+ Alumina(20%)+Titania(20%) coating on the performance and emission characteristics of diesel engine was investigated using the above fuels, in which the coating thickness was 300 microns done by a Plasma Spray Coating.For comparing the performance of the engine with coated and uncoated Engine is taken. As a low thermal conductivity material, Zirconia is capable of reducing the heat loss from cylinder to surroundings , Due to reduction in heat loss to the surroundings, the power output and brake thermal efficiency of the engine is increased.The specific fuel consumption are lowered during all operating range of the engine in case of Thermal barrier coated piston.

NOx emissions are mainly due to increased temperature and it is higher in uncoated engine but in present investigation there was a greater reduction of oxides of nitrogen due to coating because of nitrogen is absorbed by zirconia. The emission of unburned hydrocarbon and carbon monoxide are also reduced because of the decreased quenching distance and increased lean flammability limit of coated engine. The smoke emission is increased for the coated piston than the uncoated piston.
Keywords: yittria stabilised zirconia, Alumina,Titania, Pongamia, ethanol,NOx.

1. Introduction

An internal combustion engine (ICE) is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In IC Engines only 30-35% of work is converted into useful work and in which rest of the work is wasted in friction, cooling, exhaust etc. By this way some amount of thermal energy is transmitted via piston crown and it is tranferred to cooling via cylinder wall. So in order to overcome this, thermal barrier coating is done on the piston crown, which act as a thermal insulator and saves the thermal energy which improves the efficiency and it also plays a vital role in emission control. The thermal barrier is done by means of plasma spray coating by means of bond coating and different layers of ceramic coating (YSZ, alumina and titania) by varying the proportion.

2. Overview of selected material properties

- Very high Electrical insulation ($1x10^{14}$ to $1x10^{15}$ Ωcm).
- Moderate to extremely high mechanical strength (300 to 630 MPa
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- Very high compressive strength (2,000 to 4,000 MPa)
- High hardness (15 to 19 GPa)
- Moderate thermal conductivity (20 to 30 W/mK)
- High corrosion and wear resistance
- Good gliding properties
- Low density (3.75 to 3.95 g/cm^3)
- Operating temperature without mechanical load 1,000 to 1,500°C

3. Experimental Setup:

3.1. Engine Specification

a) Make	: Kirloskar
b) Model	: SV1
c) No. of Cylinders	: 1
d) Bore X Stroke, (mm)	: 87.5 X 110
e) Cubic Capacity, (Ltr)	: 0.661.
f) Compression Ratio	: 17.5: 1
g) Rated Speed	: 1800 RPM
h) Type of cooling	: Water
i) Power Rating	: 8 HP
j) Coating Material	: YSZ (60%)+ Alumina(20%) + Titania (20%)

Fig.1 Uncoated Piston

Fig.2 Thermal barrier coated piston

3. 2 Experimental Layout

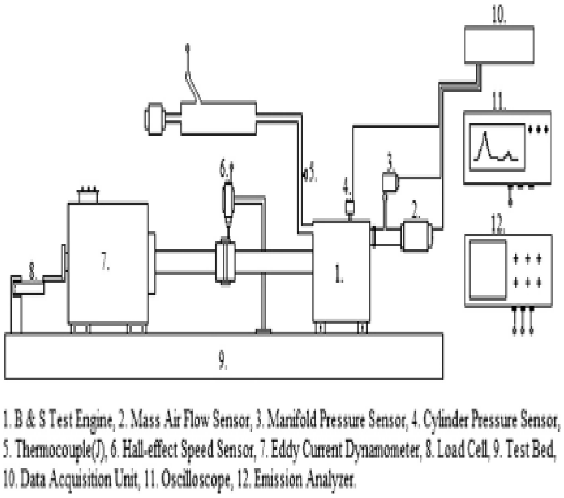

Fig.3 Test Bench Setup

4. RESULT AND DISCUSSIONS

4.1 THERMAL EFFICIENCY:

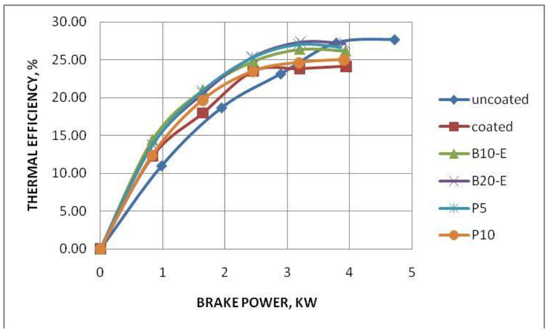

Figure.No: 4 Brake Power Vs Thermal Efficiency

Zirconia is a low thermal conductivity material, hence it act as barrier for the heat transfer to the surrounding from the engine conbustion chamber and reduces the heat loss from the engine. Also as per the first law of thermodynamics, the heat reduction in heat loss will ultimately increse the power output and thermal effiency of engine. Out of six curves as shown in Figure.no: 5.1, uncoated and coated cuve is made by Diesel Fuel, B 10-E & B 20-E is Ethanol blend with Diesel Fuel and P 5 & P 10 is Ehanol & Pongamia Blended with Diesel are used as a Fuel. It is clear that the Thermal Effiency of the engine for all fuels are slightly increases after coating,For Diesel Fuel Thermal Efficiency increased by 2.5%, Ethanol Blend fuel by 4.9% and Pongamia blended fuels by 3.8% at the Brake Power of 1 KW.

4.2 SPECIFIC FUEL CONSUMPTION:

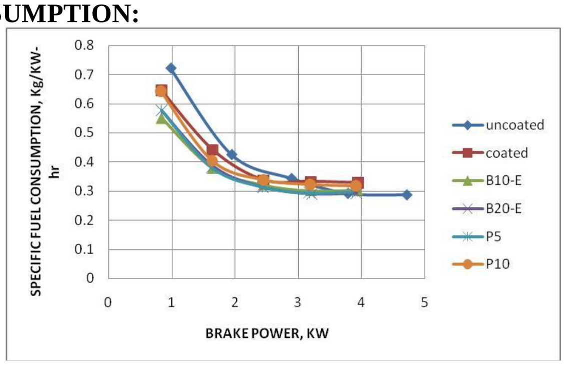

Figure.No: 5 Brake Power Vs SFC

From the Figure.No:5, It is clear that the Specific Fuel Consumption is decreasing after coating due to reduction of heat loss to surrounding from the engine, This will increases the thermal efficiency of the engine. It is clear that the Specific Fuel Consumption of the engine for all fuels are slightly decreases after coating. For Diesel Fuel, Specific Fuel Consumption decreased by 0.05Kg/Kw-hr, Ethanol Blend fuel by 0.1Kg/Kw-hr and Pongamia blended fuels by 0.06 Kg/Kw-hr at the Brake Power of 1 KW

4.3 UNBURNED HC EMISSIONS:

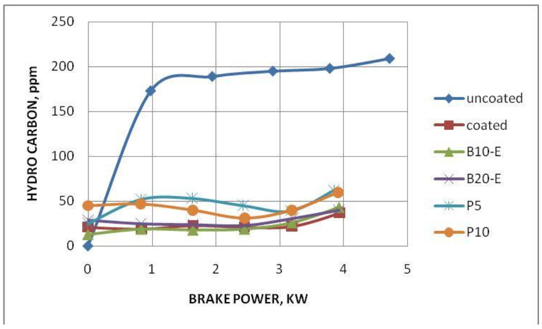

Figure.No: 6 Brake Power Vs Hydrocarbons (HC)

From the Figure.No:6, Unburned Hydrocarbon are reduced, when the engine runs with coating, Unburned hydrocarbon is slightly higher for all fuels when the engine runs without ceramic coating. The main reason for reduction of UHC is that at hihg temperature the engine will have sufficient amount of oxygen which mixes with the HC emissions, as a result of this, HC will Split into H and C which mixes with oxygen and therby it reduces the HC emissions. For Diesel Fuel Hydrocarbon drastically decreased by 170 ppm, Ethanol Blend fuel by 180 ppm and Pongamia blended fuels by 150 ppm at the Brake Power of 1 KW.

4.4 CARBON MONOXIDE EMISSIONS:

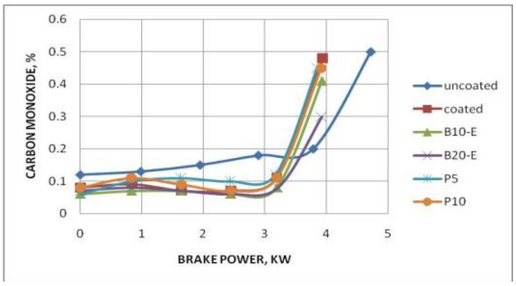

Figure.No: 7 Brake Power Vs CO

From the Figure.No:7, it is clear that CO is decreased after the coating due to complete combustion. The Carbon monoxide, which arises mainly due to incomplete combustion, is a measure of combustion efficiency. Generally oxygen availablility in diesel is high so at high temperature carbon easily combines with oxygen and reduces the CO emissions. It is observed that at part load (upto 3 KW) the CO emission are slightly decreased because of ceramic coating on piston and after that its increased at full load condition. For Diesel Fuel CO drastically decreased by 0.03%, Ethanol Blend fuel by 0.06% and Pongamia blended fuels by 0.02% at the Brake Power of 1 KW.

4.5 CARBON DIOXIDE EMISSIONS:

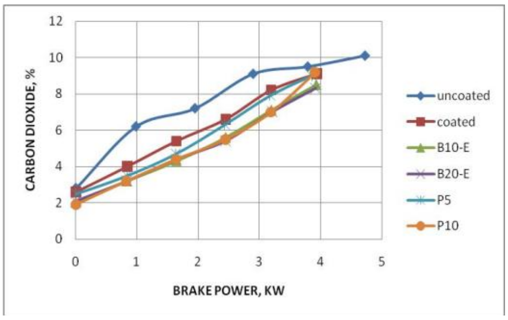

Figure.No: 8 Brake Power Vs CO_2

From the Figure.No:8, it is clear that CO_2 is decreased after the coating. The Carbondioxide, which arises mainly due to burning of fossil fuels which cause green house effect leads to global warming. It is observed that at carondioxide decreases drastically because of ceramic coating on engine. For Diesel Fuel CO_2 drastically decreased by 1.9%, Ethanol Blend fuel by 3.1% and Pongamia blended fuels by 2.4% at the Brake Power of 1 KW(Approx.)

4.6 OXIDES OF NITOGEN (NOx) EMISSIONS:

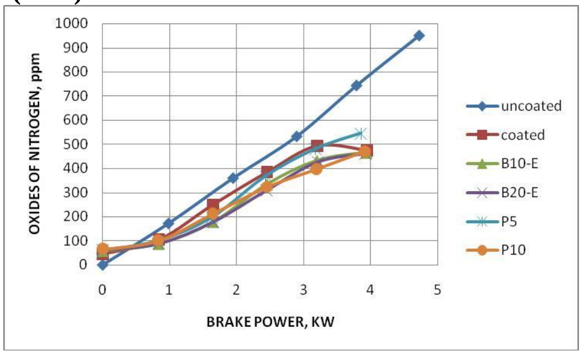

Figure.No: 9 Brake Power Vs NOx

From the Figure, it is clear that there is an greater reduction of oxides of nitrogen due to coating because of nitrogen has obsorbed by zirconia, even though the availability of oxygen is high but the availability of nitrogen is very less by the presence of impurities. Generally oxygen availability in diesel engine is high so at high temperature nitrogen easily combines with oxygen but the availability of nitrogen is ver less due to coating and forms less NOx. There is a rapid reduction of NO, for Diesel Fuel NO drastically decreased by 70 ppm, Ethanol Blend fuel by 110 ppm and Pongamia blended fuels by 50 ppm at the Brake Power of 3 KW.

4.7 SMOKE EMISSIONS:

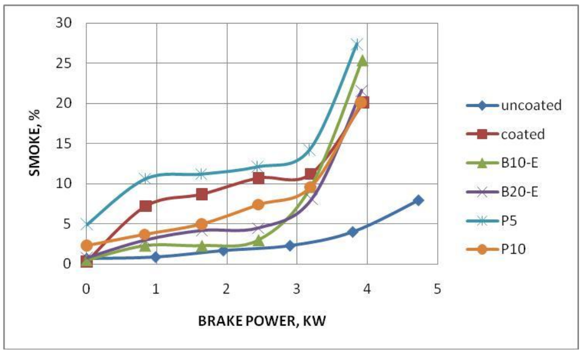

Figure.No: 10 Brake Power Vs Smoke

Smoke is a collection of airborne solid and liquid particulates and gases emitted when a material undergoes combustion or pyrolysis, together with the quantity of air that is entrained. From our graph shown, Smoke is increased for the coated engine due to the pyrolysis effect. There is a enhanced Smoke emissions for Diesel Fuel smoke drastically increased by 7%, Ethanol Blend fuel by 1.5% and Pongamia blended fuels by 9.1% at the Brake Power of 1 KW(Approx.)

5. CONCLUSION

Thermal efficiency is the true indication of the efficiency with which the chemical energy input in the form of fuel is converted into useful work. Improvement in engine thermal efficiency by reduction of incylinder hear transfer is the key objective of Thermal barrier coated engine. As a low thermal conductivity material, Zirconia is capable of reducing the heat loss from cylinder to surroundings.

Due to reduction in heat loss to the surroundings, the power output and brake thermal efficiency of the engine is increased by 2.5% at B.P of 1 KW, when compared with coating and uncoated Piston.

The specific fuel consumption is lowered by 0.05Kg/Kw-hr during all operating range of the engine in case of Thermal barrier coated piston.

NOx emissions are increased mainly due to increased temperature and it is higher in uncoated engine but in present investigation there was a greater reduction of oxides of nitrogen by110 ppm, due to coating because of nitrogen is absorbed by zirconia.

The emission of unburned hydrocarbon and carbonmoxide of 170 ppm & 0.03% at the Brake power of 1 KW are also reduced because of the decreased quenching distance and increased lean flammability limit of coated engine. The smoke emission is increased by 1.5% for the coated piston than the uncoated piston.

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