An Experimental Investigation of Piston Coating on Internal Combustion Engine

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Abstract—The thermal efficiency of most commercially used engine ranges from 38% to 42%, as nearly 58% to 62% of energy is lost in the form of waste heat. In order to save energy the hot parts are insulated. This will lead to reduction in heat transfer through the engine, involving an increased efficiency. Change in combustion process due to insulation also affects emissions. In this study an attempt is made to reduce the intensity of thermal and structural stresses by using a layer of ceramic material. Experimental investigation is carried out under different loading conditions on single cylinder two stroke spark ignition engine with its piston crown coated with Nickel-Chromium & Al2O3 to understand the influence of thermal barrier coating (TBC) on performance characteristics. Al2O3 is chosen as a candidate material for coating the piston crown because of its desirable physical properties like low thermal conductivity, high coefficient of thermal expansion, high thermal resistance, chemical inertness, high resistance to erosion, corrosion and high strength. Thermal barrier coating (TBC) is done by using Plasma Spraying Technique. Engine working conditions are maintained constant before and after coating. Experimental results revealed that the thermal efficiency is increased by 13.75%, Mass of fuel consumption is reduced by 6.02% and brake specific fuel consumption is reduced by 9.84% between coated and bare engine.

Key words: Two Stroke SI Engines, Piston Coatings, Thermal Barrier Coating Using Plasma Spraying Technique

I. INTRODUCTION

Energy conservation and efficiency have always been the quest of engineers concerned with internal combustion engines. Even the petrol engine rejects about two thirds of the heat energy of the fuel, one-third to the coolant, and one third to the exhaust, leaving only about one-third as useful power output. Theoretically if the heat rejected could be reduced, then the thermal efficiency would be improved. Low Heat Rejection engines aim to do this, by reducing the heat lost to the coolant. The rapid increase in fuel expenses, the decreasing supply of high grade fuels on the market and environment concerns stimulated research on more efficient engines with acceptable emission characteristics. The state of art thermal barrier coating (TBC) provides the potential for higher thermal efficiencies of the engine, improved combustion and reduced emission. In addition ceramic shows better wear characteristics than conventional material. [5]

Ceramics have a higher thermal durability than metals. Therefore it is usually not necessary to cool them as fast as metals. Lower heat rejection from the combustion chamber through thermally insulated components causes an increase in available energy that would increase the in-cylinder work and the amount of energy carried by exhaust gases, which could also be utilized. [4]

Using the coated piston the required temperature in the combustion chamber will be maintained. This will reduce the heat loss to the piston. This reduction in the heat loss will be used to burn the unburnt gases there by reducing the polluted exhaust gases. A bond layer with a Coefficients of Thermal Expansion (CTE) in between that of the TBC and metal substrate is typically used to improve coating adhesion. [6]

II. THERMAL BARRIER COATINGS

Thermal barrier coatings can be applied in the IC engine to insulate combustion chamber surfaces. The coatings can be applied to the entire combustion chamber or to select surfaces like the piston crown or valves. The primary purpose of the TBC is to raise surface temperatures during the expansion stroke, thereby decreasing the temperature difference between the wall and the gas to reduce heat transfer. Some of the additional heat energy in the cylinder can be converted into useful work, increasing power and efficiency. Reducing heat transfer also increases exhaust gas temperatures, providing greater potential for energy recovery with a turbocharger or possibly a thermoelectric generator. Additional benefits include protection of metal combustion chamber components from thermal stresses and reduced cooling requirements. A simpler cooling system would reduce the weight and cost of the engine while improving reliability.

Thermal barrier coatings are most commonly stabilized zirconias such as Yttria Stabilized Zirconia (YSZ), but other ceramics like Silicon Nitride (SN) have been used. Thermal conductivities (k) have ranged from less than 0.5 W/mȦK to 10 W/mȦK and thicknesses have ranged from 0.1 mm to 4.5 mm. Ceramic coatings can be applied by a variety of methods, although thermal spraying techniques such as plasma spray are the most common. A bond layer with a Coefficient of Thermal Expansion (CTE) in between that of the TBC and metal substrate is typically used to improve coating adhesion.

A. *Properties of Thermal Barrier Ceramic Materials:*

- High chemical stability.
- Resistant to high temperatures.
- High hardness values.
- Low densities.
- Can be found as raw material form in environment.
- Resistant to wear.
- Low heat conduction coefficient.
- High compression strength.[3]

B. Plasma Spray Technique:

Thermal Spraying technique consists of different types such as Chemical deposition method (CVD), plasma arc method, Physical vapour deposition method (PVD), and Plasma spray method. From the above four methods, plasma spray method is adopted in our experimental study. The main objective in plasma spraying was to constitute a thin layer that has high protection value over other exposed surfaces. Ni-Cr is sprayed in powder form molten in ionized gas rapidly on the piston crown surface to form a 100 micron thin TBC coating. A typical Plasma spray coating system is shown in Figure. The system primarily consists of power unit, powder supply unit, gas supply unit, cooling system, spraying gun and control unit. The coating material is Nickel-Chromium and Ceramic. [1]

The plasma generator consists of a circular anode, usually of copper, and a cathode of tungsten. The cathode is made of graphite in a water stabilized torch. A strong electric arc is generated between anode and cathode. This ionizes the flowing process gasses into the plasma state. Now, powdered feedstock material is injected into the plasma jet. Plasma jet will melt the material and propel it onto the work piece surface. Atmospheric plasma spraying is carried out using a Sulzer Metco F4 gun operating at power levels up to 50 kW. A gas mixture of hydrogen and argon is used as a plasma gas. The argon gas is also considered as a carrier gas for the feedstock material injection. [10]

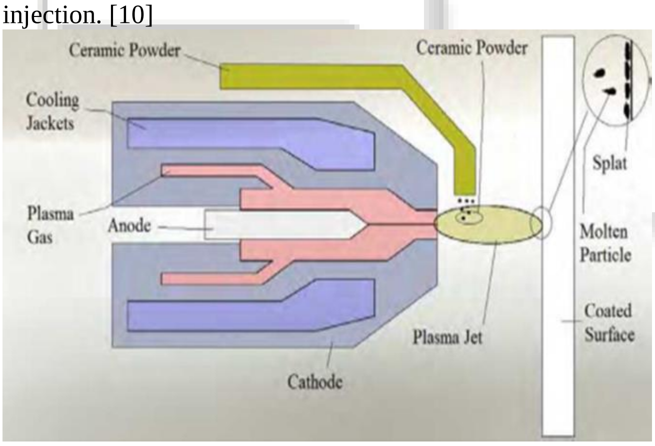

Fig. 1: Thermal Spraying technique

III. MATERIAL & METHOD

Thermal Barrier Coatings (TBCs) in petrol engines lead to advantages including higher power density, fuel efficiency, and multi fuel capacity due to higher combustion chamber temperature. Using TBC can increase engine power and decrease the specific fuel consumption and increase the exhaust gas temperature. [5]Insulating the combustion chamber of an internal combustion engine theoretically results in improved thermal efficiency according to the second law of thermodynamics. However, this may not be the case practically due to the complex nature of the internal combustion and the mechanical and thermal limitations of the insulation material and lubricants. In case of Internal Combustion Engine most of the heat generated during combustion process is absorbed by piston. This is direct heat loss to the piston. This reduces Indicated Power and in turns the performance of Internal Combustion Engine. [6]

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A. Phase I: Performance Evaluation of Normal Two Stroke S.I Engine without Piston Coating

Performance of normal engine will be evaluated and following parameter will be assessed.

- Brake Power
- Mass of fuel consumption
- Brake Thermal Efficiency

B. Phase II: Application of Coating to Piston

Thermal Barriers or coatings like Nickel chromium or ceramic will be applied to piston of normal engine using phenomena of thermal spraying, so as to convert normal engine into piston coated engine.

C. Phase III: Performance Evaluation of Piston Coated Two Stroke S.I. Engine

Performance parameters as discussed in Phase I will also be evaluated for piston coated S.I. Engine, so as to predict its performance.

D. Phase IV: Comparative Study

Comparison will be made between normal engine and piston coated engine. Improved in the performance of piston coated engine will be represented using various performance curves.

IV. EXPERIMENTAL SETUP

Fig. 2: Experimental Setup

The selected engine is a Single Cylinder Two Stroke, 150 cc, Crankcase scavenged engine. A rope brake dynamometer which consists of rope, two spring balances as shown in the fig is used for loading the engine to measure brake power.

The air flow is measured with the help of Air box, which pressure is measured with the help of U-Tube manometer, mounted itself on the air box. The fuel measurement is taken with the help of Burette which is calibrated.

A. Piston Specification

Diameter of piston	56 mm
Shank length	64 mm

No. of ports	5
Pin diameter	14 mm
No. of piston rings	2
Thickness of piston ring	1.5 mm

Table 1: Piston specification

B. *Piston Coating Specification:*

Piston with Ni-Cr Coating	20 micron
Piston with Ni-Cr+Ce Coating	20micron+100micron

Table 2: Piston Coating specification

V. ANALYSIS

After setting the test rig and various equipments, various results were taken which are shown in previous chapter in this chapter we are iterprete these results by analysing them with the help of various graphs. With the help of these graph we can also compare the results with the previous engine.

The following graphs were drawn for the performance evaluation of an engine.

1) Load Vs brake power.
2) Load Vs brake thermal efficiency.
3) Load Vs Mass of Fuel.
4) Load Vs BSFC.
5) Brake power Vs brake thermal efficiency
6) Brake power Vs Mass of fuel.
7) Brake power Vs BSFC.
8) Engine Speed Vs brake thermal eff.

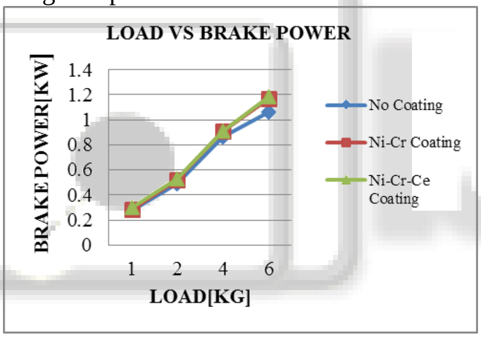

Fig. 3: Graph: Load Vs brake power

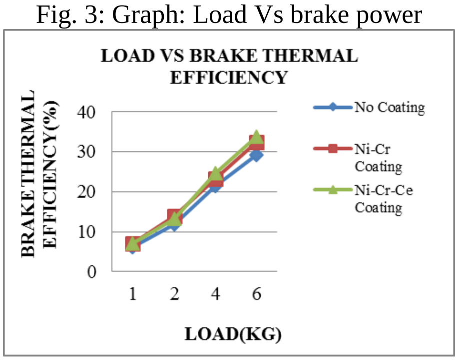

Fig. 4: Graph: Load Vs brake thermal efficiency

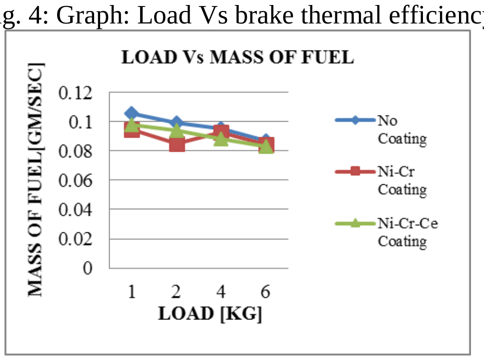

Fig. 5: Graph: Load Vs Mass of Fuel

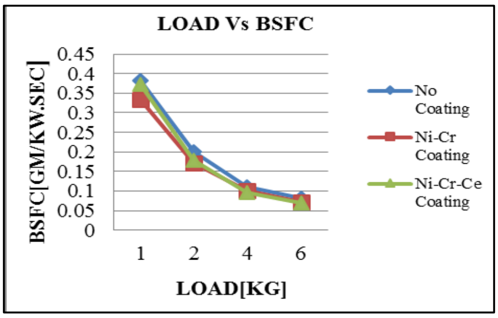

Fig. 6: Graph: Load Vs brake specific fuel consumption

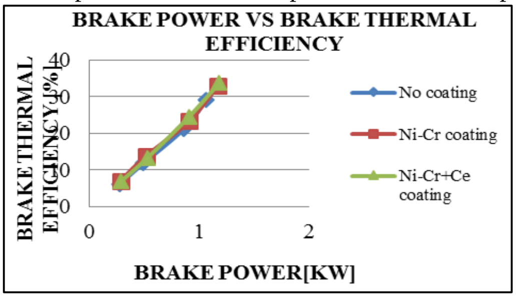

Fig. 7: Graph: Brake power Vs brake thermal efficiency

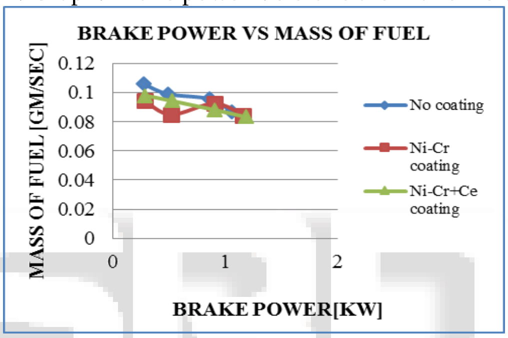

Fig. 8: Graph:-Brake power Vs Mass of fuel

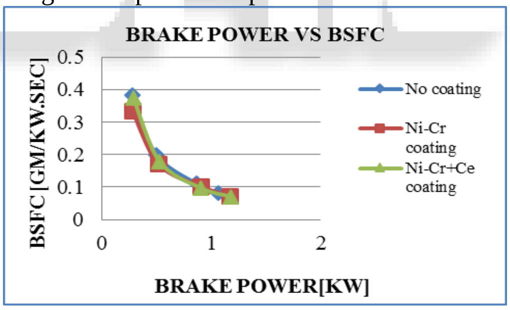

Fig. 9: Graph:-Brake power Vs brake specific fuel consumption

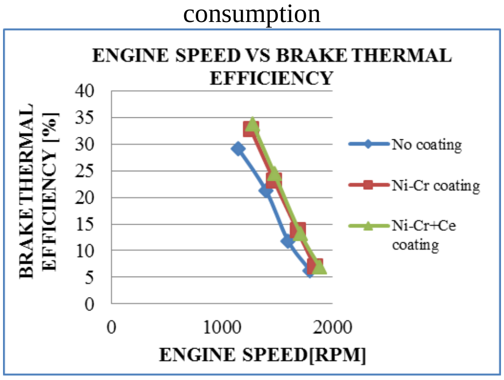

Fig. 10: Graph:-Engine Speed Vs brake thermal efficiency

VI. RESULT & CONCLUSION

Experimental investigation on piston coated two Stroke S.I engine has been conducted as under.

There is percentage increase in brake specific fuel consumption, brake thermal efficiency, mass of fuel consumed for different speeds and loads as-

1) Percentage change in mass of fuel consumed on an average between No coating[C] & Ni-Cr coating [C_1] = 7.74 %
2) Percentage change in mass of fuel consumed on an average between No coating[C] & Ni-Cr-Cr coating [C_2] = 6.02 %
3) Percentage change in mass of fuel consumed on an average between Ni-Cr coating [C_1] & Ni-Cr-Cr coating [C_2] = 5.12 %
4) Percentage change in brake thermal efficiency on an average between No coating[C] & Ni-Cr coating [C_1] = 13.15 %
5) Percentage change in brake thermal efficiency on an average between No coating[C] & Ni-Cr-Cr coating [C_2] = 13.75 %
6) Percentage change in brake thermal efficiency on an average between Ni-Cr coating [C_1] & Ni-Cr-Cr coating [C_2] = 3.49 %
7) Percentage change in brake specific fuel consumption on an average between No coating[C] & Ni-Cr coating [C_1] = 11.68 %
8) Percentage change in brake specific fuel consumption on an average between No coating[C] & Ni-Cr-Cr coating [C_2] = 9.84 %
9) Percentage change in brake specific fuel consumption on an average between Ni-Cr coating [C_1] & Ni-Cr-Cr coating [C_2] = 6.14 %

The performance of a two stroke SI engine will be improved with Ni-Cr-Ce Thermal Barrier Coating, as compared to normal piston & Ni-Cr coating. Therefore Ni-Cr-Ce Thermal Barrier Coating is an effective method to enhance performance of two stroke SI Engine.

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