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Emission Reduction in Si Engine by Using Thermal Barrier Ceramic Coated Piston

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ABSTRACT:
The petrol engine rejects about thirds of the heat energy of the fuel theoretically if the heat rejected could be reduced then the thermal efficiency would be improved at least up to the limit set by the second law of thermodynamics. Ceramic coating provided good thermal barrier properties for designer. In the design of adiabatic engines reducing in cylinder head rejection requires very special thermal barrier coating on the engine combustion chamber. Thermal barrier coating (TBC) on the top surface of the piston in the annulus from is considered as a solution for unburned HC emission produced by incomplete combustion with respect to crevice volume after SI engine. Coating combustion chamber with low heat conduction ceramic materials leads to increasing temperature and pressure in SI engine cylinder .hence an increase in engine efficiency should be observed. The main purpose of this study is to investigate the performance and emission of single cylinder four stroke SI engine using different methanol with petrol without coating and stabilized zirconia coating on cylinder liner and intake and exhaust valve.

KEYWORDS: Thermal Efficiency, Ceramic Coating, Thermal Barrier Coating, Zirconia Coating.

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I. INTRODUCTION:

The thermal barrier coating in SI engine is a subjected to research for much study especially decreasing in cylinder heat rejection of adiabatic engine because ceramic coating demonstrates good thermal property. The thermal barrier coating (TBC) technology is successfully applied to the SI engine. Insulation of the combustion chamber components of low heat rejection (LHR) engine can reduce the heat transfer between the gases in the cylinder and the cylinder wall and thus increase the combustion temperature.

The thermal barrier coating on the elements of combustion chamber of SI engine offer advantages including fuel efficiency multifuel capacity and high power density. To increase the thermal efficiency or to reduce the fuel consumption of the engine leads to the adoption of higher compression ratio in order to reduce in cylinder heat rejection and to increases in mechanical and thermal stress of material used in the combustion chamber.The base line TBC consist of partially stabilized ZrO2 with Y2O3. The ceramic layer has high oxygen permeability.

II. THERMAL BARRIER COATING:

Thermal barrier coatings have been successfully applied to the internal combustion engine in particular the combustion chamber to simulate adiabatic engine. The objective are not only for reduce in cylinder heat rejection and thermal fatigue production of underlying metallic surface but also for possible reduction of engine emissions. The application of TBC reduces the heat loss to the engine cooling jacket through the surfaces exposed to the heat transfer such as cylinder head, liner, piston crown and piston rings. The insulation of the combustion chamber with ceramic coating affect the combustion process and hence the performance and exhaust emission characteristics of the engines a typical TBC system consist of

i. The top coat a porous ceramic laying that acts as the insulator.
ii. The bond coats an oxidation resistant metallic laying between the substance and the top coat.
iii. The super alloy or other material substance that carries the structural load.

It provides production from heat, flame, fire, combustion, exhaust and will not wear, chip, flake or burn off. Teflon low friction coating provides a reduced friction surface for any metal to metal contact. Non welding or oil shed coating is used to help cool items that have direct contact with lubricating oils. Powder coating is both productive and decorative and lasts much longer than paint.

III. METHODS OF COATING:

3.1 THERMAL SPRAYING

The Thermal spraying has emerged as an important tool of increasingly sophisticated surface engineering technology. The different function of the coating, such as wear and corrosion resistance, thermal or electrical insulation can be achieved using different coating techniques and coating material. Thermal spraying is the application of a substrate by melting the material into droplets and impinging the softened or molten droplets on a substrate to form a continuous coating.

Thermal spray processes that have been considered to deposit the coatings :

1. Plasma spraying. 2. Electric arc wire spraying. 3. Flame spraying with powder. 4. Spray and fuse. 5. High velocity oxy-fuel spraying. 6. Detonation gun.

3.2 PLASMA SPRAYING:

Plasma spray is the most versatile of the thermal spray processes. Plasma is capable of spraying all materials that are considered spray able.

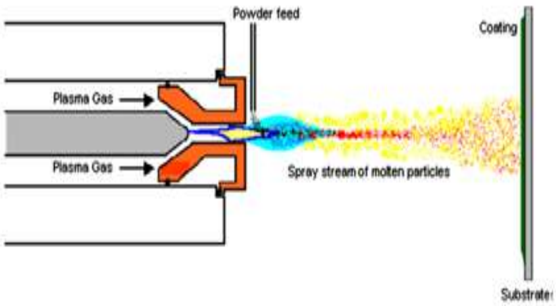

Fig : 1 plasma spray

In plasma spray devices, an arc is formed in between two electrodes in a plasma forming gas which usually consists of either argon /hydrogen or argon helium. As the plasma gas is heated by the arc it expands and is accelerated through a shaped nozzle creating velocity . temperatures in the arc zone approach 36000○F (20000 °K). temperature in the plasma jet are still 18000 °F (10,000 °K) several centimeters form the exit of the nozzle.

Fig: 2 ceramic coated piston

IV. MEASUREMENT OF FUEL CONSUMPTION

Oil tank of engine was filled with fuel. The engine was operated with average load for about one hour. The tank was again filled with the fuel. The fuel consumed in one hour was recorded.

4.1 Co vs load:

The Graph of „Load" Vs. „% of CO" infers that CO decreases with increase in load and increase in oxygen blend quantity. When there is not enough oxygen to convert all carbon to CO_2, some fuel does not get burned. Not only is CO considered an undesirable emission, but it also represents lost chemical energy. Maximum CO is generated when an engine runs with rich air fuel charge. On above graph it is concluded that the oxygen blending increases the complete combustion of fuel takes place and therefore CO pollutant in exhaust gas decreases and converted into CO_2.

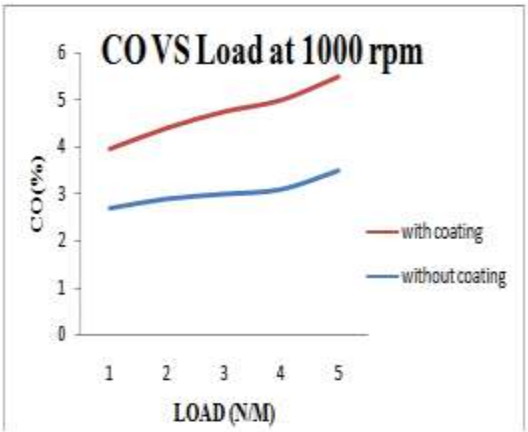

Fig: 3 Co vs load

4.2 HC Vs Load:

Graph of „Load" Vs. „HC" infers that HC increases with increase in load, but decreases with increase in oxygen blend quantity. With a fuel rich mixture there is not enough oxygen to react with all the carbon, resulting in high levels of HC and CO in the exhaust products.

This is particularly true during starting of engine, when the air fuel mixture is purposely made very rich. It is also true to a lesser extent during rapid acceleration under load. If air-fuel ratio is too lean poorer combustion occurs, again resulting in HC emissions. So proper blending of oxygen the complete combustion takes place, therefore HC emissions reduced.

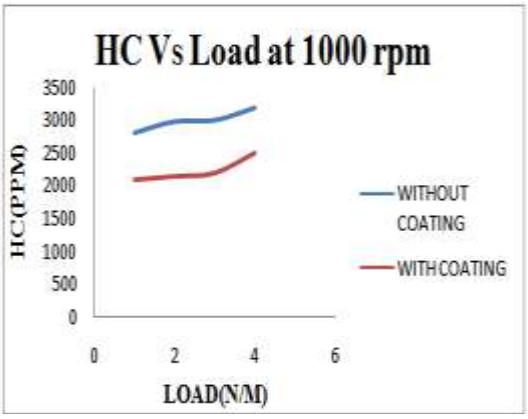

Fig: 4 HC Vs Load

4.3 CO2 Vs Load:

Graph of „Load" Vs. „% of CO2" infers that CO2 increases with increase in load and oxygen blend quantity. When oxygen blended in intake air it will get complete combustion of fuel and due to that CO is totally converted into CO2 and finally percentage of CO2 in exhaust increases.

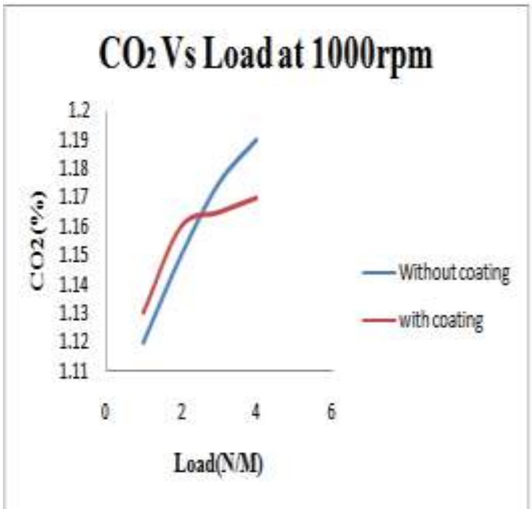

Fig: 5 CO2 Vs Load

4.4 NOx Vs Load:

Graph of „Load" Vs. „NOx" infers that NOx increases with increase in load and oxygen blend quantity. At low temperatures atmospheric nitrogen exists as a stable diatomic molecule N2. Therefore, only very small trace amounts of oxides of nitrogen are found.

The higher the combustion reaction temperature, more dissociation takes place and more NOx will be formed. At this condition flame temperature is still high, and in addition, there is an excess of oxygen that can combine with the nitrogen to form various oxides. Combustion duration also plays a significant role in NOx formation within the cylinder. As the percentage of oxygen blend increases the NOx increases.

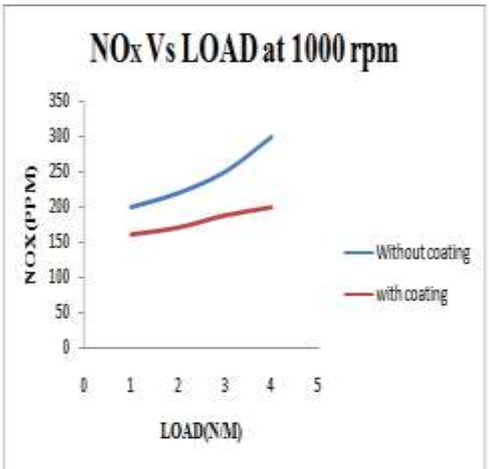

Fig: 6 NOx Vs Load

4.5 Specific Fuel Consumption (S.F.C)

Graph of „Load" Vs. „SF" it is clear that SFC is high for low loads and it is decreasing when the load increases. Moreover same for coated and uncoated pistons, but at the higher loads a significant change in SFC occurs in coated pistons. The reduction of SFC is 0.25 kg/kw-hr at 80% loads and 0.73 kg/kw-hr at full load condition for coated piston. It is due to that the TFC increases for higher load conditions.

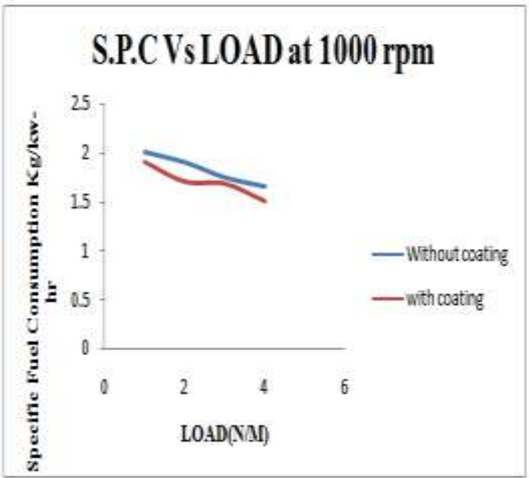

Fig: 7 S.P.C Vs LOAD

4.6 Performance of evaluation

A research study on evaluation of performance of a single cylinder four stroke Otto engine was conducted in the Lab. of Farm Power and Machinery, Sindh Agriculture University, Tandojam. The actual size of engine parameters like bore, stroke, swept volume, clearance volume, compression ratio and r.p.m. were recorded and computed.

Based on the actual size of the engine parameters the indicated horse power (ihp), brake horse power (bhp) and friction horse power (fhp) was determined and were found to be 1.54, 1.29 and 0.25, respectively. The mechanical efficiency and thermal efficiency was also calculated and were found to be 83% and 20.5%, respectively. The fuel consumption per hour was found to be 0.8 liter/hour while the fuel consumption per distance traveled was found to be 60 km/liter.

V. MAIN OBJECTIVES

1. The study engine size including measurements of bore, stroke, displacement and compression ratio.
2. Measurement of power i.e. indicated horse power, brake horse power and frictional horse power.
3. Evaluating the efficiency of engine based on mechanical efficiency and thermal efficiency, considering the input energy supplied to the engine and the output energy delivered by the engine.
4. Measurement of fuel consumption.

VI. FEATURE AND BENEFITS

1. Simultaneous analysis and display of more than 30 gases, 10-100 ppb sensitivity for many toxic gases without moisture removal.
2. Easily transportable from site to site with set up time in low.
3. Permanent calibration elimination the need for costly gas cylinder.
4. Patented linearized detector response assures all instruments maintain the same calibration.
5. User friendly software for simple operation with minimal training.
6. Integrated gas cell pressure and temperature monitoring.

VII. APPLICATIONS

1. Automobile. 2. Locomotive and catalyst exhaust monitoring. 3. Stack monitoring. 4. Continuous emission monitoring. 5. Process monitoring development and optimization. 6. Ambient air analysis 7. Selective catalytic reduction performance monitoring.

VIII. CONCLUSION

As the zirconia is a low thermal conductivity material, it reduces the heat loss from the cylinder to the surroundings. Therefore the efficiencies are increased and the emissions are reduced because of various chemical reactions takes place inside the cylinder at high temperature. Brake thermal efficiency and mechanical efficiency of coated piston are increased by the average value of 9% and 25% respectively.

The study showed that designing pistons of a SI engine with partially thermal barrier coatings which posses low heat conductance properties have a great potential to improve performance and to reduce unburned emissions at idle and partially load conditions. Low heat conductance of ceramic coatings on the top surface of the piston near the flame quenching area is able to increase the temperature from 18% to 48%.

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