Performance and Emission Test of Alumina Coated Four Stroke Single Cylinder SI Engine Using LPG as Fuel

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Abstract—This Experiment presents concept of thermal barrier ceramic coating in Internal Combustion Engines. This experiment was aimed to study effect on performance and emissions results of LPG fuelled Engine with Alumina coating. In this experiment Performance and Emission test is done with coating & without coating for Four stroke single cylinder spark ignition Engine parts. Coating is done on Piston crown & Valve bottom surface circular area.. Test is done for Load v/s Brake power, brakes thermal Efficiency, Specific fuel consumption & also for Emission results. Result is Brake Power is slightly decreases & fuel consumption reduces, Thermal Efficiency increases & Emission result is also improved. So Overall performance and emission results are improved.

Keywords: Thermal Barrier coatings, Alumina coating, Coating in LPG fuelled engines, ceramic coatings on SI Engine, IC Engine Thermal Coating.

I. INTRODUCTION

Now a day's fossils fuel are being costly due to continuing increasing of consumption of Energy .We now a day's mostly depends on Non-Renewable energy resources. Pollution control & increasing Green house effect is also serious problem. So, research interest for decreasing fuel consumption & reduce exhaust gas emissions is more area of interest in technological developments of IC Engines. Gaseous fuels creates smooth running of engine and less exhaust pollutions. Engine efficiency improvement efforts via constructional modifications are increased today, for instance, parallel to development of Thermal barrier material coatings applications in internal combustion engines grow rapidly. To improve engine performance, fuel energy must be converted to mechanical energy at the maximum value. Coating of combustion chamber with low heat conducting ceramic materials leads to increasing temperature and pressure inside internal combustion engine cylinders. So, increase of heat accumulation & thereby increasing available energy inside engine cylinder. Hence, an increase in engine efficiency should be observed.

Starting of the engine can be easier due to shortened ignition delay in ceramic coated IC engines due to increased temperature after compression because of low heat rejection through engine parts. More silent engine operation can be obtained considering less detonation and noise causing from uncontrolled combustion. Engine can be operated at lower compression ratios due to shortened ignition delay. Thus better mechanical efficiency can be obtained and fuel economy & emission results can be improved.

Thermal barrier coated engines can be thought as a step to adiabatic engines. To achieve this aim, ceramic is a preferred alternative. Thermal barrier coating is mostly done by ceramic coating of combustion chamber, cylinder head sand intake/exhaust valves

A. Introduction to Thermal Barrier Materials

Thermal barrier famous materials are ceramic materials. Ceramics have been used since nearly at the beginning of low heat rejection engines. These materials have lower weight and heat transfer coefficient comparing with materials in conventional engines. Nowadays, important developments have been achieved in quantity and quality of ceramic materials. Also new materials named as "advanced technology ceramics" have been produced.

B. 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

C. Different Ceramic Materials

- Different ceramic materials available as listed below.
- Alumina (Al_2O_3),
- Magnesia (MgO),
- Barilla (BeO),
- Yttria (Y_2O_3) and non oxide ones

D. Alumina As Ceramic Coating Material

Alumina is the most widely used oxide ceramic material. Its applications are widespread, and include spark plugs, tap washers, pump seals, electronic substrates, grinding media, abrasion resistant tiles, cutting tools, bioceramics, (hip-joints), body amour, laboratory ware and wear parts for the textile and paper industries.

Aluminum oxide exists in many forms, α, χ, η, δ, κ, θ, γ, ρ; these arise during the heat treatment of aluminum hydroxide or aluminum oxy hydroxide. The most thermodynamically stable form is α-aluminium oxide.

The characteristics which alumina has and which are important for these applications are shown below.

- High compression strength
- High hardness
- Resistant to abrasion
- High thermal Resistance
- High compression strength
- High hardness
- Resistant to abrasion
- Resistant to chemical attack by a wide range of chemicals even at elevated temperatures
- High thermal conductivity
- Resistant to thermal shock

- High degree of refractoriness
- High dielectric strength
- High electrical resistivity even at elevated temperatures
- Transparent to microwave radio frequencies
- Low neutron cross section capture area
- Raw material readily available and price not subject to violent fluctuation

E. Natural Aluminum Oxide Minerals

- Corundum, Al_2O_3
- Spinel, $MgAl_2O_4$
- Hercynite, $FeAl_2O_4$
- Galaxite, $MnAl_2O_4$
- Gibbsite, $Al(OH)_3$
- Diaspore, AlO(OH)
- Boehmite, AlO(OH)

F. Corundum Form of Alumina (Emery Stone)

Natural corundum available from nature & its structure as per indicated in figure

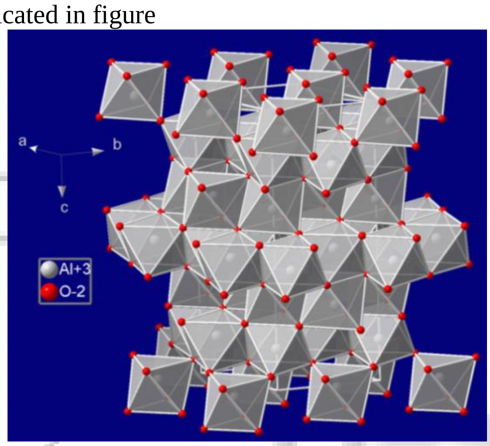

Fig. 1: Natural Corundum (Emery stone) structure

The structure of corundum can be viewed as in figure, a hexagonal close packed array of oxygen atoms with $^2/_3$ of the octahedral sites occupied by Al^{3+} ions. Thus, the Al^{3+} ions are bonded to 6 oxygen in a distorted octahedron. Corundum is a dense (specific gravity of 3.97), hard (9 on the Mohs' scale, next only to diamond), high melting (melting point 2288 K), and insoluble in water. Crystals of corundum are usually prismatic or barrel-shaped bounded by steep pyramids. A massive grey granular corundum powder is called emery

G. Lpg As Si Engine Fuel

LPG is a mixture of commercial butane and commercial propane having both saturated and unsaturated hydrocarbon. LPG is easily available commercial. LPG kit available in market and easily can be fit with 4-stroke SI Engine.

H. Properties of Lpg As Engine Fuel

LPG as Engine Fuel has following advantages.

- No soot, burners have a longer life - so maintenance is less
- 4 –stroke 100 cc engine gives mileage of 60 KMPL while with LPG gives 72 kmpl. so 25 to 35% more mileage with LPG.
- High octane number so smooth & knock free operation.
- No spillage as it vaporizes at atmospheric temperature and pressure.
- Effects of corrosion are greatly reduced
- Instantly controllable flame temperature
- Avoids Scaling and decarborising of parts
- Environmentally friendly fuel, with minimal sulphur content and sulphur- free emissions
- Very high efficiency with direct firing system Instant heat for faster warm-up and cool-down
- Can be used for a variety of applications.

II. EXPERIMENTAL SETUP

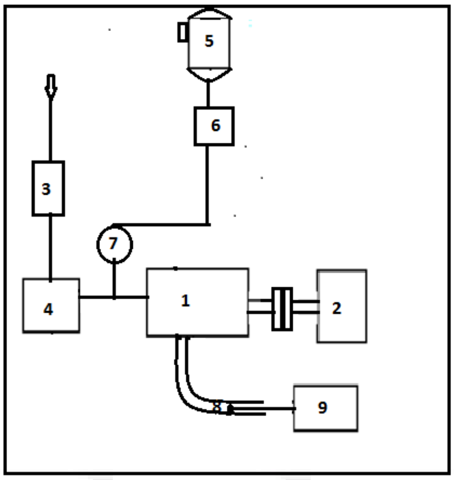

Fig. 2: Experimental Set-Up

1. Engine 2. Dynamometer 3. Air-Filter 4. Carburettor 5. LPG Tank 6. LPG control valve 7. Vaporizer 8. Exhaust pipe 9. Gas Analyzer

Table. 1: A. ENGINE SPECIFICATION

Engine Type	4-Stroke Single Cylinder Air-Cooled, DTS-i
Engine Displacement(cc)	134.21 cc
Compression Ratio	9.5:1
Maximum Power	9.64kw @ 8500rpm
Cylinder Bore	67 mm
Stoke	56.4 mm
Ignition	Microprocessor Controlled
Starting	Kick Start/ Self Start
Battery	12 V.

III. DETAIL OF CERAMIC COATING

Table. 2: Detail of ceramic coatin

Coating on surface	Piston Crown & Inlet-Exhaust valves bottom base circular surface
Bond Coating	100 microns,NiCrAl
Top Coating	200 microns, yttria stabilized Allumina(Al2 O3) in corundum form

Hardness of coating surface	60 to 70 RC
Coating system	Plasma spray method
Coating method	Robotic type
Particle size in mesh size	20 mesh
Total Cost of coating	Rs 17000

Fig. 3: With ceramic coated & without coated piston crown and valves

IV. EXPERIMENTAL PROCEDURE

- Engine is mounted on test-rig and engine crank shaft brake drum is coupled with belt brake dynamometer.
- First LPG gas supply is switched ON through regulator & gas supply made on up to vaporizor.For safety point of view arrangement is checked for leakage of gas. If no leakage is found and condition is safe then engine is started by kick-start & gas supply is maintained as per requirement of engine by vaporizer. Engine is started and kept running in idling for 1 hour.
- After, Load measurement is taken by dynamometer at 0.5kg, 2kg, 4kg, 6kg, and 8kg on Engine & measured through spring balance.
- Speed is measured by digital tachometer at different load applications.
- Stop watch is used for time measurement for stability of RPM & Engine condition to take readings.
- Gas Flow meter is used to measure quantity of gas supplied to engine means fuel consumption.
- Four Exhaust gas analyzer is used to measure level of pollutants of CO, Co_2, HC emissions at different RPM.
- After first readings without coating on Engine, it is disassembled. Piston & valves are Opened piston is disassembled from connecting rod.
- Piston & valves are sent for ceramic plasma coating process & after coating engine is reassembled & above procedure for experiment is repeated.
- Finally comparison is done for performance & Emission results for with & without coating case.

V. RESULTS & DISCUSSION

A. Performance Results

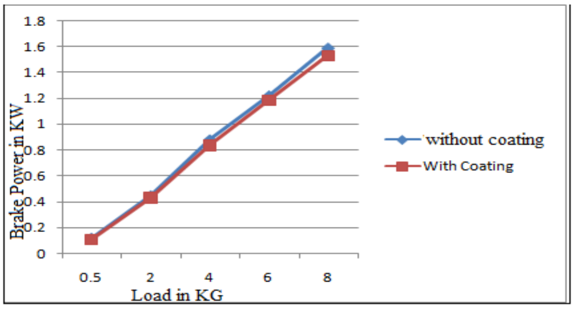

Fig. 4: Load v/s Brake Power

As load increases on engine Brake power also increases with and without coating of Engine parts. But Brake power is slight lower in coated piston & valves than brake power without coated parts. Brake power is less in 3.77% of brake power without coated at maximum load on engine, in case of 8 kg. It is 0.06KW less at 8kg load with coated engine parts.

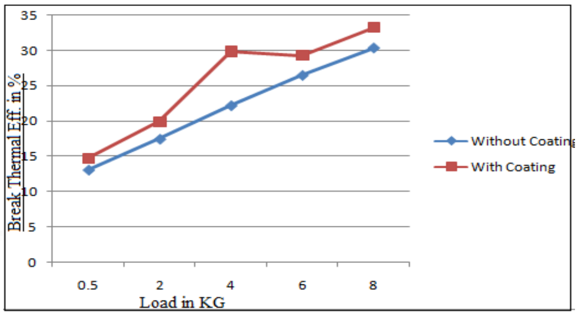

Fig. 5: Load v/s Brake Thermal Efficiency

As load increases Break thermal efficiency increases, It is always high in case of coated engine parts it is maximum at 4kg of load is 29.78% & maximum 7% higher achieved at 4 kg load, after brake thermal efficiency increases slow trend as per results plotted in graph. At maximum load it is 2.84 % higher than without coating case.

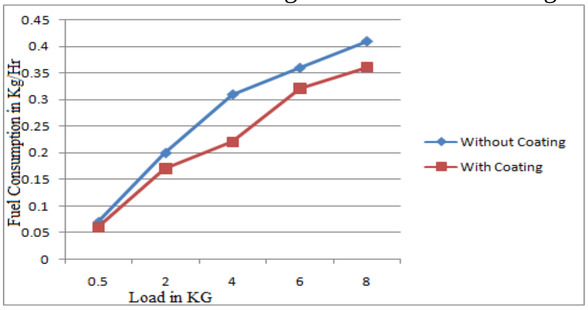

Fig. 6: Load V/S Fuel Consumption

When Load increases Fuel consumption also increases but it is lower in case of coated piston & valves conditions. Up to 4 kg load it increases slowly with coated engine parts. At 4 kg load it is 0.22 kg/hr is and 29% lower than fuel consumption without coating .Fuel consumption is 0.05 kg/hr less than without coating in case of 8 kg engine load So at maximum load it is around 12% lower than fuel consumption in without coating.

B. EMISSION RESULTS

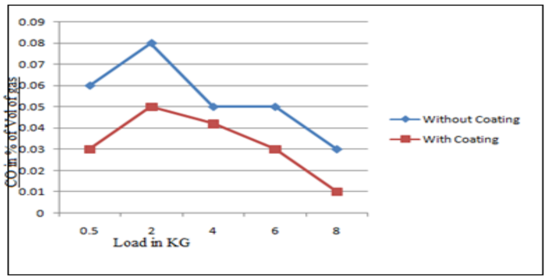

Fig. 7: Load V/S CO measurement

CO is always lower incase of coating of engine parts.CO % is 50% lower incase of with coating conditions.CO % is lower maximum upto 2 kg load but at 2kg it is 0.03% lower than without coating case.It is found maximum reduce 0.5 and 2kg for 0.03 % and found minimum reduction at 4 kg load is 0.01 %. At higher load it is reduced 0.02 %.

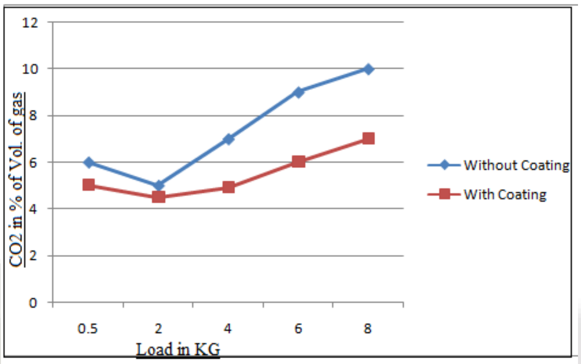

Fig:- 8 Load V/S CO_2 measurement

CO_2 is always found lower in case of with coating of Engine parts.CO2 first reduces at 2kg load in both cases but after it is increases increase in load. At 0.5 % it decreases 1%, & at 2,4,6,8 kg it reduces at 2.1%,3%,3% respectively in case of with coating Engine parts. It reduces maximum at maximum loads upto 3% in with coating .

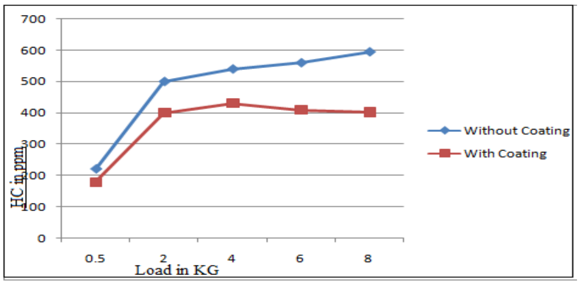

Fig. 9: Load V/S HC measurement

HC Emission first increases fastly and after increases slowly as per increase of load on engine. At 0.5,2,4,6,8 kg loads HC emissions reduces at 40,100,110,150 ppm respectively.

VI. CONCLUSION

Based on above Experimental study we conclude that by means of alumina coating on engine 's piston crown & valves bottom surface there is proven improvement in performance and emissions results with LPG as Engine Fuel.

Brake power is in slightly lower trend & it no more violates & maximum reduction is at 8 kg maximum load is only 0.06.Break thermal efficiency is always higher in coated conditions at 4 kg load it is 29 % higher of efficiency without coating, and 7% higher achieved at medium loads & at high loads it is 2.84% higher than without coating. Fuel consumptions is always reduced in coated condition. it is 29% compared lower at medium 4kg loads and 12% reduces at maximum 8kg loads.CO is reduced maximum 0.03% at medium loads & at higher loads it rescues 0.02% at 8 kg load.CO2 is first reduces up to 2kg load and after that it increases as per load increases but it is lower than without coating condition always. it reduces max. at maximum load up to 3% in emissions.HC reduces to 150 ppm maximum at maximum load of 8kg on engine. It also increases as increase in loads but always lower than without coating conditions.

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