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Performance Testing Of Diesel Engine With Tio_2coated Engine Parts

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ABSTRACT: In automobile engines, around one third of the energy is lost as heat.Ceramic materials are known for their low thermal conductivity and high lubricity.Ever since the evolution of ceramic materials it has been coated over engine partsto improve its thermal efficiency. Ceramics, due to their low thermal conductivity,when coated in engine parts would reduce the heat dissipation from the engine.Thus heat losses could be reduced. Based on the availability, cost and ease ofcoating intricate parts, titanium dioxide (TiO_2) was selected as a coating material in this work. Thevalves and piston of a single cylinder four stroke Diesel engine were coated withtitanium dioxide and a performance test was carried out. It was observed that improved in performances in terms of indicated thermal efficiency, brake thermal efficiency and mechanical efficiency were obtained.

KEYWORDS: Heat loss; Ceramic Materials; Low Thermal Conductivity; Performance test

I. INTRODUCTION

An engine or motor is a machine designed to convert energy into useful mechanical work. Heat engines burn a fuel to create heat, which then creates work.A diesel engine (also known as a compression-ignition engine) is an internal combustion (IC) engine that uses the heat of compression to initiate ignition and burn the fuel that has been injected into the combustion chamber. Of the heat produced in the engines, some heat is conducted through the engine parts and radiated to the atmosphere or picked up by the surrounding air by convection. The effect of these losses varies according to the part of the cycle in which they occur. The heat of the jacket cooling water cannot be taken as a true measure of heat losses, since all this heat is not absorbed by the water. Some heat is lost to the jackets during the compression, combustion, and expansion phases of the cycle; some is lost (to the atmosphere) during the exhaust stroke; and some is absorbed by the walls of the exhaust passages [1,2].

Ceramic coatings are widely used in industry for providing valuable improvements against wear, corrosion, erosion, and heat in designs. Thermal barrier coating (TBC) technology is successfully applied to the IC engines, in particular to the combustion chamber. Insulation of the combustion chamber components of low heat rejection (LHR) engines can reduce the heat transfer between the gases in the cylinder and the cylinder wall and thus increase the combustion temperature. The LHR engine concept is based on suppressing this heat rejection to the coolant and recovering the energy in the form of useful work[3, 4].A burned piston is a piston that has been subjected to excessively high combustion temperatures. Damage may include a hole burned through the top of the piston or the upper piston land. This type of damage is typically caused by a hot spot in the combustion chamber that becomes a source of premature ignition. The cause may be due to an extremely lean air/fuel mixture, a hot exhaust valve or even a sharp edge in the combustion chamber. Reading the spark plugs should tell you something about the air/fuel mixture and the heat range of the plugs. If overheating is involved, the scuffing will be primarily on the upper ring lands and on the sides near the wrist pins [5]. Normally the piston temperature is higher on the exhaust side so catastrophic problems will appear there first. This problem is caused due to overheating of the piston. As the temperature is higher on the piston crown it will lead to several damages over the crown surface (Fig. 1). This could be overcome by providing a thermal barrier coating over the piston crown[2].

Fig.1. Burnt out blow hole on piston [2]

In general, a four corner seizure (Fig. 2) is caused when the piston expands faster than the cylinder and the clearance between the piston and cylinder is reduced. The main reasons for this problem are overheating of the piston and the piston rings[3]. So that the thermal barrier coating will reduce the heat flowage to the piston rings and protects the piston from expanding.

Fig.2. Four corner seizure on piston [2]

Further, melting of piston crown (Fig. 3) is caused by the engine running too hot. The ash color is actually piston material that has started to flash melt and turned to tiny flakes. If the engine was left to run much longer it would probably have developed a hot spot and hole on the exhaust port side and then finally failed. Main causes are general overheating [2]. By providing a thermal barrier coating, the piston could even with stand high temperatures.

Fig.3. Melting of piston crown [2]

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In addition, erosion (Fig. 4) is the pitting or wearing away a surface over a period of time, cause by suspended abrasive particles in a liquid or gas being thrust against a surface[4]**.** The TBC provided over the crown will act as a resistant to erosion.

Fig.4 Erosion on piston crown

II. THERMAL BARRIER COATING (TBC)

Thermal barrier coatings (TBC) are highly advanced material systems usually applied to metallic surfaces, such as gas turbine or aero-engine parts, operating at elevated temperatures, as a form of exhaust heat management. These coatings serve to insulate components from large and prolonged heat loads by utilizing thermally insulating materials which can sustain an appreciable temperature difference between the load-bearing alloys and the coating surface. In doing so, these coatings can allow for higher operating temperatures while limiting the thermal exposure of structural components, extending part life by reducing oxidation and thermal fatigue. In conjunction with active film cooling, TBCs permit working fluid temperatures higher than the melting point of the metal airfoil in some turbine applications.

A ceramic thermal barrier coating (TBC) protects piston domes [5]. TBC holds heat inside the combustion chamber where it can power the sled, rather than dissipate through the piston to weaken or burn the metal. TBC also protects parts from high temperature oxidation and reduces heat transfer by spreading the heat over the entire coated surface. This encourages proper flame travel and eliminates hot spots. Less heat conduction through the wrist pins and rods keeps the crank and bearings cooler, too. And, the coating is thin enough that no clearance provisions have to be made [6].

Ceramic thermal barrier coatings were originally developed and commercialized for gas turbine and jet engine applications [3]. Many investigations have been conducted on various aspects of applying such coatings to the walls of combustion chamber in internal combustion engines [2, 3]. The prime objective which has been sought is to achieve higher thermal efficiencies by reduction of heat rejection from the combustion chamber. Experiments with diesel and gasoline engines suggest that thin coatings produce higher engine efficiency than thick coatings, in spite of being less effective as heat insulators. This behavior of ceramic coatings has not been satisfactorily explained. It is believed that some detailed heat transfer characteristics must have a more profound effect on thermodynamic efficiency than the overall heat rejection rate from the engine.

Several ceramic materials such as zirconium oxide, titanium dioxide, chromium oxide, aluminum oxide, and mullite have been investigated as in-cylinder engine coatings. Titanium dioxide, thanks to its low thermal conductivity and its thermal expansion coefficient which is compatible with that of metals, has become the preferred and most studied material. Ceramic coatings can be deposited by plasma spraying or from ceramic slurry. The thermal spraying technique using a plasma torch has been used most extensively for this purpose. Inthe plasma spray process zirconia is fed as a powder into the plasma stream of the torch where it is melted at temperatures as high as 16,000°C. The high pressure plasma gas stream propels the molten particles onto the coated surface where they solidify. Powder and process parameters are used to control the structure and properties of the coating. The thickness of coatings can range

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from 0.05 to 2 mm. The optimal thickness of realistic materials is usually below 0.5 mm thin coatings were reported to exhibit both better performance and durability.The coating of high heat resistantmaterial over the piston crown will result in: wear resistance, corrosion resistance, heat resistance, thermal barrier, high resistance to spallation, good erosion resistance, phase stability, prevents heat loss through the piston, keeps combustion temperatures up, fuel burns more efficiently, increased horsepower and educes heat transfer to the top ring [7].

III. SELECTION OF CERAMIC MATERIALS OVER IC ENGINE PARTS

Ceramic materials are inorganic, non-metallic materials made from compounds of a metal and a nonmetal. Ceramic materials may be crystalline or partly crystalline [1, 3].Ceramic materials have excellent thermal properties. They have a very low thermal conductivity. So providing a ceramic coating would provide a thermal insulation to the engines.Increases in temperature can cause grain boundaries to suddenly become insulating in some semiconducting ceramic materials, mostly mixtures of heavy metal titanates. The critical transition temperature can be adjusted over a wide range by variations in chemistry. In such materials, current will pass through the material until joule heating brings it to the transition temperature, at which point the circuit will be broken and current flow will cease. Such ceramics are used as self-controlled heating elements in, for example, the rear-window defrosts circuits of automobiles.At the transition temperature, the material's dielectric response becomes theoretically infinite. While a lack of temperature control would rule out any practical use of the material near its critical temperature, the dielectric effect remains exceptionally strong even at much higher temperatures. Titanates with critical temperatures far below room temperature have become synonymous with "ceramic" in the context of ceramic capacitors for just this reason. Based on the availability and ease of coating, Titanium di oxide was selected as the coating material.
Titanium dioxide, also known as titanium (IV) oxide or titania, with its molecular formula TiO_2 and molecular weight 79.87, is a kind of powder. Titanium dioxide color is white. Formula for titanium dioxide is TiO_2. Titanium dioxide is a soft solid and melts at 1800 Degrees Celsius. It has special performance, such as insulation, corrosion, flags, etc. It is polymorphous and it exists in three types of crystal structures: (a) rutile, (b) anatase and (c) brookite. Only rutile is used commercially and the structure is shown in the Fig.5.

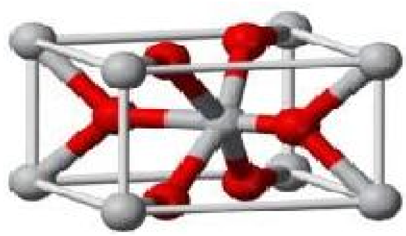

Fig.5 Structure of Titanium [7]

Table 1 Properties of Titanium di oxide are:

Molar mass	79.8658 g mol^{-1}
Refractive index	2.76 ~ 2.55
Mohs Hardness	6-7, 5.5-6
Capacitance ratio	114 to 31
Coefficient of linear expansion	25 °C
Thermal Conductivity	1.809 to 10.3
Oil Absorption	16 ~48,18 ~30
Particle size	0.2 ~ 0.3, 0.3

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IV. COATING THE ENGINE PARTS

Piston and valves are coated by the process of plasma spraying. Plasma spray process is a method of giving a material a protective coating through the form of a plasma spray. The wide range of process temperatures allows using many different materials and compounds, from high to low melting temperatures. The process itself can be rather complex, because of all the interacting parameters. The applications for this process are increasing every year and will continue to increase because of the ability to vary coatings for different materials. The potential for this process is almost unlimited for substrate coatings. The most favored primary gas in this process, it is usually used with a secondary gas as well. This is being one of the other three gases that can be used in the process. When used with a secondary gas, the argon wants to increase its energy. Argon is the easiest gas to form plasma and it isn't as hard on the equipment used.TBC coating systems must possess a combination of properties to be effective. These include a low thermal conductivity, high resistance to spallation, good erosion resistance, phase stability and pore morphological stability. Thermal barrier coatings (TBC) provide the potential for higher thermal efficiencies of the engine, improved combustion and reduced emissions. Lower heat rejection from 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 the exhaust gases, which could be also utilized. Thermal barrier ceramic-coatings are becoming more common in automotive applications. They are specifically designed to reduce heat loss from engine exhaust system components including exhaust manifolds, turbocharger casings, exhaust headers, down pipes and tailpipes.

In plasma spraying process (Fig. 6), the material to be deposited (feedstock) typically as a powder, sometimes as a liquid, suspension or wire is introduced into the plasma jet, emanating from a plasma torch. In the jet, where the temperature is on the order of 10,000 K, the material is melted and propelled towards a substrate. There, the molten droplets flatten, rapidly solidify and form a deposit. Commonly, the deposits remain adherent to the substrate as coatings; free-standing parts can also be produced by removing the substrate. There are a large number of technological parameters that influence the interaction of the particles with the plasma jet and the substrate and therefore the deposit properties. These parameters include feedstock type, plasma gas composition and flow rate, energy input, torch offset distance, substrate cooling, etc[7].

Fig. 6. Plasma spray unit

Sandblasting (Fig. 7) is a general term used to describe the act of propelling very fine bits of material at high-velocity to clean or etch a surface. Sand used to be the most commonly used material, but since the lung disease silicosis is caused by extended inhalation of the dust created by sand, other materials are now used in its place.

Fig. 7. Sand blasting equipment

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Any small, relatively uniform particles will work, such as steel grit, copper slag, walnut shells, powdered abrasives, even bits of coconut shell. Due to the dangers of inhaling dust during the process, sandblasting is carefully controlled, using an alternate air supply, protective wear, and proper ventilation.

Fig. 7.TiO_2Insulated piston

Insulation is a new way of approaching or utilizing the maximum heat produced during the combustion process which is made up on the top of the piston for about 0.5mm with the help of plasma spray technique the above shown Fig. 7 is the titanium dioxide coated piston which is made as a part of kirloskar 5HP engine for observing increased performance**.**

V. RESULTS AND DISCUSSION

Test engine used here in a 5 HP, four stroke, and single cylinder diesel engine. Details of the test engine are given in Table 2.

Table 2 Engine specifications

Engine type	Kirloskar
Stroke number	4
Cylinder number	1
Bore	80 mm
Stroke	110 mm
Compression ratio	16.5:1
Maximum engine power	3.7 KW
Maximum engine speed	1500 rpm
Specific fuel consumption	175 g/Kwh
Cooling type	Water
Cubic capacity	533 cc

The engine with coated and uncoated pistons was tested for its performance characteristics.

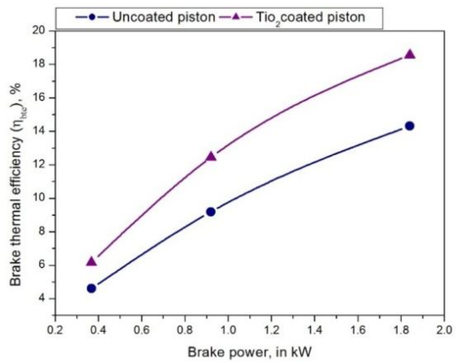

Fig.11BP vs BTE

The graph shows start with good increase in efficiency with added brake power .This results that the change in pressure leads to a pop of 5% with increased load with constant speed. Variations are seen overview for the mechanical efficiency and get noted the amount of fuel consumed for the applied load.

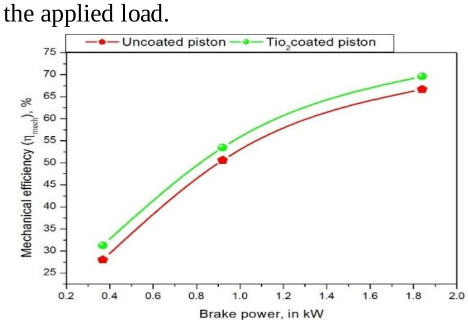

Fig.12 BP vs ME

Efficiency is get increased as 6-7 % for the TiO_2 coated piston when compared to uncoated piston for the change in pressure of 900 lb/in^2

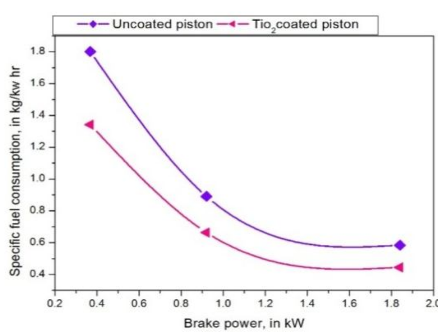

Fig.13BP vs SFC

For the load applied for coated and uncoated piston revise of fuel consumption plays a important role in how efficient the work output is done for appropriated fuel consumption and utilization of that fuel as much as for combustion process. The graph shows a considerable decrease of fuel consumption for coated piston for the same load parameters of uncoated piston.

VI. CONCLUSION

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The following conclusion is made for the performance of TiO_2 coated piston and uncoated pistons:

- TiO_2 believed to be a low thermal conductive material results in improved efficiency when coated over the parts of the engine. The efficiency is said to be increase to **5%** for coated than uncoated piston for varied injection pressure.

- Coating results in decreased fuel consumption as 0.3 kg/kW hr thus shows that maximum utilization of fuel takes place inside the combustion chamber of the diesel engine.

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