EXPERIMENTAL ANALYSIS OF THERMAL BARRIER COATING IN TWO STROKE SI ENGINE

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ABSTRACT

The demand for energy is increasing day by day . The world is depending mostly on fossil fuels to face this energy needs. The increase in standard of living demands better mode of transport , hence a large number of automobile companies has been introduced. Automobiles provide better transport but the combustion of fuel in automobile engine creates harmful effluents, which has an adverse effect on water and air. Combustion generated pollution is by far the largest man made contribution to atmosphere pollution. The principle pollutants emitted by the automobile engines are CO,NOX,HC and particulates. The modern day automobiles is a result of several technological improvements that have happened over the years and would continue to do so to meet the performance demands of exhaust- gas Emissions , fuel consumption, power output, convenience and safety . In order to reduce emissions and increasing engine performance , modern car engines carefully designed to control the amount of fuel they burn. An effective way for reducing automotive emission and increase engines performance is accomplished by coating automobile piston head with low thermal conductivity material such as ceramic. This process is known as Thermal Barrier Coating(TBC) and this experimental analysis deals with its analysis.

INTRODUCTION

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. 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.[1]

Thermal barrier coating used in piston increasing the brake thermal efficiency and decreasing the specific fuel consumption for light heat rejection (LHR) engine with thermal coated piston compared to the standard engine. There was increasing the NOx emission and O2 for thermal barrier coated engine. However there was decreasing the CO and HC emissions for thermal coated piston engine compared to standard engine.[2]

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.[3]

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]

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 selected surfaces like the piston crown or valves. The primary purpose of the TBC is to raise surface temperatures during the expansion stroke, there by 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.[5]

Terminology of TBC

Structure of thermal barrier coating

In order to ensure a good performance of a TBC in different applications the different types of ceramic materials are used. A structure of a coating however is quite similar for all applications. The typical TBC is built of several material layers where each has a different function. There are three main layers in a TBC.

Top coat:

This layer is the main functional layer if the thermal barrier coating that is it satisfies the purpose for which it iis applied to the engine components and it is thermal insulation of the engine combustion chamber to reduce heat loss. This coating is made up of ceramic material which has low thermal conductivity, high temperature stability and the most important thermal expansion coefficients close to the substrate material to reduce the effect of thermal misfit.[6]

Bond coat:

This layer is provided in between the top layer and the substrate material to provide flexibility against thermal misfit, to ensure the soft materials like MCrALYids used. This material absorbs the thermal strains produced while operation of engine. This layer also prevent the high temperature corrosion of the substrate material, in our case it is aluminium alloy piston. It prevents corrosion by avoiding oxygen(O2) diffusion at high temperature through porosity in ceramic layer.[6]

Thermally grown oxide layer:

This helps in preventing oxygen diffusion to the substrate material. This has some drawbacks, as it is brittle, cracking occurs at high temperature which leads to the failure of coating. [6]

Materials of TBC

Zirconates

The main advantages of zirconates are their low sintering activity, low thermal conductivity, high thermal expansion coefficient and good thermal cycling resistance. The main problem is the high thermal expansion coefficient which results in residual stress in the coating, and this can cause coating delamination.[9]

Yittria stabilized zirconia

7-8% Yittria stabilized zirconia has high thermal expansion coefficient, low thermal conductivity and high thermal shock resistance . disadvantages of yittria stabilized zirconia are sintering above 1473K, phase transformation at 1443K, corrosion and oxygen transparent.[9]

Mullite

Mullite is an important ceramic material because of its low density, high thermal stability, stability in severe chemical environment, low thermal conductivity and favourable strength and creep behaviour. Compared with yittria stabilized zirconia, mullite has a much lower thermal expansion coefficient and higher thermal conductivity, and is much more oxygen resistant than yittria stabilized zirconia. The low thermal expansion coefficient of mullite is an advantage relative to yittria stabilized zirconia in high thermal gradient and under themal shock conditions. However, the large mismatch in thermal expansion coefficient with metallic substrate leads to poor adhesion. The other disadvantage of mullite is crystallization at 1023-1273K.[9]

Alumina

It has very high hardness ansd chemical inertness. Alumina has relatively high thermal conductivity and low thermal expansion coefficient compared with yittria stabilized zirconia. Even though alumina alone is not a good thermal barrier coating candidate, its addition to yittria stabilized zirconia can increase the hardness of the coating and improve the oxidation resistance of the substrate. The disadvantages of alumina are phase transformation at 1273K, high thermal conductivity and very low thermal expansion coefficient.[9]

Spinel

Although spinel has very good high temperature and chemical properties, its thermal expansion coefficient prevents its usage as a reliable choice for thermal barrier coatings.[9]

Forsterite

The high thermal expansion coefficient of forsterite permits a good match with the substrate. At thickness of some hundred microns, it shows a very good thermal shock resistance.[9]

METHOD OF COATING

Thermal Sprayings

Thermal spray techniques are processes in which powders heated to melting temperature are directed in a fast flow towards the desired surface, and deposited on it. Electrical arc or thermal plasma is used a source of heat. Materials like metals, alloys, ceramics or plastics in a form of powder or wire can be used. For the coating process to be effective the sprayed material cannot however decompose when melted. Since the bonding of the coating to the substrate is mechanical the adhesion is dependent on the cleanliness and pre-treatment of the substrate surface. The pre-treatment is often done by grit blasting which aims to roughen the surface.

There are many variants of thermal spraying methods like:

High velocity oxy-fuel coating spraying (HVOF)

Wire arc spraying

Plasma spraying

Detonation spraying

Flame spraying

Warm or Cold spraying

CONCLUSION

By insulating piston crown, it is possible to reduce heat lost by this part such as about 50 % of this energy is lost through the piston and 30 % through the head. Also the present trend in the engine technology is to us light weight components to improve performance and the research is following this trend. Ceramic materials which have low thermal conductivity and high thermal expansion coefficient are used for making combustion chamber components thermal insulated. In this paper, the primary stages of coating process were reviewed. For a successful coating thermal coating, ceramic material has a high melting point, high oxygen resistance, high thermal expansion coefficient, high corrosion resistance, high strain tolerance, and low thermal conductivity and phase stability. The objectives of improved thermal efficiency, improved fuel economy and reduced emissions are attainable, but much more investigations under proper operating constraints with improved engine design are required to explore the full potential of Low Heat Rejection engines.

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