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A REVIEW ON THERMAL BARRIER COATINGS ON GAS TURBINE ENGINE BLADES AND VANES

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Introduction

Thermal barrier coatings (TBC) are highly sophisticated materials systems commonly applied to metallic surfaces, such as on gas turbine or aero-engine components, working at excessive temperatures, as a kind of exhaust heat control. Thermally insulating materials that can maintain a noticeable temperature differential between the load-bearing metals and the coated surface are used in these coatings to

protect components from heavy and extended heat loads. [1] In \sdoing so, these coatings may allow for greater operating temperatures while minimising the heat exposure of structural components, increasing part life by lowering oxidation and thermal fatigue. In combination with active film cooling, TBCs allows working fluid temperatures greater than the melting point of the metal airfoil in certain turbine applications.

What is meant by exhaust gas management and how it is linked to Thermal barrier coatings?

MATERIALS FOR THERMAL BARRIER COATING

The materials that may be used as thermal barrier coatings must meet a number of criteria. These properties include a high melting point, no phase transition from room temperature to operation temperature, low thermal conductivity, chemical inertness, thermal expansion matching with the metallic substrate, good adhesion to the metallic substrate, and a low sintering rate of the porous microstructure So yet, only a few materials have been identified that generally meet these criteria. There are several ceramics which are utilised for thermal barrier coating below.

Thermal barrier coatings (TBC): As a result of their very low thermal conductivity and a coefficient of thermal expansion that is greater than the majority of insulating ceramics, stabilised zirconia is the most often employed coating in high temperature engine applications today. Coating thicknesses used in engine applications have ranged from 0.1mm to 4.5mm, with thicker coatings supposedly giving higher resistance to heat flow. The most frequent means of applying these coatings has been by plasma spraying which has been used to apply coatings both selectively to certain engine components (i.e. valves, cylinder head, piston crown) and to the whole combustion chamber. The principal issues offered by heat barrier coatings inside engine conditions originate from their longevity. Due to their low coefficients of thermal expansion (CTE) in comparison to the metallic substrates upon which they are applied, ceramic TBCs are prone to cracking, spalling and eventual failure resulting from the cyclic thermal stresses created by the temperature differential between the coating and the substrate. In an effort to ameliorate these difficulties, novel nano-structured ceramic and metal-based TBCs with CTEs more akin to normal metallic substrates have been investigated, with some encouraging results. The elevated surface temperatures in a TBC-covered combustion chamber may also result in the deterioration of engine lubricants, while lowering the volumetric efficiency of the engine owing to heating of the intake charge. As we'll see, greater temperatures may have a substantial impact on combustion, which, in turn, has a direct impact on emissions from engines. The use of TBCs in compression and spark ignition engines to manage heat losses has been studied extensively, although they are not presently employed in production engines. The next section provides a quick rundown of what's already out there in terms of research in these two domains.

Engine efficiency

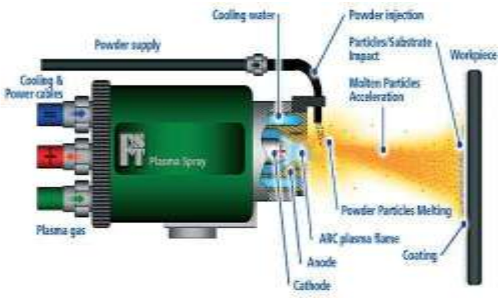
Volumetric Efficiency: When it comes to the engine's capacity to exhale, the volumetric efficiency is a good indicator. It depends on the ambient and operating conditions of the engine. The LHR engine's combustion chamber walls become hotter when ceramic insulation is used to reduce heat rejection. The inducted air's density should decrease due to the hotter walls and remaining gas, reducing the volumetric efficiency. As predicted all the experiments such as Gatowski , Miyairi et al. on LHR engine indicate lower volumetric efficiency. The loss in volumetric efficiency of the LHR engine may be avoided by turbo-charging and that there can be more efficient usage of the exhaust gas energy.

The quantity of nitrogen oxides versus the brake power

Thermal Efficiency: The increase in engine thermal efficiency through decrease of in-cylinder heat transfer is the fundamental target of LHR engine research. There has been a great deal of investigation into the potential of LHR engines to reduce heat rejection and achieve high thermal efficiency at various research centres. Researchers such as Havstad et al. Moore et al. Morel et al, and many more have found increase in thermal efficiency using LHR engine. They ascribethis reduces the heat flow and reduces the amount of energy transferred. Research done by others, however, such as those of Cheng et al., Woschni et al., and Furuhama et al., has shown that Insulation lowers thermal efficiency, according to Dickey and others. It's believed that this is due to an increase in the convective heat transfer coefficient, increased heat flux (increase in heat transfer), and poorer combustion cylinder heat transfer characteristics of the LHR engine, all of which are still not fully understood. Thus the influence of combustion chamber insulation on minimising heat rejection and thus on thermal efficiency is not completely recognised as on data.

Objective

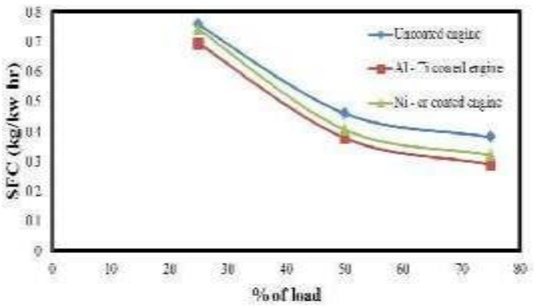
The performance of internal combustion engines should be increased relying on specific technical needs and quick growth in the fuel prices. Alternative fuels and environmental regulations, on the other hand, are driving advancements in engine materials. Therefore, the performances of engine materials become more significant. For increasing the performance of engine, thermal barrier coatings (TBCs) represent a potential step forward. In this experimental work, alumina – (40 percent) titanium and nickel - chromium are employed as the thermal barrier materials. The goal of employing these materials is to limit the heat loss from engine. Plasma spraying is used to create TBCs in an atmospheric environment.



The plasma generator is made up of a copper anode and a thoriated tungsten cathode, both of which are round in shape. The cathode is produced of graphite in a water stabilised torch. A powerful electric arc is formed between anode and cathode. This ionises the flowing process vapours into the plasma state. Now, powdered feedstock material is introduced into the plasma jet. Plasma jet will melt the material and drive it onto the work piece surface. A Sulzer Metco F4 cannon with a maximum output of 50 kW is used for atmospheric plasma spraying. A gas combination of hydrogen and argon is utilised as a plasma gas. The argon gas is also regarded as a carrier gas for the feedstock material injection. Compressed air was employed as the cooling gas during plasma spraying

Coated piston and cylinder head

RESULTS AND DISCUSSION



The performance and Emission characteristics of Al-Ti and Ni-Cr coated piston crown and cylinder head diesel engine was researched and compared with conventional engine. The findings gained from the trials done on the engine are provided in Figure 3 through Figure 7.

Figure 3: Comparison of Specific Fuel Consumption for different loads.

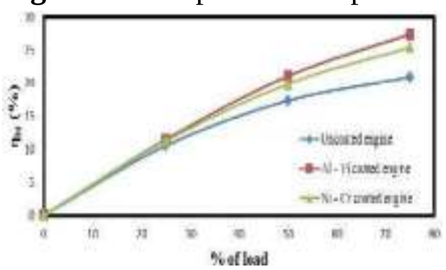


Figure 4: Comparison of Brake Thermal Efficiency for different loads.

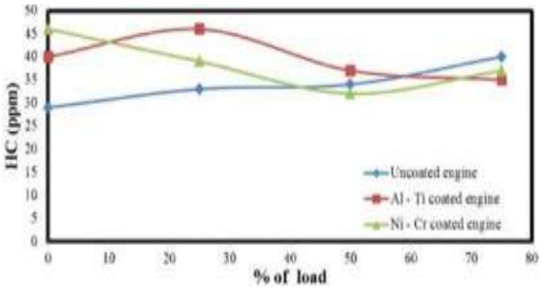


Figure 5: Comparison of Hydrocarbon emission for different loads.

Sl. No	Parameters	Value
1.	Spray gun	3 MB
2.	Nozzle	GH
3.	Current (A)	490
4.	Voltage (V)	60 – 70
5.	Powder feed (	40-50
6.	Spray distance	76.2 - 127
7.	Particle velocity (	Up to 450
8.	Arc Temperature	16,000

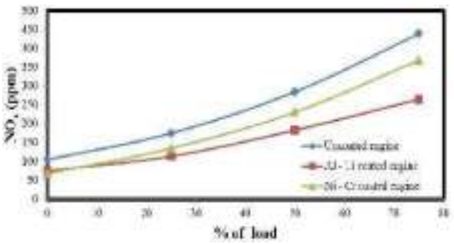


Figure 6: Comparison of Oxides of Nitrogen emission at various loads.

On the other hand, Al-Ti and Ni-Cr coated piston crowns and cylinder heads in Figure 3 exhibit a wide range of specific fuel consumption. When compared to a conventional engine, particular fuel consumption is lowered by 16.6% for an Al-Ti coating and by 9.86% for a nickel chromium coating. Complete combustion of gasoline within the cylinder may lower the quantity of fuel used. According to T. Hejwowski and A. Weroski (2002), a coated engine's specific fuel consumption drops by 15–20%.

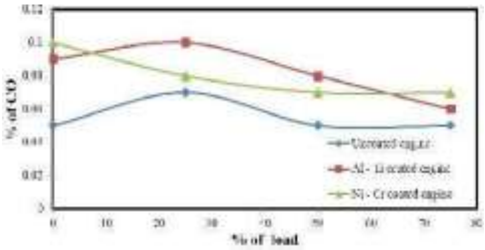


Figure 7: Comparison of carbon monoxide emission with various loads.

As can be seen in Figure 4, the brake thermal efficiency varies with engine load for both Al-Ti and Ni-Cr coated engines as well as a conventional engine. It is crucial that upgraded engine has better efficiency than that of base line engine. The improved thermal efficiency of the brakes might be due to decreased thermal loss. The greatest braking thermal efficiency achieved for engine running on Al-Ti coated and normal engine are 20 percent and 14.26 percent respectively.

Figure 5 illustrates the comparison of hydrocarbon emission under various loads. Temperature changes in the combustion chamber are inversely related to the amount of HC that is emitted. Low and medium loads are where HC exceeds the traditional diesel engine, but high loads are where it falls short. Modified engine HC emission is decreased by roughly 10 percent at full load condition.

Figure 6 depicts the relationship between nitrogen oxides and engine load for Al-Ti and Ni-Cr coated engines, as well as a conventional one. NOx is formed largely from nitrogen present in air and partly from fuel. The inherent availability of nitrogen and oxygen in the fuel increases the creation of NOx. As the temperature of the burning fuel rises, so does the amount of NOx produced. In Al-Ti and Ni-Cr coated engine, the NOx level is lowered by 40 and 20 percent correspondingly. Reduced combustion chamber temperature owing to decreased fuel use can be the explanation for lower NOx levels.

An engine with an Al-Ti or NiCr coating as well as a regular one had its CO emissions analysed and the results are presented in Figure 7. There is a minor increase in CO emission over traditional diesel engines at low and medium loads, but a decrease in CO emission at high loads thanks to full combustion.

CONCLUSION

An Al-Ti and Ni-Cr-coated diesel engine replaces a normal, modern diesel engine. The engine's performance and emissions were assessed using SFC and emissions measurements. The experiment's findings lead to the following conclusions.

Al-Ti coated diesel engine demonstrates improved specific fuel consumption compared to conventional and Ni-Cr coated diesel engine which is 16.6 percent lower than the normal engine. The Al- Ti coated engine's NOx emission is 40% lower than that of the standard engine. Results demonstrate improvement in brake thermal efficiency after coating.

With the findings obtained it is obvious that the coated engines are ideal for low and medium load situations and more appropriate for high load conditions as compared to normal engine.

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