

Study of Effect of Coating of Piston on the Performance of a Diesel Engine

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ABSTRACT

Insulation of pistons in engines is aimed at reducing the heat losses and thus increasing the indicated efficiency. Thermal barrier coatings (TBCs) were used to simulate adiabatic engines with the intention not only for reduced in-cylinder heat rejection and thermal fatigue protection of underlying metallic surfaces, but also for possible reduction of engine emissions. The application of TBCs reduces the heat transfer to the engine cooling jacket through the combustion chamber surfaces (which include the cylinder head, liner, and piston crown) and piston rings. The insulation of the combustion chamber with this coating, which is ceramic based, influences the combustion process and hence the performance and exhaust emissions characteristics of the engines. In the scenario of fast rising oil prices, insulation technologies are gaining importance as they help in saving fuel. A plasma sprayed thermal barrier coating was deposited on top of a piston for a Diesel engine and its effect on the engine performance is studied. It is found to increase thermal and mechanical efficiency.

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INTRODUCTION

The thermal efficiency of internal combustion engines can be increased by improving the combustion process and reducing loss of heat through the exhaust gases by applying thermal barrier coatings on the piston crown. This also helps to reduce specific fuel consumption and emissions. Atmospheric plasma spraying technique is used to apply the ceramic coatings which is versatile and can be used to apply wide variety of coatings on a spectrum of substrates to obtain homogenous coatings. Besides, fast rise of the oil prices tend to attract insulation of combustion chamber with TBCs to reduce fuel consumption. For better efficiency, the combustion chamber has to be completely insulated to obtain near adiabatic process.

Piston crowns were coated with a layer of ceramic made of yttria-stabilized zirconia (YSZ) and fuel consumption was measured and comparison of engine performance before and after the application of YSZ coatings deposited onto the piston

crowns was made by Chan and Khor [1] and achieved fuel economy up to 6% at low engine power. Tests were performed by Ekrem Bykkaya et al on a six cylinder, direct injection, turbocharged Diesel engine whose pistons were coated with a 350 μm thickness of MgZrO_3 over a 150 μm thickness of NiCrAl bond coat and found that there is 1-8% reduction in brake specific fuel consumption [2]. Engine components were coated with $\text{ZrO}_2/\text{Al}_2\text{O}_3$ using Plasma Spray Coating technique by Sathiyagnanam et al for a thickness of 150 microns and the results indicated reduction in fuel consumption, NOx emission and slight increase in thermal efficiency of the engine [3]. Tests were performed on a single cylinder, four stroke, direct injection, diesel engine by Shirao and Pawar who coated piston crown, cylinder head and valves with a 0.5 mm thickness of $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ (mullite) over a 150 μm thickness of NiCrAlY bond coat and showed that there was 2.18% decrease in specific fuel consumption, 12% increase in exhaust gas temperature, 20.64% increase in NOx emission and 22.05% decrease in CO emission of exhaust gas and 28.20% decrease in HC emission of exhaust gas.

decrease in on HC emission of exhaust gas of low heat rejection engine with turbocharger compared to standard engine at full load [4]. Vijaya Kumar and Sundareswaran coated combustion chamber of a Diesel engine with the coating made up of 20% PZT (Lead Zirconate Titanate) in 60% Cyanate modified Epoxy system and showed that the specific fuel consumption reduced by 15.89 % in their study on the effect of thermal barrier coatings on Diesel engine performance[5]. In this work, since the piston contributes mainly to heat loss and is the hottest part, piston is coated with Titanium dioxide to form a thermal barrier coating.

THE COATING MATERIAL

Titanium dioxide which is a hard ceramic is used as the coating material. The properties of Titanium dioxide are given in [Table 1](#)

Table 1. Properties of Titanium Dioxide

Density	4 g/cm ³
Compressive Strength	680MPa
Poisson's Ratio	0.27
Fracture Toughness	3.2 Mpa.m ^{-1/2}
Modulus of Elasticity	230GPa
Micro hardness (HV0.5)	880
Thermal Conductivity (25°C)	11.7 W/mK
Molar mass	79.87 g/mol
Melting Point	1870 °C (3398 °F)
Boiling Point	2972 °C (5381.6 °F)

THE COATING PROCESS



Figure 1. AV1 Diesel engine piston coated with titanium dioxide

Kirloskar AV1 diesel engine piston coated with Titanium dioxide using Atmospheric plasma spray coating technology is shown in [Figure 1](#). Trichloroethylene was used to clean the crown and remove all dust particles. 24 mesh Al₂O₃ was used to grit blast the crown to create rough surface so that the mechanical bond between coating and substrate remains strong. To provide good bonding for the coating material on base metal, a bond coat Nickel was applied. Then TiO₂ powder was sprayed using a gun with a standoff distance of about 10 cm onto the piston crown to a thickness of 100 µm. Hydrogen and argon gases were used as inert gases and current and voltage were maintained at 495 amperes and 70 volts respectively during the coating process.

EXPERIMENTAL SET UP

Table 2. Engine Specifications

Engine type	Kirloskar AV1,
Stroke number	4
Cylinder number	1
Bore	80 mm
Stroke length	110 mm
Compression ratio	16.5 : 1
Maximum engine	3.7 KW
Maximum engine	1500 rpm



Figure 2. Coated piston before running the engine