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Thermal analysis of Nano ceramic coated piston used in natural gas engine

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Abstract

Nano ceramic coatings have low thermal conductivity which can provide good heat insulation properties, and therefore they have been widely used in industrial design as thermal barrier coatings (TBCs). In the design of internal combustion engines, TBCs have been used on combustion chamber components to improve engine performance. In this paper, improvement in the working performance of natural gas engines is demonstrated when an aluminum alloy piston is sprayed with a Y_2O_3 partially stabilized zirconia (PYSZ) ceramic coating. Steady-state thermal analyses were used to determine the effects of the ceramic coating on temperature distributions. Output was compared with results from an uncoated conventional piston using the finite element method. Results show that the temperature at the top surface of coated piston is significantly higher (about 44% or 153^{o}C higher) than that of the uncoated piston. This higher combustion chamber temperature results in better engine thermal efficiency and lower emissions. Simultaneously, the temperature of the coated piston substrate is much lower (about 12% or 43^{o}C lower) than that of the uncoated piston. The lower metallic substrate temperature provides better thermal fatigue protection for the piston.

Keywords

Nano ceramic; Thermal barrier coating; Natural gas engine; Temperature; Finite element method

1. Introduction

Ceramic coatings are widely used in industry to protect a variety of structural engineering materials from corrosion, wear, erosion, and to provide heat insulation. In the design of internal combustion engines, the thermal barrier coating (TBC) is a typical and widely used ceramic coating material for thermal insulation. Although this coating has been used extensively in engines for the aerospace industry, it has only been tentatively applied to the internal combustion engine (ICE). Thermal barrier coatings (TBCs) made of low thermal conductivity ceramics can effectively reduce the in-cylinder heat loss of an internal combustion engine and hence impact an engine's working performance [1]. Applications of TBCs in internal combustion engines have been the subject of substantial investigation. Ceramic coatings have been applied as thermal barriers on surfaces of combustion chamber components to reduce the heat transfer between in-cylinder gases and the cylinder wall, reduce heat loss and increase in-cylinder temperature, thereby improving the thermal efficiency of the engine as defined by a reduction in exhaust emissions. In addition, TBCs can provide thermal fatigue protection for the metallic combustion chamber components of engines. In general, insulation with TBCs on the surface of combustion chambers impacts combustion emissions and the structural performance of internal combustion engines.

A pioneering investigation of the application of TBCs in diesel engines was conducted by Kamo et al [2]. Thermal insulating materials such as silicon nitride were used as TBCs to cover

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