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The effect of thermal barrier coating on a turbo-charged Diesel engine performance and exergy potential of the exhaust gas

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Abstract

In this study, the effect of insulated combustion chamber surfaces on the turbocharged, direct injection Diesel engine performance was experimentally investigated. Satisfactory performance was obtained with the low heat rejection (LHR) engine. In comparison to a standard Diesel engine, specific fuel consumption was decreased by 6%, and brake thermal efficiency was increased by 2%. It was concluded that the exhaust gas process was the most important source of available energy, which must be recovered via secondary heat recovery devices. The available exhaust gas energy of the LHR engine was 3–27% higher for the LHR engine compared to the standard (STD) Diesel engine. However, it is impossible to recover all the exhaust gas energy in useful work. It is found that the maximum extractable power is less than 47% of the exhaust power.

Keywords: Thermal barrier coating; Diesel engine; Performance; Exhaust energy; Exhaust gas exergy

1. Introduction

Low heat rejection engine designs promise to meet the increasingly stringent regulations in the areas of fuel economy and permissible emissions levels. It is well known that insulating the combustion chamber components of LHR engines can reduce the heat transfer between the gases in the cylinder and the cylinder wall. The low heat rejection (LHR) engine concept is based on

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Nomenclature

$\bar{e}$	specific molar exergy of exhaust gas stream (kJ/kmol)
$\bar{e}_{tm}$	thermomechanical molar exergy of exhaust gas stream (kJ/kmol)
$\bar{e}_{cm}$	chemical molar exergy of exhaust gas stream (kJ/kmol)
$\dot{E}_{EX}$	exhaust power (kW)
$\bar{h}$	molar specific enthalpy (kJ/kmol)
$\dot{n}_{EX}$	molar flow rate of exhaust gas stream (kmol/s)
p	pressure (bar)
$\overline{R}$	universal gas constant (kJ/kmol K)
$\bar{s}$	molar specific entropy (kJ/kmol K)
x	mole fraction of species
$\dot{W}_{EX,max}$	maximum available exhaust power (kW)
η_{EX}	exhaust efficiency

Subscripts

i	species
$i,0$	species for inlet conditions
tm	thermomechanical
cm	chemical

Abbreviations

BMEP	brake mean effective pressure (bar)
BSFC	brake specific fuel consumption (g/kWh)
BTDC	before top dead center
CA	crank angle (°)
DI	direct injection
LHR	low heat rejection
rpm	revolutions per minute
STD	standard
T/C	turbocharged

suppressing this heat rejection to the coolant and recovering the energy in the form of useful work [1–3].

Some important advantages of the LHR concept are improved fuel economy, reduced hydrocarbon, smoke and carbon monoxide emissions, reduced noise due to a lower rate of pressure rise and higher energy in the exhaust gases [2,4–6]. Low cetane fuel can also be burned in LHR engines. This is enabled by the higher temperature at the time of fuel injection [7–11]. Within the LHR engine concept, the Diesel combustion chamber is insulated using high temperature materials on engine components such as pistons, cylinder head, valves, cylinder liners and exhaust ports.

Some researchers have reported that shorter ignition delay was obtained with the LHR engine, leading to a decreased premixed fraction and a corresponding increase in the amount of fuel