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COMPONENTS HEAT TRANSFER STUDIES IN A LOW HEAT REJECTION DI DIESEL ENGINE USING A HYBRID THERMOSTRUCTURAL FINITE ELEMENT MODEL

C. D. Rakopoulos and G. C. Mavropoulos

Internal Combustion Engines Laboratory, Thermal Engineering Section, Mechanical Engineering Department, National Technical University of Athens, 42 Patission Str., Athens 10682, Greece

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Abstract—The development of a hybrid three-dimensional finite element thermostructural model is presented in this work, which is used to study the behaviour of various combustion chamber insulation configurations of a four-stroke, direct injection (DI), diesel engine on its performance, components temperatures, and heat fluxes under various steady operating conditions. The model incorporates a comprehensive thermodynamic engine cycle simulation model in combination with a detailed structural analysis model. Separate representation of the various subregions of each component, effected by the hybrid model, makes it possible for the quantitative estimation of the effect of contact resistances and included air gaps on the amount of heat rejected to the combustion chamber walls. Connection between the resulting finite element submodels at the interface of any two subregions is accomplished through appropriate use of the heat balance method. For this purpose, an iterative procedure is developed, which is capable of overcoming numerical instabilities occuring during convergence even for the most difficult case of the three-dimensional finite element analysis. The model is applied for two of the most commonly used engine insulation configurations, i.e. plasma sprayed zirconia and silicon nitride monolithic designs. The complex heat flow paths through the various combustion chamber components are analysed and the corresponding temperature distributions are presented. A satisfactory degree of agreement is found between theoretical predictions and experimental measurements for the uninsulated engine, thus confirming the model's validity. Furthermore, the uninsulated engine data case (baseline configuration) forms a sound basis against which the corresponding performance of the two engine insulation cases can be compared and assessed.

Keywords Low heat rejection, diesel engine, finite elements, hybrid thermostructural model.

NOMENCLATURE

A	region (area) of interest (m^2)
c	specific thermal capacity (J/kg K)
$[H_S]$	heat convection matrix (W/K)
$[h_S]$	heat convection matrix (W)
h	heat transfer coefficient (W/m^2 K)
$[K]$	conduction matrix (W/K)
k	thermal conductivity (W/m K)
n	engine speed (rpm)
$\vec{n}$	surface unity vector (m)
p	pressure (N/m^2)
$[q_S]$	heat flux matrix (W)
q	heat flux (W/m^2)
R_c	specific (thermal) contact resistance (m^2 K/W)
r	radial coordinate (m)
S	boundary area (m^2)
T	absolute temperature (K)
T_∞	ambient temperature (K)
$[T]$	vector of temperature at grid points (K)
t	time coordinate (s)
V	volume (m^3)
z	axial coordinate (m)

Greek letters

ρ	density (kg/m^3)
φ	engine crank angle (°CA)