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Optimizing piston velocity profile for maximum work output from a generalized radiative law Diesel engine

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ABSTRACT

A Diesel cycle engine with internal and external irreversibilities of finite combustion rate of the fuel, friction and heat leakage is investigated in this paper. The heat transfer between the working fluid and the environment outside the cylinder obeys generalized radiative heat transfer law [$q \propto \Delta(T^n)$]. Under the conditions of the fixed total cycle time and fuel consumed per cycle, the optimal piston motion trajectories for maximizing the work output per cycle of the cases with unconstrained and constrained piston accelerations are derived on each stroke by applying optimal control theory. The optimal distribution of the total cycle time among the strokes is also obtained. The optimal piston motion along the power stroke with constrained acceleration consists of three segments including the initial motion delay, the middle motion and the final maximum deceleration segments. Numerical examples for the case with the radiative heat transfer law [$q \propto \Delta(T^4)$] and constrained acceleration are provided, and the obtained results are also compared with those obtained with Newtonian [$q \propto \Delta(T)$] and linear phenomenological [$q \propto \Delta(T^{-1})$] heat transfer laws. The results show that optimizing the piston motion for the case with the radiative heat transfer law can improve both the net work output per cycle and the net efficiency of the standard engine by more than 7%, and heat transfer laws have significant effects on the optimal piston motion trajectory for maximum work output.

1. Introduction

There are two standard problems in finite time thermodynamics [1–19]: one is to determine the objective function limits and the relations between objective functions for the given thermodynamic system, and another is to determine the optimal thermodynamic process for the given optimization objectives. The former belongs to a class of static optimization problems, which can be solved by the simple function derivation methods, while the latter belongs to a class of dynamic optimization problems, which should be solved by applying optimal control theory. There are only analytical solutions for a few optimal control problems, while for most of the others, one has to refer to numerical calculation methods. Mozurkewich and Berry [20,21] investigated the optimal piston motion of an Otto cycle engine with Newtonian heat transfer law [$q \propto \Delta(T)$] for the maximum work output. It turned out that optimizing the piston motion can improve engine power and efficiency by more than 10%. Hoffmann et al. [22] and Blaudeck and Hoffmann [23] further investigated the optimal piston motion of a Diesel cycle engine with Newtonian heat transfer law for the maximum work output. It turned out that optimizing the piston motion can improve engine net work output per cycle and net efficiency by 10%. Teh and Edwards [24–26] and Teh et al. [27] investigated the optimal piston motions of adiabatic internal combustion engines for the maximum work output [24], minimum entropy generation [25,26], and maximum efficiency [27]. Watowich et al. [28,29] investigated the

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