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Efficiency of a Miller engine

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Abstract

Using finite-time thermodynamics, the relations between thermal efficiency, compression and expansion ratios for an ideal naturally-aspirated (air-standard) Miller cycle have been derived. The effect of the temperature-dependent specific heat of the working fluid on the irreversible cycle performance is significant. The conclusions of this investigation are of importance when considering the designs of actual Miller-engines.

Keywords: Finite-time thermodynamics; Miller cycle; Heat resistance; Friction; Temperature-dependent specific-heat

Introduction

The Miller cycle, named after its inventor R.H. Miller, has an expansion ratio exceeding its compression ratio. The Miller cycle, shown in Fig. 1, is a modern modification of the Atkinson cycle (i.e., a complete expansion cycle). The compression ratios of spark-ignition, gasoline-fueled engines are limited by knock and fuel quality to being in the range between 8 and 11, depending upon various factors, such as the engine's bore and stroke as well as engine speed.

Significant achievements have ensued since finite-time thermodynamics was developed in order to analyze and optimize the performances of real heat-engines [1–3].

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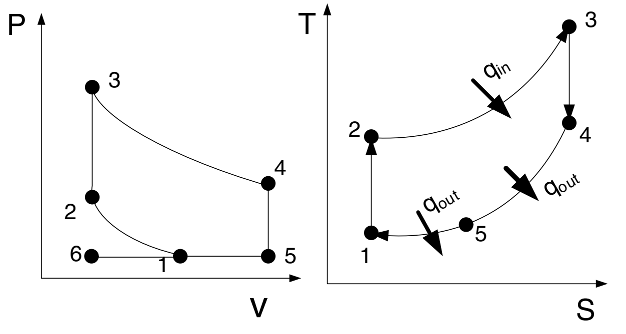

Fig. 1. P–V and T–S diagram of a Miller cycle.

Hoffman et al. [4] and Mozurkewich and Berry [5] used mathematical techniques, developed for optimal-control theory, to reveal the optimal motions of the pistons in Diesel and Otto cycle engines, respectively. Aizenbud et al. [6] and Chen et al. [7] evaluated the performances of internal-combustion engine cycles using the optimal motion of a piston fitted in a cylinder containing a gas pumped at a specified heating-rate. Orlov and Berry [8] deduced the power and efficiency upper limits for internal-combustion engines. Angulo-Brown et al. [9], Chen et al. [10] and Wang et al. [11] modeled the behaviors of Otto, Diesel and Dual cycles, with friction losses, over a finite period. Klein [12] investigated the effects of heat transfer on the performances of Otto and Diesel cycles. Chen et al. [13,14] and Lin et al. [15] derived the relations between the net power and the efficiency for Diesel, Otto and Dual cycles with due consideration of heat-transfer losses. Chen et al. [16,17] determined the characteristics of power and efficiency for Otto and Dual cycles with heat transfer and friction losses. Chen et al. [18], Al-Sarkhi et al. [19] and Sahin et al. [20] studied the optimal power-density characteristics for Atkinson, Miller and Dual cycles without any such losses. Qin et al. [21] deduced the universal power and efficiency characteristics for irreversible reciprocating heat-engine cycles with heat transfer and friction losses. Parlak et al. [22] optimized the performance of an irreversible Dual cycle: the predicted behavior was corroborated by experimental results. Fischer and Hoffman [23] concluded that a quantitative simulation of an Otto-engine's behavior can be accurately achieved by a simple Novikov model with heat leaks. Al-Sarkhi et al. [24] recently found that friction and the temperature-dependent specific heat of the working fluid of a Diesel engine had significant influences on its power output and efficiency. This paper describes a corresponding analysis of the behavior for an irreversible Miller-cycle with losses arising from heat resistance and friction.

An air standard Miller-cycle model

As in Fig. 1, the compression $1 \rightarrow 2$ process is isentropic; the heat addition $2 \rightarrow 3$, an isochoric process; the expansion $3 \rightarrow 4$, an isentropic process; and the heat rejec-