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Influence of heat loss on the performance of an air-standard Atkinson cycle

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Abstract

This study is aimed at investigating the effects of heat loss, as characterized by a percentage of fuel's energy, friction and variable specific heats of the working fluid, on the performance of an air-standard Atkinson cycle under the restriction of the maximum cycle-temperature. A more realistic and precise relationship between the fuel's chemical-energy and the heat leakage is derived through the resulting temperature. The variations in power output and thermal efficiency with compression ratio, and the relations between the power output and the thermal efficiency of the cycle are presented. The results show that the power output as well as the efficiency, for which the maximum power-output occurs, will rise with the increase of maximum cycle-temperature. The temperature-dependent specific heats of the working fluid have a significant influence on the performance. The power output and the working range of the cycle increase while the efficiency decreases with the rise of specific heats of working fluid. The friction loss has a negative effect on the performance. Therefore, the power output and efficiency of the Atkinson cycle decrease with increasing friction loss. It is noteworthy that the results obtained in the present study are of significance for providing guidance with respect to the performance evaluation and improvement of practical Atkinson-cycle engines.

Keywords: Atkinson cycle; Heat leakage; Friction; Irreversible; Variable specific-heat

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Nomenclature

a_p	constant, defined in Eq. (4)
b	friction-like term loss, $b = \mu(Ncx_2)^2$.
b_v	constant, defined in Eq. (5)
C_{pm}	molar specific-heat at constant pressure
C_{vm}	molar specific-heat at constant volume
c	constant, defined in Eq. (22)
f_μ	friction force, defined in Eq. (20)
k	specific heat-ratio, $k = C_{pm}/C_{vm}$
k_1	constant, defined in Eqs. (4) and (5)
L	the total distance that the piston travels per cycle
m_a	mass of air per cycle
m_f	mass of fuel per cycle
N	cycles per second
P	net actual power-output of the cycle, defined in Eq. (24)
P_R	power-output without friction losses, defined in Eq. (19)
P_μ	lost power due to friction, defined in Eq. (21)
Q_{fuel}	total energy of the fuel per second input into the engine
Q_{in}	heat input
Q_{leak}	heat leakage per second
Q_{LHV}	lower heating value of the fuel
Q_{out}	heat reject
$\bar{v}$	piston's mean-velocity
R	gas constant of working fluid
T	temperature
T_1, T_2, T_3, T_4	temperatures at state points 1, 2, 3, 4, respectively
V	volume
v	piston's velocity
x	piston's displacement
x_1, x_2	piston positions corresponding to the volumes V_1 and V_2 respectively of the trapped gases

Greek symbols

α	heat-leakage percentage
γ_c	compression ratio, $\gamma_c = V_1/V_2$
η	efficiency of the cycle
λ	excess-air coefficient
μ	coefficient of friction

1. Introduction

In the expansion process of a traditional four-stroke Otto-cycle engine, the gas pressure within the cylinder and at the exhaust-valve opening is greater than atmospheric. When the exhaust valve is opened, the pressure in the cylinder is decreased to atmospheric,