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Performance analysis and optimization of a supercharged Miller cycle Otto engine

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Abstract

One of the major alternatives of the Otto cycle has been examined to determine its potential for increased efficiency and net work power in the spark ignited internal combustion engine is to shorten the compression process relative to the expansion process by early close or late of intake valve. The modified Otto cycle is called Miller cycle. This paper deals with the analysis of a supercharged Otto engine adopted for Miller cycle operation. The Miller cycle shows no efficiency advantage and suffers a penalty in power output in the normally aspirated version. In the supercharged Otto engine adopted for Miller cycle version, it has no efficiency advantage but does provide increased net work output with reduced propensity to engine knock problem. Sensitivity analysis of cycle efficiency versus early close of intake valve and that of cycle net work versus early close of intake valve are performed. Optimization on the cycle efficiency is obtained.
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Keywords: Miller cycle; Supercharging; Analysis; Optimization

1. Introduction

The spark ignited internal combustion engine is modeled as an Otto cycle. The four stroke ideal Otto cycle models the intake of fuel–air mixture (isobaric process 1–2) as the piston moves from top dead center (TDC) to bottom dead center (BDC) position with the intake valve open. Then the mixture is compressed (isentropic process 2–3) as the piston moves back to TDC with the intake valve closed. At TDC, the spark instantaneously ignites the fuel–air mixture (isochoric process 3–4) providing a heat input. The mixture is expanded (isentropic process 4–5) as the piston

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Nomenclature

A	factor defined in Eq. (10)
c_p	specific heat at constant pressure process
c_v	specific heat at constant volume process
h	enthalpy per unit mass
k	specific heat ratio c_p/c_v
m	mass
MEP	mean effective pressure
p	pressure
Q	heat
q	heat transfer per unit mass
r	compression ratio
r_c	compression ratio
r_e	expansion ratio
s	entropy per unit mass
T	temperature
u	internal energy per unit mass
V	volume
v	volume per unit mass
W	work
w	work per unit mass
w_{net}	net work per unit mass
λ	ratio of r_e/r_c
η	cycle efficiency

moves from TDC to BDC. At BDC the exhaust valve opens and pressure drops so that the exhaust process (isochoric process 5–6) followed by positive displacement pumping out of the products of combustion as the piston moves from BDC to TDC (isobaric process 6–1) with the exhaust valve open. At TDC the exhaust valve closes and the intake valve opens so the cycle can repeat as shown in Fig. 1. Fig. 1 is a pressure (p) versus volume (v) diagram on which the areas underneath the processes represent work (w) done or added. The net output work for one cycle is represented by $(w_{45} - w_{23})$, with w_{12} and w_{61} ideally equal and opposite and so cancelled. Notice that the length of the compression stroke (isentropic process 2–3) and that of the expansion stroke (isentropic process 4–5) are equal in the Otto cycle.

The major four functions (process 2–3, process 3–4, process 4–5, and process 5–6) described above are executed in just two strokes: the power stroke and the compression stroke. The traditional thermodynamic analysis of the four-stroke Otto cycle is the same as that of a two-stroke Otto cycle as shown in Fig. 2. The Otto cycle is assumed executing in a closed system. The energy balance for any of the processes is expressed, on a unit mass basis, as

$$(q_{in} - q_{out}) + (w_{in} - w_{out}) = u_{final} - u_{initial} \tag{1}$$