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An easy and inexpensive way to estimate the trapping efficiency of a two stroke engine

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Abstract

This paper presents a new analytic model for the estimation of the trapping efficiency of two-stroke engines using an extremely reduced number of measured physical variables. Mainly, the model estimates the trapping efficiency according to the Ostwald diagram, to the molal concentration of carbon dioxide and oxygen at tailpipe and according to the mass flow of air and fuel. In order to provide a measure of effectiveness for the proposed model, a use case has been chosen. The model's effectiveness has been evaluated comparing its outcomes with the results obtained by thermo-fluid dynamic simulation of the use case on a 0D-1D commercial code, whose scavenging model has been previously validated by an extensive experimental activity. The present study shows that, for all the cases considered, the model results differ no more than 11% in absolute value from the simulated ones. In brief, the accuracy of the model allows the estimation of the trapping efficiency for two-stroke engines with reasonable confidence, reduced computational effort and time and costs lower than the currently available techniques.

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Keywords: Two-stroke engines; Trapping efficiency measurement; Ostwald diagram

1. Introduction

Methods for quantifying the scavenging process in two-stroke engines are usually classified into two main categories: measurements in motored engines and measurements in fired engines [1]. While the former postulates that the scavenging characteristics does not depend on the combustion process, the

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latter depicts the process under real operating conditions in full-size engine tests. When operating in lean conditions, the current methods for estimating the trapping and/or scavenging efficiency are based on gas samples at both intake opening and exhaust closing. Although this system allows studying cyclic variability, yet requires to buy and install fast sampling valves close to scavenging and exhaust ports. Moreover, a homogeneous composition of the gaseous mixture into the cylinder must be assumed [1].
The aim of this paper is to describe and test a new method for quantifying the trapping efficiency for a two-stroke engine possibly operating in lean conditions through: the Ostwald diagram related to the fuel used; the measurement of the molal concentration of Carbon Dioxide and Oxygen at tailpipe; the intake air and fuel mass flows.

Nomenclature

E	Air Excess [%]
m_{ar}	Mass flow of residual air from the previous cycle [kg/s]
m_{as}	Supplied air mass flow [kg/s]
m_b	Fuel mass flow [kg/s]
m_{cy}	Mass flow trapped into the cylinder[kg/s]
m_{ex}	Mass flow at tailpipe [kg/s]
m_{gc}	Combustion products mass flow [kg/s]
m_{sc}	Short-circuited air mass flow [kg/s]
m_{sref}	Reference air mass flow rate [kg/s]
m_{ta}	Total trapped air mass flow [kg/s]
m_{tas}	Fraction of the supplied air mass flow trapped into the cylinder [kg/s]
m_{th}	Theoretically required air mass flow for complete combustion [kg/s]
SE	Scavenging efficiency [%]
SR	Scavenge ratio [%]
TE	Trapping Efficiency [%]
V_{gas}	Volumetric flow rate of the gaseous species [m^3/s]
α_{st}	Stoichiometric air-to-fuel ratio [-]
ε_{gas}	Concentration of the gaseous species at tailpipe [-]
ρ_{gas}	Density of the gaseous species [kg/m^3]
ν_{gas}	Molal concentration of the gaseous species referred to combustion products [-]

2. Theory

2.1. Definitions and notations