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THERMODYNAMIC SIMULATION OF A LEAN BURN NATURAL GAS SPARK IGNITION ENGINE: COMPARISON BETWEEN CALCULATIONS AND EXPERIMENTAL VALUES

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Abstract

Thermodynamic models are useful tools to predict energy and environmental performances of internal combustion engines. It helps to conceive engines, to develop control systems and to optimize the number and the cost of tests. This paper proposes a comparison between calculations from a thermodynamic model and experimental data. The main comparison concerns the cylinder pressure, the inlet flow rate, the mean indicated pressure (MIP), the specific consumption and the NO concentration in exhaust gases. A two-zone model is applied to a lean burn natural gas spark ignition engine. Heat transfer is calculated using Eichelberg's correlation. Correlations for ignition delay, combustion duration and shape factor are applied in a Wiebe function to describe the combustion process. Mass losses due to blowby are taken into account. NO concentration is calculated using the extended Zeldovitch mechanism for thermal NO and the Fenimore mechanism for prompt NO as it becomes predominant in lean burn. Measurements have been done on a 6-cylinder turbocharged lean burn natural gas spark ignition engine, with a total displacement volume of 17 964 cm3 and a compression ratio of 11. More than 100 operating points have been recorded for an engine speed of 1500 rpm, in the range 8 to 23°CA for spark advance, 1.35 to 1.70 for air-fuel equivalence ratio and 0.80 to 1.70 bar for inlet pressure. The way the model reproduces the impact of operating parameters variations is satisfying on the whole, but significant differences are observed between calculations and experimental values for the maximum cylinder pressure (up to 5%), the MIP (up to 5,5%) and the specific consumption (up to 7,5%). More significant differences are observed for the NO concentration (up to 25%). However, the inlet flow rate is predicted with a better accuracy: differences observed are less than 2%. The sensitivity of the model can explain some differences observed between experimental results and calculations. Indeed, low variations on combustion duration, compression ratio, air-fuel equivalence ratio and inlet pressure have significant and non-linear effects on calculation results. Consequently, comparison must be done cautiously when uncertainties exist on experimental input data. Neverthless, thermodynamic models remain useful tools to study the impact of operating parameters changing on engine performances and emissions.

Keywords

Thermodynamics, simulation, lean burn, natural gas, engine.