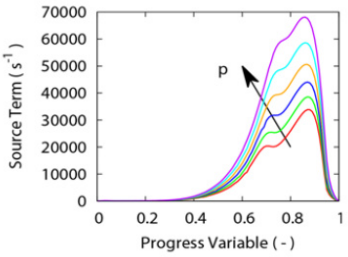
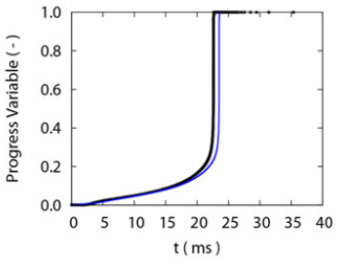
Large Eddy Simulation of Auto-Ignition and Flame Progagation in a HCCI Engine Using a Progress Variable Approach





Introduction

Homogenous Charge Compression Ignition (HCCI) engines are of great technological interest as they combine the advantages of both spark-ignition (SI) and conventional compression ignition engines. Firstly, due to the highly diluted charges, high flame temperatures are avoided, thus reducing the formation of nitric oxides. Secondly, the thermal efficiency can reach values similar to conventional compression ignition engines due to the high compression ratio.[1] In HCCI engines, the premixed charge ignites homogeneously due to the high temperatures acheived during the compression. In contrast to SI engines, where after the spark ignition the flame front propagates through the charge HCCI conditions this phenomenon is hardly present.[2]

Methods

Hence, the modeling of an HCCI engine can be separated into two steps: first the auto-ignition process is considered and successively its transition towards flame propagation. The present work focuses first on the various aspects of the auto-ignition, second the transition between ignition and flame propagation. Particularly, the gasoline-HCCI engine built and experimentally investigated at the Institute of Piston Machine (IFKM), Karlsruhe Institute of Technology has been simulated. The computations have been performed using the KIVA-4mpi code. In previous studies [3,4] simulations of internal combustion (IC) engines using KIVA-3V with LES have been also carried out. In this work, Large Eddy Simulation has also been employed to describe the highly unsteady flow field including the occurrence of cycle-to-cycle variations. In order to capture the complex dynamics of the auto-ignition process the code has been further extended to account for tabulated chemistry based on a progress variable approach. The combustion modelling is based on tabulated chemistry approach. For ignition and flame propagation two different tables are delivered by Benzinger from

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Institute of Technical Thermodynamics, Karlsruhe Institute of Technology (KIT). The LES solver is to be first validated for the cold flow case. For this purpose engine simulations with 50 cycles have to be performed and compared with experimental data. The newly implemented auto ignition model has to then be tested against the detailed reaction scheme using simulations of simple ignition scenarios in homogenous reaction systems (Figure 1) and then for a complex engine geometry (Figure 2).

Outlook

Further, the new implemented flame propagation model and the transition model between ignition kernel and flame propagation have to be tested for simple geometries and then for the related engine configuration. Finally 50 full engine cycles must be simulated using the new combustion modelling approach will be presented.

Figures

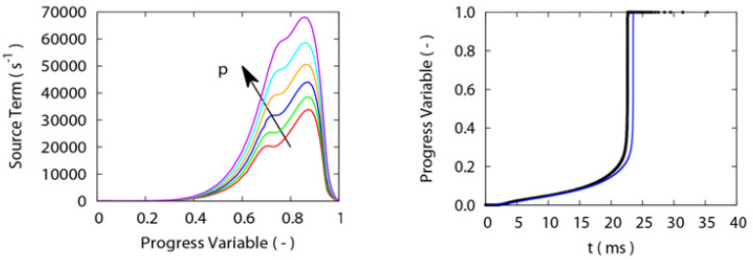

Fig. 1: Left: slice of the chemistry table showing the progress variables source term for pressure levels from 10bar - 31bar (TD=833K). Right: temporal evolution of an ignition sequence (pD=12bar, TD=833K) predicited with detailed chemistry (points) an progress variable approach in KIVA-4mpl.

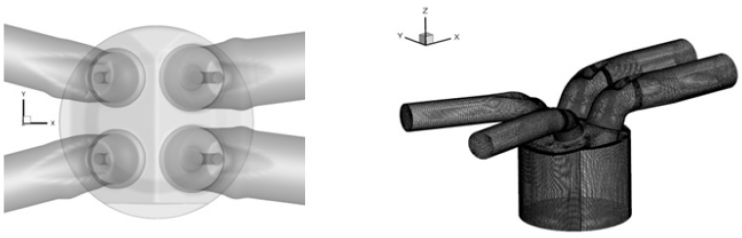

Fig. 2: Left: Geometry of the Karlsruhe engine at 360° CA. Right: Geometry of the Karlsruhe engine at 540° CA.

Reference

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