Introduction

In this numerical study, we investigate the effect of water on the chemical and sensor response using 3D CFD RANS and detailed chemistry. In the first step, the influence of different amounts of water vapor on ignition delay time, laminar flame speed, and heat capacity is investigated. In the second step, the impact of water vaporization is analyzed for different injection strategies, such as port and direct injection. Therefore, the water mass flow and the injection pressure are varied. A steady state, medium speed, high-load engine operating point is investigated with focus on the effect of water injection on knock tendency and exhaust temperature.

Detailed Chemistry

The oxidation chemistry in the unburned zone is modelled using the Ethanol Toluene Reference Fuel (ETRF) reactions scheme by Seidel [1] that allows for a flexible surrogate definition. This scheme was developed taking the core model from Seidel et al. [3], and reduced following the methodology in [4]. Netzer et al. [4, 5] showed that the prediction of auto-ignition in the unburned zone and laminar flame speed using this ETRF reaction scheme are comparable to the research/motorized octane number (RON/MON) rating of the surrogate and to the spark ignition timing. For the analysis in this work, a surrogate that represents a typical European gasoline fuel with a RON/MON of 94.5/88.8 is chosen. The surrogate is composed of 49.5% iso-octane, 12.7% n-heptane and 37.8% toluene by mass. Even though the reaction scheme can treat an ETRF surrogate, a TRF surrogate is chosen to reduce the number of influencing factors in the present study.

Combustion Modelling Approach

The combustion is predicted using the G-equation [9] and well stirred reactors [10] in the unburned zone to predict auto-ignitions. Auto-ignitions and laminar flame speed are predicted applying the ETRF reaction scheme from Seidel [1]. The laminar flame speed is calculated and stored in look-up tables using LOGE-Research [11].

Conclusion

The analysis shows that for a prediction of water injection it is essential to apply a flame speed model and a chemical reaction scheme that accounts for the increasing water amount [11].

Knick Evaluation

To find the KLSA a spark timing sweep is performed. If one of the ignition kernels is found to be in the developing detonation regime, the KLSA is exceeded. Therefore, we define as KLSA the earliest spark timing for that all ignition kernels are in deflagration or non-knocking regime (beyond the upper limit of the peninsula).