TURBULENT COMBUSTION MODELLING

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Introduction

The Diesel engine offers a very high efficiency and is therefore widely used in power generation, heavy-duty off-road application, passenger/freight transportation and ship propulsion. In addition to the traditional development goals (high reliability, fuel efficiency and power output), modern Diesel engines have to comply with increasingly stringent emission legislations. Some of these development targets exhibit a trade-off behaviour and therefore require a complex optimisation process. Due to the availability of highly flexible Common Rail injection systems also for marine Diesel engines operating on heavy fuel oil, the number of parameters in this optimisation has increased by orders of magnitude. New development tools and approaches are called upon, to help reduce the number of tests and thereby development time and costs [1]. Computational Fluid Dynamics (CFD) has been used extensively in the past to investigate the phenomena occurring in spray combustion. Due to the complexity of the processes, a high degree of modelling and simplification is necessary.

Objectives

The main goal of this project is the implementation of a combustion model based on Conditional Moment Closure (CMC) in the framework of the flow solver STAR-CD. Requirements for the combustion model are the capability to predict pressure curves and NO_x emissions for varying operating conditions and injector configurations. Computational efficiency of the coupled code is a prerequisite for its use as a tool to carry out predictive parametric studies in the engine development process.

Approach

For non-premixed turbulent combustion, presumed PDF approaches have gained increased popularity in the past decade. The approach chosen is based on CMC, for which the governing equations of conditional species mass fraction and enthalpy have been rigorously derived in [2]. Combustion models based on CMC are capable of overcoming the problems associated with turbulence/chemistry interaction in turbulent reacting flows and can in principle use arbitrarily complex chemistry. Details concerning the implementation can be found in [3].

Results

For model validation, the constant pressure test chamber for which experimental data is reported in [4], was numerically investigated. Parameters considered are on the one hand the temperature of the background air and secondly, the influence of presence of turbulence in the background air at the start of injection. The mechanism employed is a reduced mechanism for n-heptane [5]. Simulated ignition delays agree well with the experimental data, particularly at higher temperatures. The trend towards shorter ignition delays for all temperatures in the case of turbulent background air at start of injection is also correctly captured by the simulation. The effect of enhanced mixing for the case with initial turbulence can be observed in the shorter and wider spray shape.

Outlook

Various CMC sub-models and their influence on simulation results need to be investigated.

Project Partners

- Dr. E. Mastorakos, University of Cambridge, Department of Engineering http://www.eng.cam.ac.uk
- Wärtsilä Switzerland Ltd http://www.wartsila.com
- Bundesamt für Berufsbildung und Technologie, KTI http://www.bbt.admin.ch/kti/d
- Bundesamt für Energie, BfE http://www.energie-schweiz.ch

References

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