Berichte aus der Strömungstechnik

Dominik Kuhnke

Spray/Wall-Interaction Modelling by Dimensionless Data Analysis

D 17 (Diss. TU Darmstadt)

Shaker Verlag
Aachen 2004
Spray wall interaction is a phenomenon commonly observed in modern direct injecting engines at stratified charge. To optimise the engine design with respect to soot, NO$_x$ and un-burnt hydrocarbon emissions, simulation techniques increasingly complement prototyping. Thus it is necessary to use a model that describes wall interaction as realistic as possible. Existing models are often valid in a restricted range of conditions only. Hence there is a demand for a more general model combining the existing knowledge from previous models with new detailed experimental data.

Although first investigations on drop/wall-interaction started in the 19th century, the mechanisms of drop impact are still far from clear. A large number of studies dealing with the investigation of the impingement process have been published, examining the impingement phenomena from the theoretical or the experimental side. Especially theoretical studies trying to consider the underlying physical mechanisms that occur during the interaction process show that even if the physics is known it is still hardly possible to simulate the impingement of a single drop with accuracy in a reasonable time. As especially the influence of the thermal processes is still not fully understood and as computing power is still too low it will – at least in the near future – remain impossible to simulate the details of the impingement of millions of droplets.

With this knowledge it is obvious, that one can only simulate the spray impingement process by simplifying the mechanisms by application of a suitable model, which can be derived from theoretical considerations or by deduction from experimental observations.

The model described in this work is based on and developed from existing models and new experimental data of the recently terminated European project DWDIE (Droplet Wall Interaction Phenomena of Relevance to Direct Injection Gasoline Engines). By an analysis of models and data of single drop and drop chain impingement with respect to the experimental conditions, the borders between different impingement phenomena are identified in a first step. While suitable dimensionless variables representing the dynamic properties of the drops are essentially agreed on in the literature, less accordance is found for the corresponding critical value. In the presented work it is thus analysed how the critical variable depends on the wall conditions dry/wet and the temperature.

In a second step the properties of post-impingement drops are defined for the single drop interaction phenomenon, again combining knowledge from existing models and new experimental data. As this is not sufficient for the description of a spray, simple physical models are set up in a third step to describe a transition from the single drop to the spray impingement model. An essentially new feature herein is the consideration of the lateral spacing between drops. Since only little data is available for this case, physical models were complemented with heuristic assumptions and deductions.

The model is then implemented as a sub-routine into the CFD code FIRE of AVL GmbH Graz. A quantitative evaluation is then performed with the measurement of a real spray of a six hole high pressure injector. For a meaningful comparison of the simulated spray to the measured, the spray propagation itself needed to be studied first in order to provide an impinging spray that has similar characteristics as the real impinging spray. This includes the analysis of grid dependences and turbulence models on the spray propagation.

The new model now allows simulations of mixture formation in the direct injection engine by accounting for the different effects that occur when the spray impinges on the piston surface or other walls. The accounted conditions include those which are present in real engines concerning temperature, surface structure or film formation.

In consideration of the complexity of impingement phenomena and the heuristic modelling that was necessary for lateral interaction phenomena the resulting correspondence of simulated and real spray is very well for both visual impression and droplet velocities and sizes. This emphasises the improvement that is reached in the model by taking into account all effect that were identified to be of relevance.