6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11 – 15 June 2018, Glasgow, UK

Numerical investigation of inert and reactive spray characteristics during pilot injection of a dual fuel injector

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Key Words: *CFD, Dual Fuel, Spray Characteristics, Combustion Process*

Due to the introduction of the so called Emission Controlled Areas within the IMO Tier III legislation, dual fuel combustion will become more important in the field of maritime propulsion. To meet the stringent emission targets, ships propelled with HFO may switch to dual fuel operation mode in the protected areas. The combustion process is characterised by the injection of a small amount of fuel oil, which ignites a premixed natural gas air mixture. The resulting short injection durations oblige the injector into the ballistic working regime. This influences spray penetration, mixture formation and ignition behaviour.

In the present work, a CFD model of a dual fuel injector was developed using the commercial code AVL FIRE. Due to the ballistic working regime, the main challenge for the modelling is to capture the opening and closing behaviour of the injector. Therefore, optical investigations were carried out in an injection bomb to characterise the liquid and the vapour phase at an early stage of spray propagation. Based on the experimental observations, a methodology assuming constant momentum along the spray axis was applied to estimate the initial penetration velocities. The injection profile is adjusted for different fuel quantities to investigate the resulting spray characteristics. To realise the observed dependencies of the spray penetration from chamber conditions in simulation and to depict the decrease of liquid length after the end of injection, a suitable initial droplet spectrum was defined. The developed model is able to predict the experimental observed penetration and contour of the spray plume.

The spray model is extended by a detailed reaction mechanism to simulate the combustion process of the diesel jet. The ignition delay was validated using measurements of the OH* emission of the flame. Measured OH* intensities enable a detailed characterisation of the development and the propagation of the first flame structures. The distribution of the simulated OH concentration shows a good correlation with the experimental data concerning the contour und the penetration behaviour of the flame.