Warszawa, dn. 31.01.2023 r.

mgr inż Jakub Bachanek

Abstract of the doctoral dissertation:

„Experimental and numerical study on direct-injection sprays formed under flash-boiling conditions"

Flash boiling is a widely known phenomenon leading to vapour generation inside the liquid and enhanced evaporation. Despite a long time of both scientific and applicational interest, the rapid nature of flashing mechanism demand a deep understanding of physics behind it. As the flash-boiling lead to potentially improved liquid atomization, a strong emphasis on superheated liquid spray studies can be noticed. Improved spray quality leads to better fuel-air mixtures formation, improved combustion and thus, lower fuel consumption and emissions.

Various experimental analyses were conducted allowing to find the parameters describing the individual aspects of flash-boiling. Both quantitative and qualitative investigations bring more and more information about potential advantages and risks of achieving superheated fuel state in spray. However, complexity and short-time scale prevent from introducing simplification in order to attain the universal approach of predicting the effect of flash-boiling on spray formation. Along the experimental research the trials of numerical modelling of flash-boiling were done. Starting from classical nucleation theory a lot of approaches and models were proposed with better or worse applicability. The initial one-dimensional models allowed to predict the vapour generation, further 3D multiphase simulations brought information difficult to observe. However, the struggle of the computational fluid dynamics (CFD) simulations is in many cases to find the compromise between the calculations accuracy and the computational time. Due to spray applicability in internal combustion engines (ICE) design, the Lagrangian Discrete Droplet Model (DDM) is widely used. However, it is challenging to apply a rapid flash-boiling driven spray changes to stochastic DDM model.

To attain simplified, yet accurate numerical model, both the experimental and numerical investigation into flash-boiling spray in multi-hole system were conducted. The aim was to analyse both superheat of the fuel and injection pressure as the parameters controlling the spray process. A series of experiments allowed to collect spray penetration and angles. It was found that for flash-boiling spray the angle enhancement decreases with increased spray injection due to axial-to-radial momentum ratio change. Information and data collected in the experiments allowed to propose empirical model implemented into the CFD code. The numerical model was calibrated using the literature data of droplet size reduction led by flash-boiling atomization. The results showed that the proposed model predicts the spray collapse mechanism well and the impact of the injection pressure was noticeable. Future work should include more detailed research into droplet diameter reduction as well as possible vapour condensation.

Keywords: flash-boiling, atomisation, CFD, spray angle, high-pressure injection

Jakub Bachanek

Podpis Doktoranta