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A Multiphase Flow Approach for Ethanol Blended Fuels

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Extended Abstract

Type of fuel used in an internal combustion engine (ICE) is an important influencer on cavitation and cavitation induced erosion behaviour inside the fuel injectors [1]. Nowadays ethanol is widely used across the world in gasoline operated ICEs, in blends with gasoline, due to the fact that it helps reducing the petroleum consumption and support reducing the air pollution [2]. Since cavitation issue is one of the key challenges in fuel injectors, it is crucial for powertrain component manufacturers to predict cavitation behaviour precisely, by means of computational fluid dynamics (CFD) simulations, during the design phase in order to realize robust products. To achieve this use of appropriate fuel properties and multiphase modelling of ethanol blended fuels have great importance. In this study it is aimed to develop a multiphase flow approach that solves the necessary equations for ethanol and gasoline separately and uses their thermophysical properties in a non-mixed way, to explore the potential outcomes of the blended fuel components' non-homogeneous distribution within the simulation domain.

In the study, for taking the mass transfer due to cavitation into account a Rayleigh-Plesset equation-based cavitation model, Schnerr-Sauer [3], is implemented to a base incompressible multiphase flow solver of OpenFOAM. The resulting solver is able to solve more than two phases plus pressure-based phase change phenomena. Ethanol blended fuels can be found in the market in different volume fractions ranging from 5 to 85% [4]. To address this possibility the solver is adapted in a way where the thermophysical properties of pure ethanol and gasoline, at a specific reference pressure and temperature condition, is defined only once, however, different ethanol blends variations can be considered with the help of boundary condition assignments. To evaluate the cavitation behaviour of various ethanol blended fuels a set of simulations are conducted, to be specific for E10, E30 and E50. Besides, simulations with gasoline are also conducted. A total pressure of 300 bar is applied in the high-pressure side of the system and the counter pressure is set to 15 bar. From the simulation outcomes flow characteristics, cavitation behaviour and pressure fluctuations on the walls for different fuel types are evaluated.

For comparison purposes, numerical simulations are accompanied by experimental campaign in which a climatic chamber is used for ambient conditioning and a high-speed camera is utilized for image acquisition. The geometry used in the experiments has two chambers separated with a nozzle. An inclined test specimen, made of copper, is placed inside the low-pressure chamber, and aligned with the nozzle. Flow characteristics are examined with shadowgraph technique and the development of vapor formation in flow domain is pictured. Eroded areas on the test specimens are measured with help of an electron microscope. Similarities are observed when the time average flow structures between simulation and experimental results are compared. The comparison of calculated temporal standard deviation of the pressure field and the erosion location obtained from the experiment on test specimen also showed resemblances in specific regions.

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