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Numerical Investigations of Fuel-Water Emulsion Combustion in DI-Diesel Engines

Mr. Peter Eckert, Universitaet Karlsruhe (TH), Germany
Mr. Amin Velji, Universitaet Karlsruhe (TH), Germany
Mr. Ulrich Spicher, Universitaet Karlsruhe (TH), Germany

Abstract: Direct injection Diesel engines are today the power source with the highest thermal efficiency in heavy-duty, stationary power generation and marine applications. However, the Diesel engine suffers from relatively high pollutant emissions. Especially the opposing behaviour of the two main components oxides of nitrogen and particulates creates problems in meeting future emission regulations. While conventional modifications of the combustion process were successfully used to lower emissions in recent years, the potential of a further reduction of NOx and particulates by conventional means is limited and is also not possible without an unacceptable increase in specific fuel consumption. Exhaust gas after-treatment devices like particulate traps and selective catalytic reduction (SCR) offer high conversion rates, but also cause high costs. Furthermore, exhaust gas-after-treatment is not an option if heavy fuel oil is used. One method to reduce emissions especially suited for marine and stationary power plant engines is the introduction of water into the combustion chamber. Emulsions of water and fuel offer the potential to simultaneously reduce NOx and soot emissions while maintaining a high thermal efficiency.

This article presents a theoretical investigation of the use of fuel-water emulsions in DI-Diesel engines. The numerical simulations are carried out with the 3D-CFD code KIVA3V. The phenomenon of microexplosion of emulsion fuels, which is frequently observed in experimental investigations, is assessed in the simulations. Evaporation of the emulsion droplets is described by using a semi-continuous evaporation model that describes the hydrocarbon fuel as a continuous mixture of alkanes. Further models used in the computations include a cylinder crevice model, the Kelvin-Helmholtz/Rayleigh-Taylor hybrid models for droplet breakup, the shell ignition model, a characteristic turbulent and laminar time scale combustion model and NO kinetics. The evaporation model is first validated with experimental single droplet evaporation data. The computational model is then used to assess the use of Diesel fuel-water emulsions in a heavy-duty direct-injection diesel engine.