Numerical Investigation of the Needle Opening Process in a High Pressure Gas Injector

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Abstract : Gas internal combustion engines are widely used as propulsion systems or in power plants to generate heat and electricity. While there are different types of injection methods including the manifold port fuel injection and the direct injection, the latter has more potential to increase the specific power by avoiding air displacement in the intake and to reduce combustion anomalies such as backfire or pre-ignition. During the opening process of the injector, multiple flow regimes occur: subsonic, transonic and supersonic. To cover the wide range of Mach numbers a compressible pressure-based solver is used. While the standard Pressure Implicit with Splitting of Operators (PISO) method is used for the coupling between velocity and pressure, a high-resolution non-oscillatory central scheme established by Kurganov and Tadmor calculates the convective fluxes. A blending function based on the local Mach- and CFL-number switches between the compressible and incompressible regimes of the developed model. As the considered operating points are well above the critical state of the used fluids, the ideal gas assumption is not valid anymore. For the real gas thermodynamics, the models based on the Soave-Redlich-Kwong equation of state were implemented. The caloric properties are corrected using a departure formalism, for the viscosity and the thermal conductivity the empirical correlation of Chung is used. For the injector geometry, the dimensions of a diesel injector were adapted. Simulations were performed using different nozzle and needle geometries and opening curves. It can be clearly seen that there is a significant influence of all three parameters.

Keywords : high pressure gas injection, hybrid solver, hydrogen injection, needle opening process, real-gas thermodynamics
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