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NON-NEWTONIAN TRANSPORT MODELS FOR COMPRESSIBLE MULTIPHASE FLOWS IN OPENFOAM

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Fouling of heat exchangers causes macroeconomic losses of around 0.25% of GDP in industrially developed countries [1]. Consequently, more and more attention is being paid to the development of efficient cleaning concepts and their validation by numerical methods. In this context current research focuses on the design of customized multiphase cleaning fluids and their application. Up to now, the numerical treatment of such approaches is predominantly carried out with commercial tools, as open source software offer insufficient capabilities for combined analyses of compressible and non-Newtonian media. However, in terms of licensing costs and scalability (HPC), the usage of open source software is highly recommendable. Models for non-Newtonian multiphase flows are already implemented in open source software, e.g. [2], but just for incompressible cases.

In the present study, non-Newtonian models for compressible solver are developed and implemented in the open source framework OpenFOAM 5.0 [3]. To this end the thermophysical model library is extended by additional transport models. In order to compute the rheological behavior of fluids, the shear stress is derived from the velocity gradients and the initial viscosity field. The model-specific calculation of the varying viscosity is actualized iteratively, using the changing shear rate values. The common non-Newtonian approaches such as Bird Carreau, Cross Power Law or Power Law are implemented, whereby the characteristic fluid parameters are specified within the standard structure of the software.

Considering the provided approach, transient multiphase simulations with a compressible phase and different shear-thinning xanthan gum solutions are performed in parallel, using the solver compressibleInterFoam. These are carried out in a 3D backward-facing step domain for a better review of the physical plausibility. Related to the applied boundary conditions and the investigated xanthan gum concentrations, a viscosity distribution of three orders of magnitude is observed for the non-Newtonian phase without any instability problems. Furthermore, the results are verified against data achieved by the commercial software ANSYS CFX. First simulation results of a real cleaning process of a plate heat exchanger illustrate turbulent flow characteristics and show significant differences in fluid behavior and cleaning efficiency compared to common Newtonian cleaning fluids. Therefore, the issue of turbulence modeling for non-Newtonian fluids is discussed.

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