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CFD Modelling of Compressible Two-Phase Flow with Phase Change Using OpenFOAM

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Extended Abstract

In our recent research work on innovative superheated steam dishwashers, we performed computational fluid dynamics simulations of an idealized 3D dishwasher operated with superheated steam at 180 °C and 10 bar [1]. We used the interThermalPhaseChangeFoam solver, which is a new two-phase fluid volume solver based on OpenFOAM that accounts for heat transfer with phase change [2]. Bacteria inactivation was described using an Arrhenius-type of equation. The simulation results confirmed that potentially harmful heat-resistant bacteria can be killed in a short time span of 25 s. The superheated steam dishwasher is a promising alternative to conventional dishwashers, especially in professional environments where hygienic safety and cleanliness are important, such as hospitals and restaurants. Further, it can significantly reduce water consumption and cleaning time without the use of chemical detergents. One drawback of the interThermalPhaseChangeFoam solver used in our simulations is that it assumes a constant mass density of the two phases and only accounts for compressibility effects due to phase change. To more accurately predict the heat transfer in future simulations, we have extended the solver to the compressible case. Additional terms related to compressibility appear in the continuity and phase fraction equations. In addition to the mass densities of the fluid components, other thermodynamic properties are considered as functions of pressure and temperature. The correlations are obtained by polynomial fitting of experimental data from the CoolProp library [3], an open-source thermophysics library. The energy transport equation is solved for enthalpy with phase change heating as the source term, and temperature is recovered iteratively from enthalpy. Our approach does not require an equation of state and can well capture the behavior of steam up to high pressures and temperatures. While the computational cost of the numerical solution is higher, the new solver allows for more quantitative analysis of the flow pattern, the effects of shock interactions, and the bacterial inactivation rate for different nozzle configurations. This study will help to identify the zones of low heat transfer and areas of low liquid-surface interaction inside the dishwasher, due to the presence of plates in a compressible turbulent steam jet flow, which can be overcome with an optimized multi-nozzle configuration for efficient cleaning.

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