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Numerical Simulations of Transcritical Natural Convection

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ABSTRACT

In modern engineering applications, system overheating is a key issue that needs to be solved with efficient and reliable cooling technologies. Among the possible mechanisms that these are based on, natural convection cooling is one of the most frequently employed, with applications ranging from cooling of computer micro-components to large nuclear reactors. While many studies have been performed on natural convection employing supercritical or subcritical fluids, little attention has been given to fluids in their transcritical regime. The latter has the potential to yield high performances while avoiding detrimental effects of two-phase systems (e.g. cavitation). In the present study, 2D simulations of a theoretical transcritical natural convection cooling system are performed. Thermal properties changes and their influences on the overall heat transfer dynamics are investigated. To assess the performance of transcritical natural convection, heat flux and frequency content of hydrodynamic mixing are analyzed. Two fluids are employed (H20 and R134a), with four different temperature settings. Flow visualizations show circulations patterns typical of natural convection but with peculiarities due to pseudo-boiling conditions such as absence of nucleate boiling. With increasing top-down temperature difference, steady-state equilibrium heat flux is achieved sooner. Dimensional scaling techniques are used to collapse heat flux time spectra for all the temperature differences considered. This study is the first step towards high-fidelity numerical modeling and understanding of transcritical fluid behavior in natural convection systems that can be used in high-performance cooling devices.

KEYWORDS

Pseudocritical, Natural Convection, Temperature, Heat Flux, Transcritical, and Critical Heat Flux