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Numerical Study of Supercritical Turbulent Convective Heat Transfer of n-Decane with constant heat flux and Endothermic Pyrolysis

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Numerical investigations of supercritical turbulent flow and convective heat transfer of n-decane undergoing endothermic pyrolytic reactions in a mini tube under a constant heat flux were conducted. A complete set of conservation equations of mass, momentum, energy and species mass fractions have been solved with accurate estimation of the thermophysical properties. The transport properties, e.g. the viscosity and thermal conductivity, were calculated using an extended corresponding-state method, while the fundamental thermodynamic theories and a Soave-Redlich-Kwong equation of state were combined to evaluate the thermodynamic properties of the supercritical mixture, e.g. the heat capacity. A simplified one-step pyrolytic reaction mechanism of n-decane, which could reduce the number of conservation equations in terms of species mass fractions and decrease the computational time for thermophysical property calculations, was employed in the present numerical studies. The effect of inlet velocity on the supercritical heat transfer phenomena and the variations of the Nusselt number were investigated. Results indicate that the endothermic pyrolytic reactions could benefit the regenerative cooling process significantly. The heat absorption rate of n-decane through pyrolytic reactions increases remarkably as the inlet velocity decreases from 5.5 m/s to 4.5 m/s. The relative errors of Dittus-Boelter and Gnielinski expressions for the supercritical heat transfer predictions were within 25% in present studies.

Keywords: Turbulent Flow; Convective Heat Transfer; Pyrolytic Reaction; Hydrocarbon Fuel; Constant Heat Flux