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Numerical stability analysis of supercritical water in a vertical channel with upward flow

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Natural thermal hydraulic instabilities are likely to occur in supercritical water reactors due to the variations of physical properties along the heated pipe. These instabilities are of two types: static, or excursive, and dynamic, or oscillatory. The oscillatory instabilities are called density-wave oscillations. Both types of instabilities are highly undesirable and should be strongly avoided. Numerical analysis of supercritical water flowing upward in a vertical heated pipe is carried out using a RANS model in the CFD ANSYS CFX v14.0 code. CFD confirms the occurrence of density wave oscillations as well as static instability at specific flow conditions. The thresholds of oscillatory and static instabilities are determined using the CFD code and are compared with 1-D linear and non-linear code solutions. The CFD results are for 2-D axisymmetric up-flow using the $\kappa-\varepsilon$ turbulence model. Upon matching the CFD frictional pressure-drop with the 1D model, the 1D solution of the flow instability boundary under-predicted the CFD solution by ~22% in the case of oscillatory instability. However, Chatoorgoon's condition for approximating the flow instability threshold, suggesting that instability takes place at the mass flow rate corresponding to $\partial^2 \Delta(p+\rho u^2) \partial m^2=0$, was verified by the CFD code solution for the case reported.

Biography

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