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Thermal Stress Analysis for a Circular Piping Subjected to Internally Stratified Flow

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Abstract

This paper presents an effective numerical method for predicting the transient temperature distributions in a horizontal circular pipe subjected to internally stratified flow. The method employs a body-fitted, non-orthogonal grid system to accommodate the pipe wall of circular geometry and the interface of the two fluids at different temperatures, of which the level is variable. The transient behaviors of fluid flow and temperature distribution in the piping are simulated using the finite volume approach. The convection term is approximated by a higher-order bounded scheme named COPLA, which is known as a high-resolution and bounded discretization scheme. The cell-centered, non-staggered grid arrangement is adopted and the resulting checkerboard pressure oscillation is prevented by the application of modified momentum interpolation scheme. The SIMPLE algorithm is employed for the pressure and velocity coupling. As an illustrative problem, the present method has been applied to the stratified flow in the pressurizer surge line of nuclear reactor, and the results have been discussed in detail. In addition, some stress analyses have been performed for the thermally stratified piping using finite element method (FEM) in this study. Non-dimensional hoop stress and radial stress as a function of time have been obtained along the piping wall. The result shows that the hoop stress near the pipe inner surface decreases rapidly and increases again as the time increases. It means the fatigue damage due to thermal stratification is very large near the pipe inner surface.