Flow physics, stress analysis and Uncertainty Quantification for thermal transients in a U-bend

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ABSTRACT

The U-shaped configuration is commonly used in cooling systems for different applications, and is a good model to demonstrate stress and fatigue due to conjugate heat transfer in stratified fluid flows. In many working conditions, such as the nuclear cooling pipes, the U-shaped pipe will withstand multiple cycles of hot-cold thermal fluids with large temperature differences. These components have a high risk to have stress-corrosion cracking or even pipe fracture in service, which will cause secondary hazards in reality [1].

In this study, the responses of a U-shaped pipe to thermal transients are investigated through numerical simulation that are based on the methodology of Viollet [2]. A thermal transient is introduced at the inlet and increases to a maximum value linearly. A High-temperature thermal transient is used in this study to reflect some extreme working conditions. The thermally induced variations of Young's modulus and thermal conductivity are taken into account in this study, as they vary significantly over these temperature ranges. Different materials of the U-shaped pipe are simulated. The propagation of thermal transients within a u-shaped bend are analysed. The influence of the thermal transient on wall temperatures, thermal stresses and thermal expansions are assessed and compared between different materials. As the resulting thermal stratification induces thermal stresses, and multiple hot-cold cycles lead to thermal fatigue and possible structural failure, the fatigue life of the U-shaped pipe with different materials are predicted under the present working conditions. In order to achieve these goals, the present study established a framework that coupling the Computational Fluid Dynamics (CFD) solver with a stress analysis solver for wall temperature assessment in the fluid domain and the thermally induced stress/expansion in the solid domain. As solid displacements have an insignificant influence on the fluid flow, a one-way coupling method is performed. The widely applied empirical fatigue models are employed for the fatigue analysis. we also applied advanced uncertainty quantification techniques which allow us to maximise the knowledge extracted from the modelled system and its response to uncertain input parameters.

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REFERENCES

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