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An Efficient Approach for Benchmarking Axial Flow-Induced Vibration for Nuclear Applications

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The fretting wear at the grid assemblies in fuel assemblies as a result of flow-induced vibration (FIV) is one of the main causes of fuel failures in the Light Water Reactor (LWR). Therefore, accurately predicting FIV is crucial to mitigating this issue, and a computationally efficient simulation method is necessary. In this regard, the Unsteady Reynolds-Averaged Navier-Stokes (URANS) approach is applied as a promising and efficient simulation method for FIV prediction. While previous studies have primarily relied on Large Eddy Simulation (LES) for the fluid domain, URANS provides an attractive alternative due to its lower computational demands, especially for a strong 2-way fluid-structure interaction (FSI) coupling. This paper aims to explore efficient approaches for benchmarking axial FIV for nuclear applications, focusing on a high-stiffness rod subjected to axial turbulence flow. The experiments conducted at Vattenfall AB, which involved a steel beam constrained on both ends, were used to predict the damping of vibration in an axial turbulent flow. The results show that URANS and even the laminar fluid model accurately predict the added mass effects of the vibration. The paper then examines self-exciting axial FIV and compares the experiments of axial FIV over a cantilevered rod at the University of Manchester using different URANS models and convective momentum equation divergence schemes. In both variations for the closure of the URANS model, which are the eddy viscosity model, the k-ω SST model and the Reynolds Stresses Model (RSM), the Launder, Reece and Rodi (LRR) model, accurately predicted the frequency of vibration, while the former predicted with a lower amplitude of vibration. Modification of the k-ω SST model with a higher-order cubic interpolation for the convective of the momentum equations could achieve accurate amplitude of vibration.

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