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Analysis of Vortex-Induced Vibration Characteristics for a Three-Dimensional Flexible Tube

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Abstract : Numerical simulations of vortex-induced vibration of a three-dimensional flexible tube under uniform turbulent flow are calculated when Reynolds number is 1.35×10⁴. In order to achieve the vortex-induced vibration, the three-dimensional unsteady, viscous, incompressible Navier-Stokes equation and LES turbulence model are solved with the finite volume approach, the tube is discretized according to the finite element theory, and its dynamic equilibrium equations are solved by the Newmark method. The fluid-tube interaction is realized by utilizing the diffusion-based smooth dynamic mesh method. Considering the vortex-induced vibration system, the variety trends of lift coefficient, drag coefficient, displacement, vertex shedding frequency, phase difference angle of tube are analyzed under different frequency ratios. The nonlinear phenomena of locked-in, phase-switch are captured successfully. Meanwhile, the limit cycle and bifurcation of lift coefficient and displacement are analyzed by using trajectory, phase portrait, and Poincaré sections. The results reveal that: when drag coefficient reaches its minimum value, the transverse amplitude reaches its maximum, and the “lock-in” begins simultaneously. In the range of lock-in, amplitude decreases gradually with increasing of frequency ratio. When lift coefficient reaches its minimum value, the phase difference undergoes a suddenly change from the “out-of-phase” to the “in-phase” mode.

Keywords : vortex induced vibration, limit cycle, LES, CFD, FEM
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