Mechanical Engineering Master’s Defense

Effects of Structural Uncertainty on the Dynamic Response of Nearly Straight Fluid-Filled Pipes: Modeling and Numerical Validation

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abstract

Investigation is focused on the consideration of structural uncertainties in nearly-straight pipes conveying fluid and on the effects of these uncertainties on the dynamic response and stability of those pipes. Of interest more specifically are the structural uncertainties which affect directly the fluid flow and its feedback on the structural response, e.g., uncertainties on/variations of the inner cross-section and curvature of the pipe. Owing to the complexity of introducing such uncertainties directly in finite element models, it is desired to proceed directly at the level of modal models by randomizing simultaneously the appropriate mass, stiffness, and damping matrices. The maximum entropy framework is adopted to carry out the stochastic modeling of these matrices with appropriate symmetry constraints guaranteeing that the nature, e.g., divergence or flutter, of the bifurcation is preserved when introducing uncertainty. To achieve this property, it is found that the fluid related mass, damping, and stiffness matrices of this stochastic reduced order model (ROM) are all determined from a single random matrix and a random variable. Both cases of simply supported and cantilevered pipes are considered with the latter requiring the additional stochastic modeling of the exit velocity variability induced by the localized uncertainty at the free end of the pipe.

To support the appropriateness of the stochastic ROM, a series of finite element computations were next carried out for pipes with straight centerline but inner radius varying randomly along the pipe. In the former computations, it is observed that the effects of uncertainty are much larger for the cantilevered case than the simply supported one due to the exit velocity variability effect. Comparisons of these results with their counterparts derived from the stochastic ROM show that there is a very good qualitative and quantitative match between them providing a strong support for the appropriateness and applicability of the stochastic ROM. In addition, stochastic ROM model have been developed to include the uncertainties associated with pipes having extremely small curvature. Alternative approach has been proposed to address the differences in previously developed theories on fluid filled pipes with curvature.

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