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Title

Parametric Uncertainty Quantification in Coalescence Flutter

Abstract

Current safety certification procedures are, for the most part, structured within a conventional deterministic framework, which implicitly deals with the nominal values of parameters without systematically and rationally considering the associated uncertainties. The uncertainty is accounted via the use of safety factors. Such treatment of uncertainty raises some concerns, since the safety factors are empirically chosen. Furthermore, these safety factors cannot be directly related to the probability that the system response or the stability margin will exceed a predetermined critical level. On the other hand, a probabilistic approach provides a rational framework to deal with the uncertainty in the model and its parameters. The rational treatment of uncertainty and the assessment of associated risk and reliability levels permit a cost effective and optimal design and analysis of engineering systems at different stages in its life cycle.

In this thesis, a probabilistic methodology is applied to the analysis of the coalescence flutter, influenced by the parametric uncertainties associated with the structure. Coalescence flutter is a two mode aeroelastic dynamic instability, which can occur on flexible structures exposed to air flow, such as an aircraft, bridge or a wind turbine. In this thesis, a two degree-of-freedom elastically mounted rigid wing and a uniform cantilever wing models are considered for numerical investigations. For these systems, the effect of uncertainties is studied on the flutter speed and the pre-flutter modal parameters. Monte Carlo Simulation is performed to estimate the probability density functions of the output quantities of interest (i.e. modal parameters and flutter speed). Based on such probabilistic analysis, an optimal flutter speed may be selected for certification. In addition, appropriateness of the rigid wing model approximation of a cantilever wing is investigated. It is shown that this approximation is acceptable only for the cases, where the modes involved in the flutter mechanism can be adequately represented by a combination of the fundamental bending and torsional mode of a uniform cantilever without air flow. Furthermore, the effect of quasi steady and unsteady aerodynamic forcing is examined for both, the rigid wing model and a cantilever wing model, from a probabilistic prospective. The effect of statistical correlations among parameters is also examined on the flutter speed and the modal parameter estimates.

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