INNOVATION DESIGN OF A CURVE RIBBED-PLATE SUBJECTED TO TURBULENT BOUNDARY LAYER EXCITATIONS

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ABSTRACT

Flow-induced vibration and noise is a design focus for the aerospace and automotive industries, among others. Despite the increased computational power of today's high performance computers, fully-coupled high-fidelity models of fluid, structure, and their interaction remain out of reach for large models. When the one-way coupling assumption is valid, however, simulation can be used to gain an understanding of the effects of design decisions on noise and vibration due to turbulent boundary layer (TBL) excitation.

In this paper, one-way coupling is used to investigate the noise and vibration generated by TBL flow over an elastic structure. The first step is to characterize the boundary layer, which is achieved using panel methods in conjunction with boundary layer models developed by Thwaites, Michel, and Head (Thwaites, B, Incompressible Aerodynamics, 1960; Michel, R ONERA Technical Report, 1951; Head, Aeronautical Research Council, England 1960). A panel method is used in order to capture the influence of plate curvature on the TBL fluctuating pressure. The TBL excitation is calculated using methods described by Goody (AIAA 2004) once the critical boundary layer parameters

have been determined. This excitation is combined with structural acoustic transfer functions generated by Energy Finite Element Analysis (EFEA) to predict the structural and acoustic responses. EFEA is a computationally-efficient means of calculating high-frequency acoustic and vibration effects. The combined techniques provide a quick turn-around model for TBL-induced noise and vibration.

More interestingly, the integrated model has been exercised by optimization algorithms to explore the relationship between design parameters and design performance. The analysis of TBL-based excitation effects has been completely automated to achieve this aim. Using optimization to manipulate the model enables engineers to perform simulation-driven design, where decisions are directly informed by the physics in a manner that frequently reduces risk and increases performance. In this case, stiffened plate geometry, thickness, damping, and curvature are modified by the algorithm to search the design space and identify the best design for acoustic performance within the defined parameter bounds. Optimization is conducted by gradient-based and genetic optimization algorithms and the results and optimal designs are compared and discussed.