DFD09-2009-020007

Abstract for an Invited Paper
for the DFD09 Meeting of
the American Physical Society

Stochastic Dynamics Models for Laminar-to-Turbulent Transition on a Flight Vehicle

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Random pressure fluctuations within a turbulent boundary layer provide dynamic excitation to a flight vehicle. These random fluctuations must be adequately modeled and appropriately utilized by high fidelity structural dynamics finite element models in order to achieve accurate predictions of structural random vibration response. Most work in this area assumes the fluctuating pressure field to be fully turbulent. However, most flight vehicles experience a transition within the boundary layer from laminar to turbulent flow. This transition event also provides dynamic excitation to the vehicle, resulting in structural response that, for some systems, can be very significant. Herein, we provide a model for the pressure field acting on a flight vehicle in the laminar-to-turbulent transition zone for the purpose of predicting associated structural vibration response. The model is a Gaussian random field modulated by a Poisson field to capture the intermittent characteristics of turbulent flow in the transition zone. Computer algorithms to generate samples of the random pressure field are provided, and these samples are applied to a finite element model for a flexible beam with attached oscillator for illustration.