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PROCEEDINGS

Effects of Structural Deflection on Nonlinear Flutter of Preheated Functionally Graded Panels in Supersonic Airstream

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ABSTRACT

Panel flutter is an aeroelastic phenomenon characterized with thermo-mechanical coupling and geometric nonlinearity. In high speed air vehicles, panel flutter introduces violent vibration of the skin structures and leads to structural failure with fatigue cracks. When functionally graded materials (FGM) are adopted as the thermal isolator on high speed vehicles, the thermo-mechanical performance of skin panels is increased while the panel flutter is affected by the asymmetry. It is of great interest to study the nonlinear phenomenon of FGM panel flutter.

In this work, an aeroelastic model of preheated FGM panels are established. The Mindlin plate theory is employed for the structural finite element equations, the first-order piston theory is adopted for the supersonic quasi-static aerodynamic loads, the von-Karman strain-displacement relation is used to model the geometric nonlinearity rising from the large deflection of the panel. The FGM is homogenized by using the rule of mixture, and the constitutive components (ceramics and metals) are assumed to vary according to the simple power law distribution through the panel thickness. The equilibriums of the nonlinear aeroelastic system are studied based on the reduce-order model. Nonlinear panel flutter response is simulated by solving the aeroelastic equations in time domain.

Numerical results show that in a regime with relatively low dynamic pressure (flow speed) and high temperature, several stable equilibriums exist in post-buckled FGM panels. The initial conditions such as structural deflection and initial oscillating velocity affect the evolution of nonlinear dynamic response, which leads to another flutter mechanism related with the multiple stable equilibriums and the saddle-node bifurcation (secondary instability). The critical aerodynamic pressure of the secondary instability flutter is lower than that of the classical flutter arise from the Hopf bifurcation, which means panel flutter may occur at relatively low aerodynamic pressure for the application of FGM panels in supersonic aircraft cruising at high altitude and the spacecraft at its launch and re-entry stage.

KEYWORDS

Panel flutter; functionally graded materials; nonlinear dynamics; aeroelasticity

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