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Exact eigensolutions for flutter of symmetric cross-ply composite laminates at high supersonic speeds

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ABSTRACT: Exact eigensolutions for flutter of two-dimensional (2D) symmetric cross-ply composite laminated panel with all combinations of simply supported (S), guided(G), clamped (C) and free (F) boundaries are derived according to classical laminate theory(CLT) and first-order piston theory. The flutter mechanism is revealed with the benefit of eigenvalue properties from both mathematical and physical senses. It is concluded that the coupled-mode flutter, single-mode flutter and zero-frequency flutter or buckling can be observed in 2D composite panel. The effects of aerodynamic damping, chord-thickness ratio, in-plane loads, boundary conditions and orthotropic modulus ratio on flutter properties are examined, and in-plane loads and boundary conditions are stressed since they affects both flutter boundary and type. The exact solutions are compared with the results of Galerkin method and the comparison results show that the Galerkin method using the first three modes gives accurate enough flutter solutions.

Keywords: flutter; laminated panel; eigenvalues; flutter type

1 Introduction

PANEL flutter is a self-excited oscillation of elastic structure which results from the coupling effects of aerodynamic, elastic and inertial forces. It is an aeroelastic phenomenon that usually causes fatigue damage, not instantaneous fracture of flight vehicles. Characteristics of panel flutter are that, panel is subjected to supersonic airflow over one surface, and that, flutter, which primarily affects skin panels, occurs due to the interaction of panel and airflow.

Flutter phenomenon was first observed in 1940's [1], and has had a rich study since 1950's. In 1950's, panel flutter was clearly observed in experiments and attracted numerous theoretical studies [2]. Comprehensive reviews of both theoretical and experimental investigations before 1960 were presented by Fung [3] and Stocker [4], in all the papers cited of which, the differential equations and boundary conditions were linearized.

During the period prior to 1960, panel flutter had been considered more or less an academic problem, not a significant structural problem which caused broad attention until 1959 [2] since wind-tunnel tests showed that certain structural components of X-15 airplane were susceptible to panel flutter [4, 5]. Johns [6, 7] summarized the achievement of such early stage researches before 1965. Literature [7] reviewed the best theory and experiments of panel flutter and reported research works in the NATO Nations. The theoretical and experimental studies including linear and nonlinear panel flutter before 1970 were summarized by Dowell [8]. As nonlinear analysis of panel flutter became popular, Mei [9] gave a summary of which before1999. More information about panel flutter can be found in publications [10-21].