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Flutter of Stiffened Composite Panels Considering the Stiffener's Base as a Structural Element

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Abstract

Flutter in aeronautical panels is a type of self-excited oscillation which can occur during supersonic flights. At the flutter point the vibrations of the panel become unstable and increase significantly in time. This manuscript presents a semi-analytical model taking into account the stiffener's base effects, in order to predict the aeroelastic response of laminated composite stiffened panels under supersonic flow. Krumhaar's modified supersonic piston theory, which considers the radius effect, is adopted to model the aerodynamic loading. The proposed model has been validated against results available in the literature for various configurations. A parametric study considering different panels and stiffener configurations is also presented. The numerical results indicate that the stiffener base significantly affects the panel aeroelastic behavior. Preliminary studies also indicate that redistributing the laminate plies from the stiffener's flange to its base significantly increases the torsion stiffness of the panel locally, opening new design possibilities that may lead to higher critical flutter speeds and therefore to better designs. The results also indicate that designs with plies distributed on the base may lead to a better flutter performance when the airflow is transverse to the longitudinal stiffener direction.

Keywords: composite, semi-analytical, flutter, stiffened plate, stiffened shell, stiffener's base

1. Introduction

With the increasing use of composite materials in aeronautics, space and defense many numerical approaches have been reported in the literature in order to address the panel flutter phenomena, which happens to be a self-exited oscillation of the structure under inertial, elastic and aerodynamic forces, usually at the supersonic regime [1]. Knowing the critical speed that will cause flutter in a stiffened panel is fundamental to keep safe operational levels of typical aircraft structures.

It is well known that the size, fiber orientation angle and location of stiffeners should be carefully selected in order to control the specific frequency and mode shapes of a given structure [2], [3]. This will directly impact the flutter behavior and this selection usually is performed along with optimization tasks, where the use of semi-analytical tools allows a fast prototyping and evaluation time when compared to the finite element method.

More dedicated finite element models have been proposed in the literature to address panel flutter analyses in a more efficient way. Holopainen [4] presented a finite element model for the free vibration of isotropic stiffened plates, using the first-order shear deformation theory (FSDT). One of the problems verified by the authors was the relative error in results, which was up to 15% when distorted meshes were employed. Lee and Lee [2] presented a finite element model using the FSDT to evaluate the flutter of laminated composite stiffened plates, verifying that a 1-D beam model for the stiffeners can represent with a high fidelity the structural dynamic behavior. Several other authors addressed the flutter behavior of laminated plates or shells using the finite element method [3] [5] [6] [7] [8], but only few studies applying semi-analytical models for flutter analysis of composite plates and shells have been reported [1] [9].

In Fig. 1 it is shown a schematic view of a cylindrical panel with a blade-type stiffener. The two main structural elements of this stiffener are the flange and the base. The semi-analytical models found in Refs. [1] and [9] only include the flange effect and to the authors´ knowledge there are no publications available in the open literature presenting a semi-analytical that captures the stiffener's base effect on the aeroelastic response of laminated stiffened panels. The stiffener's base is a common assembly feature that, if taken into account will lead to additional design possibilities and possibly to better design solutions. The present study addresses this topic and investigates new design variables that can be included when the stiffener's base is modelled.

The first section addresses all the formulation related to the proposed model followed by sections that deal with its verification and application.

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