Journal of Fluids and Structures 115 (2022) 103756

Contents lists available at ScienceDirect

Journal of Fluids and Structures

journal homepage: www.elsevier.com/locate/jfs

Nonlinear flutter of composite laminates with curvilinear fibres using a full linearized aerodynamic theory

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A R T I C L E   I N F O

Article history:
Received 14 July 2021
Received in revised form 6 September 2022
Accepted 7 September 2022
Available online 13 October 2022

Keywords:
Nonlinear flutter
Composite laminates
Curvilinear fibres
Finite element
Low supersonic airflow

A B S T R A C T

This paper studies nonlinear flutter of rectangular variable stiffness composite laminates (VSCLs) subjected to a low supersonic airflow. The VSCLs are formed by different individual laminae where a polymeric matrix is reinforced by curvilinear carbon fibres. The plate's displacement field follows a Third-order Shear Deformation Theory (TSDT); a *p*-version finite element is employed to discretize the displacement components. A full linearized (inviscid, potential flow) aerodynamic theory is used to approximate the aerodynamic pressure. The self-exciting vibrational model is formed using the principle of virtual work. The equations of motion representing the model are solved using Newmark method. Limit cycle oscillations (LCOs) of these plates are studied using time histories, phase-plane plots and FFT spectra. A damage onset criterion is utilized to control the structural health of the laminates during nonlinear flutter. Effects of curvilinear fibre path angles on linear and nonlinear flutter behaviour, as well as the damage onset in VSCLs are investigated.

1. Introduction

This paper studies nonlinear flutter of variable stiffness composite laminates (VSCL) subjected to a low supersonic airflow. The possible improvements achievable in linear and nonlinear aeroelasticity by using curvilinear fibre paths in a composite laminate are a topic of this research. Critical speeds at which aeroelastic instabilities occur are examined. The limit cycle oscillations that ensue are also of interest, not only in what concerns the relation between amplitude and aerodynamic pressure, but also modal interactions. A damage criterion is utilized to control failure onset during flutter.

Composite laminated plates are frequently made of layers where straight reinforcement fibres are embedded in a polymeric matrix. These laminates, which can be designated as constant stiffness composite laminates (CSCLs), often have better stiffness and strength properties, per unit weight, than metals. Going a step further, variable stiffness composite laminates (VSCLs) with curvilinear fibres can be employed to redistribute stresses from high to low stress locations and, therefore, can advantageously be used in the aerospace industry. For example, stress concentration around windows in an airplane fuselage or around a hole in a plate can be avoided via the variable stiffness concept (Ungwattanapanit and Baier, 2014; Hyman et al., 1969). These laminates can also be used to achieve desired stiffness or strength properties in a structure using less material and, therefore, reducing weight (Ribeiro et al., 2014). Although other methods exist, VSCLs often are manufactured using an automated fibre placement (AFP) machine (Lukaszewicz et al., 2012).

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https://doi.org/10.1016/j.jfluidstructs.2022.103756