Optimization of thin-walled panels with stability considerations

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Panel stability has been a longstanding research subject in structural mechanics. When a thin plate (or panel) is subjected to a flow at supersonic speeds it undergoes a loss of stability. This limits the maximum speed of aerospace structures that incorporate such components. Due to the widespread use of these elements and their importance in enabling high-speed aerospace systems, considerable effort has been devoted for optimizing these panels aiming at improving their flutter performance. While early works focus on optimizing the thickness of these elements to reduce their weight, today, composite designs are utilized for the same purpose. However, these works mainly concentrate on optimizing the material layout and fibres in the thickness direction.
Recent advances in manufacturing methods, particularly the integration of automated processes such as 3D printing, have made the design of multi-material components, in which the material is spatially varying, increasingly feasible. To leverage these capabilities, optimization-based design has proven highly valuable due to its ability to produce non-intuitive structures without geometric restrictions.
This work presents an optimization framework for panels operating at supersonic speeds with the goal of enhancing aerodynamic stability. The aim is to investigate the potential for achieving weight reduction while limiting the degradation in flutter stability by designing longitudinally tailored by material structures.
A gradient-based optimization approach is proposed with analytical derivation of the sensitivity analysis. The optimization problem is formulated to determine the spanwise material distribution in the panel, aiming to maximize the aerodynamic pressure under a predefined weight constraint. The linear piston theory is adopted for modelling the aerodynamic forces, and the flutter point is determined by solving a stability problem in the form of an eigenvalue analysis.
The optimal designs of bi-material panels are investigated under various boundary conditions. The results indicate that a substantial weight reduction can be obtained by tailoring two materials in the spanwise direction.

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