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Experiments on the thermal post-buckling of panels, including localized heating

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Abstract

The suppression of expansion in thin clamped panels subjected to elevated thermal loading often results in buckling. However, a number of possible post-buckled equilibrium configurations typically exist, and which shape ensues depends on a number of factors including the role of symmetry, boundary conditions, aspect ratio, and the effect of small geometric imperfections associated with the initial shape. It is possible to force the panel to go between different buckled shapes, given a sufficiently large perturbation. Sometimes the panel will spontaneously jump, or snap, when the temperature is gradually increased or decreased (mode jumping). The extent to which these features occur when the thermal loading is applied locally is also investigated. This paper describes some interesting nonlinear (essentially buckling) behavior in thermally-loaded panels from a primarily experimental perspective, with an additional focus on non-uniform heating. The full force of stereo 3D digital image correlation and forward-looking infrared cameras are exploited to provide a relatively complete picture of this behavior.

Keywords: thermal loading, plates, buckling, localized heating, experiments, full-field measurements, nonlinear behavior

1 Introduction

It is not uncommon in problems of axially-loaded slender structures with nominal geometric and loading symmetry to observe an uncertain direction of post-buckling deflection [1]. Even the pin-ended Euler strut, the most classical example of buckling, presents a system in which the direction of the buckling depends on the presence of even very small geometric imperfections or perhaps a tiny axial load eccentricity, that has the tendency to break the symmetry [2, 3]. Thus, a preferred direction is followed under the slow increase of loading through the buckling process. However, this does not mean to say that the complementary (alternative) equilibrium path - the path *not* naturally followed, does not exist: it simply requires a relatively large perturbation to deviate from the *natural* loading path [4]. That is, it is possible to physically push the strut from one equilibrium configuration to its opposite side. This is not dissimilar to the frequency sweep in dynamics (for example, through a nonlinear resonance), in which the response followed is typically associated with a local evolution, in which any remote response is not necessarily picked-up. This path dependency is dramatically different from a linear system with its unique equilibrium configuration and response.

When the structural system is a nominally flat panel or plate the same situation occurs, only now, further boundary conditions and the aspect ratio of the panel provide additional geometric variables. For relatively elongated plates, the aspect ratio is relatively large (in contrast to a square plate for example), and it is possible for the plate to exhibit a number of different modes, able to persist in their stable state [5]. Again, a large (judiciously chosen) perturbation can be applied to carry the system between these equilibria. In some circumstances the plate jumps between equilibria quite naturally under slowly changing loading, typically

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