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Dynamic snap-through bucking of cylindrical panels

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Thin cylindrical shells are widely used in aerospace, mechanical and civil engineering due to their efficient load-carrying capabilities. Typical examples include aircraft, tanks, pipelines, offshore platforms, and so on. Because of the slenderness, these structures have high risk of encountering buckling failures. One type of loss of stability is snap-through buckling where a structure jumps to a remote equilibrium state. In a static context, the structure displaying snap-through typically has multiple equilibria. Under dynamic excitation, the structure can vibrate between these equilibria resulting in large amplitude, highly nonlinear oscillations. Dynamic snap-through oscillations produce quick curvature reversals that greatly reduce the fatigue life of the structure. Therefore, it is useful to identify the instability boundaries of the structure. Although dynamic snap-through buckling is detrimental to the integrity of the structure, it is not always possible to avoid these behaviors for slender panels especially in modern aircraft, often subject to severe loading conditions. Thus, it is also important to assess the likelihood of the structure to survive if it moves into the postbuckling regime.

In this work, we use the state-of-the-art nonlinear finite element formulations to investigate the dynamic snap-through buckling of cylindrical panels under external dynamic excitations. We focus on studying the influence of the bifurcation and limit points on snap-through boundaries and postbuckling responses. Firstly, we identify panels that have different number or arrangement of critical points (in the static context) by varying certain geometric parameters. Transient analysis of these structures is then performed with a robust and efficient time integration algorithm. The dynamic snap-through boundaries for panels with different number of critical points are identified. The similarities and differences of the boundaries are characterized, which is useful for the preliminary design of these structures. Then, complex nonlinear dynamic behaviors in the postbuckling areas are classified into different categories based on the effect of the responses on the fatigue. Such classifications contribute to improving the design of these structures.