IMPACT OF FRICTIONAL STRUCTURAL NONLINEARITY IN THE PRESENCE OF NEGATIVE AERODYNAMIC DAMPING

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Limit Cycle Oscillations (LCO) have been a prevalent aeroelastic problem on several current fighter aircraft. This phenomenon usually occurs for aircraft with external stores throughout, but not limited to, the transonic flight regime, although a business jet wing LCO was also reported recently. Complicated by the problem geometry, e.g. the aircraft-store system, the LCO mechanisms still remain to be fully understood. In fact, there exists few analytical techniques available for LCO prediction and an insufficient understanding of its physics.

With aerodynamic feedback, LCO are sustained periodic oscillations which neither increase or decrease in amplitude over time for a given flight condition. A series of researchers believe that the wing/store LCO is a purely aerodynamic phenomenon, largely due to transonic shock oscillation and shock induced flow separation. This LCO scenario, which is referred to as the Transonic Shock/Separation (TSS) model, has been suggested to be, with viscous effects, one of the major factors contributing to transonic LCO for wings.

A radically different LCO model was recently proposed that is based on the observation that the wing/store LCO can be a post-flutter phenomenon whenever the flutter mode contains low unstable damping. In such a scenario, a structural nonlinearity must be present to stabilize the response and it was argued that a Nonlinear Structural Damping (NSD) mechanism, specifically friction, would be phenomenologically consistent with the available flight and wind tunnel data.

In this light, the goal of the present study was to provide a first validation of the NSD model and, accordingly, it focuses on the response of simple mechanical systems under the combined effects of a negative dashpot (modeling the aerodynamic effects) and friction. The results of this investigation demonstrate that friction can indeed dissipate the energy provided by the negative dashpot and lead to limit cycle oscillations. While a detailed parametric study has shown that the stabilization occurs only for a limited range of negative damping ratios which is strongly dependent on the system parameters (e.g. stiffnesses and masses), it was found that these conditions (damping ratios and system parameters) are well within the range of values compatible with the aircraft considered. Further, the presence of complex response patterns, e.g. continuous slip and stick-slip limit cycles with one or several dominant harmonics, has been observed and the transitions between these different behaviors has been clarified. Finally, current efforts to extend these results to a more complex wing model exhibiting an internal friction device will be discussed.