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QUASI-TRANSIENT STABILITY ANALYSIS OF A CONVENTIONAL AEROELASTIC LAUNCH VEHICLE

Abstract

Examples of control problems occurring during flight tests of fighter aircraft are well documented. In many cases, the cause of the problem could be characterised as inadequate modelling or other inappropriate treatment of the aeroelastic effects on the vehicle dynamics and/or the flight-control design. However, such problems are not restricted to just aircraft. Especially long and slender bodies, such as (small) conventional launch systems, may suffer from an unwanted coupling between the rigid body and its flexible modes. In addition, due to fuel consumption during the flight, the change in atmospheric environment, and aerodynamic effects, the entire flight profile should be examined, rather than a single worst-case point, to identify the stability and controllability performance of the launch vehicle.

Since large flexible structures are quickly modelled as distributed parameter systems, their motion is described by a system of coupled ordinary and partial differential equations, of which the latter are difficult to deal with both analytically and computationally. Therefore, approximate finite-dimensional equations of motion are frequently used. In the assumed-modes method, the deflection of continuous elastic structures is modelled by a finite series of space-dependent functions that are multiplied by specified time-dependent amplitude functions.

In previous research, a two-dimensional assumed-modes analysis of a single point of maximum dynamic pressure for a small launcher was examined. The current research treats the launch vehicle as a flexible beam with lumped masses to account for the subsystems and fuel, using a three-dimensional assumed-modes method with longitudinal and lateral effects. A simplified mass-spring system models the mechanical aspects of fuel sloshing. The resulting model is analysed with finite-element software to establish the relevant flexible modes.

In this paper, multiple discrete flight points are considered for aeroelastic analysis at different stages of the ascent profile. These individual points are analysed as quasi-static, quasi-steady inputs for a continuous flight trajectory simulation. The stability and controllability for the entire flight under the influence of wind gust and turbulence is estimated based on this simulation.