Paper ID: 35230
oral

MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures - Dynamics and Microdynamics (3)

Author: Dr. Erwin Mooij
Delft University of Technology (TU Delft), The Netherlands

Dr. Derek Gransden
Delft University of Technology (TU Delft), The Netherlands

THE IMPACT OF AERO-ELASTIC EFFECTS ON THE CONTROLLABILITY OF CONVENTIONAL LAUNCH VEHICLES

Abstract

Over time several specific examples of control problems occurring during flight tests of fighter aircraft have become apparent. In each case 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. Therefore, this coupling should be analysed in detail and could be safely ignored once proven to be insignificant.

Since large flexible structures are best 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 usually 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.

The assumed-modes method is applied to the conceptual design of a small launcher. The launcher is treated as a flexible beam with lumped masses to account for the subsystems and the fuel. A simplified mass-spring system is taken to model the mechanical aspects of fuel sloshing. The resulting model is analysed with finite-element software to establish the relevant bending modes.

A multi-disciplinary design approach integrating the models for trajectory, the structure, aerodynamics, and control system is employed to study the behaviour of a controlled, flexible launch vehicle in response to atmospheric turbulence. Sensor structural feedback and propellant sloshing have an adverse effect on the stability, and the vehicle flight loads show a large increase due to structural vibrations.