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ELASTIC DEFORMATION MODELING OF THE VS-40M SUBORBITAL ROCKET WITH SARA PAYLOAD

Abstract

The aim of this paper is to present the flight dynamics analysis of the suborbital rocket VS-40 with SARA (Atmospheric Reentry Satellite) payload by taking into account the elasticity of the launcher in the equations of dynamics. The SARA payload is a reusable space vehicle developed to perform microgravity experiments.

The thrust and the aerodynamic forces during the atmospheric flight cause elastic vibrations of the vehicle, which in turn affect its performance. The final dynamic equations of the system represent a combined flight mechanics / fluid / structure interaction approach where different disciplines are fully coupled.

The way to include structural dynamics in such an approach is the main topic of this paper. In order to include the flexibility in the overall dynamic analysis of the launcher, a mathematical model of a fully flexible structure subjected to aerodynamic and gravity forces is presented. By opportunely writing the translational, rotational and flexible dynamic equations, it is possible to obtain a fully non-linear system of equations of motion where the roles of the macro dynamics (representative of the translational and rotational flight mechanics of the launcher) and the micro dynamics (elastic vibrations) can be clearly appreciated.

The elastic displacement of the launcher is represented through the modal superposition technique whereas the micro dynamics effects are obtained via Galeerkin approach.

In order to have an accurate representation of the elasticity, the structural parameters (natural frequencies, modal shapes and modal participation factors) of the complete structure, that is, SARA plus launcher, are obtained by using a commercial software for FEM analysis.

The flight dynamic parameters are obtained by using a numerical code developed to solve a set of differential equations of motion that includes flexible modes. As a result, the complete solution (macro- and micro-dynamics) is available.

An accurate analysis of macro and micro-dynamics effects, at the early stage of the project, helps the designers on the prediction of possible structural and control interaction that may affect the control stability, performance, and resonance problems that may, in the worst case, cause mission failures.

The consistency of the results, modal parameters and the trajectory of the launcher, are checked by comparison with its rigid body trajectory calculated using a qualified trajectory code.

The proposed methodology presents a useful way for preliminary analyzes of deformation magnitude, trajectory deviation, and design and test of control system strategies for flexible launchers, among other possibilities.