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VLM-1 MODELING AND CONTROL WITH STRUCTURAL BENDING MODES

Abstract

The aim of this paper is to describe the modeling and control architecture for the problem of controlling the VLM-1 (Micro-satellite Launcher Vehicle) trajectory with structural bending modes. VLM-1 is a three-stage Brazilian micro-launcher, under development, composed by a 12 tons solid rocket motor in the first and second stages whose motor cases are made in carbon fiber (filament winding). In general, structural bending modes are very difficult to deal with during the design of the controller for launchers, since their natural frequencies are much higher than those of the rigid body dynamics. Furthermore, the high frequency range is where other features of the system appear, such as sensors and actuators. The mixing in the same range of frequencies of structural dynamics (poles of the transfer function) and of control devices like the latter (poles and zeros of the transfer function) can create serious issues during the design of the controller. One solution is to use dedicated control devices, tailored to take care of every single bending mode included in the model. This solution is effective, but nevertheless it comes with some drawbacks: a) the characteristics of the elastic behavior (i.e. natural frequency and damping) must be perfectly known; b) the gains of the controller shall be continuously updated along the flight trajectory (gain scheduling); c) the resulting controller might be of high order and therefore quite complex from the implementation point of view. Another solution that can be investigated is the use of a robust controller, which can naturally deal with unknown dynamics (e.g. the bending modes) and unknown parameters of the model, without continuous gain scheduling and maintaining lower complexity. These advantages come at the cost of a more complicated controller design phase. The rocket is modeled with a finite number of bending modes, that are not completely available in the control design phase. In this sense, a full and a reduced model (with and without all the bending modes) are presented. The outputs include the normal accelerometer measured at different points of the body (the center of gravity, the nose and the tail) and rategyro measures. The structural parameters associated to the vehicle mass variation and loads (thrust and aerodynamics) used in the control architecture are obtained on time by using a FEM code that model the VLM-1 structure as a beam.