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CONTROL-ORIENTED MODELIZATION OF A SATELLITE WITH LARGE FLEXIBLE APPENDAGES AND USE OF WORST-CASE ANALYSIS TO VERIFY ROBUSTNESS TO MODEL UNCERTAINTIES OF ATTITUDE CONTROL

Abstract

The design of large space flexible structures (LSFS) requires the use of design and analysis tools that include different disciplines. For such a kind of spacecrafts it is in fact mandatory that mechanical design and GNC design are developed within a common framework. One of the keypoint in the development of LSFS is related to the dynamic phenomena. These phenomena usually lead to two different interpretations. The former one is related to the overall motion of the spacecraft, i.e. the motion of the center of gravity and motion around the center of gravity. The latter one is related to the local motion of the elastic elements that leads to oscillations. These oscillations have in turn a disturbing effect on the motion of the spacecraft. From an engineering perspective, the structural model of flexible spacecrafts is generally obtained via FEM involving thousands of DOFs. Many of them are not significant under the attitude control point of view. One of the procedures to reduce the structural DOFs is tied to the modal decomposition technique. In the present paper a technique to develop a control-oriented structural model will be proposed. Starting from a detailed FE model of the spacecraft, using a special modal condensation approach, a Continuous Model is defined. With this transformation the number of DOFs necessary to study the coupled elastic/rigid dynamic is minimized. The final dynamic model will be suitable for the control design implementation. In order to properly design a satellite controller, it is important to recall that the characteristic parameters of the satellite are uncertain. The effect that uncertainties has on control performance must be investigated. A possible solution is that, after the attitude controller is designed on the nominal model, a Verification and Validation (VV) process is performed to guarantee a correct functionality under a large number of scenarios. The VV process can be very lengthy and expensive: difficulty and cost do increase because of the overall system dimension that depends on the number of uncertainties. Uncertain parameters have to be parametrically investigated to determine an estimate of the worst case stability and performance of the control laws. A gridding approach can be used and the VV can be obtained with the Worst-Case Analysis, i.e. an optimization process, to find an estimation of the true worst-case behavior, such to verify that the design is robust enough to meet the system performance specification under worst-case conditions and tolerances.