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INTEGRATED CONTROL/STRUCTURE DESIGN METHOD FOR FUTURE LARGE FLEXIBLE SPACECRAFT

Abstract

The design of new generation space vehicles is increasingly becoming subject to design integration, that is, close coordination in the design of various systems constitutive of the spacecraft. Not only is integrated design important because of its development cost saving, but also because of the valuable advantage it provides as it enables simultaneously meeting different subsystem specifications, improving the quality of space system design. For instance, space structures involving very large complex chains composed by rigid and exible bodies require integration between the Attitude Control System (ACS) and the structure to avoid elastic instabilities. However, integrated spacecraft design requires new methods which tie together spacecraft structural dynamics and control laws design.

This work presents a cutting-edge methodology which enables simultaneous ACS/structure optimization. The aim is to optimize a robust attitude controller for the spacecraft at the same time that several structural parameters are optimized without losing controller performance requirements. These structural parameters can be appendages mass, length, stiffness or cross-section inertia among others. Active control of spacecraft structure can be studied as well by optimizing actuators placement along the spacecraft.

This multi-disciplinary methodology is possible thanks to the advanced structural dynamics modelling tools and the controller synthesis technique developed for this study. Structural dynamics are modelled with Linear Time Invariant (LTI) representations using Finite Elements Models (FEM). The controller synthesis is performed with a technique called structured H-inf synthesis, which enables designing robust controllers with a given architecture. The structural dynamics of the spacecraft is tied together with the controller synthesis technique in a simple way, enabling simultaneous structure/control optimization.

A generic flexible spacecraft is used as an example to introduce the integrated design approach proposed in this paper. This structure consists of a central rigid hub to which two appendages are symmetrically attached. Each truss-like appendage carries a payload at its tip. Under normal operation, this spacecraft undergoes planar rotational manoeuvres about the inertially fixed axis z. During the rotational manoeuvers, tips displacement must be damped so that the payload can achieve its mission. The study shows how the method is able to accurately provide a structured robust controller meeting control requirements for tip displacements at the same time the structure is optimized to meet both control and structure requirements. Results show that this methodology can overcome the future challenge of complex spacecraft architecture design, reducing time and cost of phase 0-A projects.