Paper ID: 76303
oral

IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures II - Development and Verification (Deployable and Dimensionally Stable Structures) (2)

Author: Mr. David Paolo Madonna
Sapienza University of Rome, Italy

Prof. Paolo Gasbarri
University of Rome “La Sapienza”, Italy
Dr. Mauro Pontani
Sapienza University of Rome, Italy
Mr. Fabrizio Gennari
Thales Alenia Space Italia (TAS-I), Italy

NON-INERTIAL STRUCTURAL EFFECTS IN FLEXIBLE SPACECRAFT WITH SPINNING APPENDAGE

Abstract

New generation satellites often show innovative configurations, designed to fulfill increasingly demanding tasks in space operations. This work focuses on one of these configurations, which consists of an Earth observation spacecraft equipped with a large rotating payload, linked to the main bus by a flexible boom. The payload motion aims at expanding the scanned area, resulting in a reduction of the time required to complete a set of measurements, thus considerably enhancing the expected performance. On the other hand, this configuration implies greater complexity both in the analysis of the dynamical behavior and in the design of the control architecture. In fact, when modeling flexible structures subject to rotational motion, the stiffening effect resulting from inertial loads (in particular, from the centrifugal action) can play a crucial role. In this work, the dynamical equations of the multibody flexible spacecraft are derived using Kane’s formulation, which provides a minimum set of ordinary differential equations, while simplifying their derivation. Because the link is regarded as an elastic beam, flexibility is introduced through a modal decomposition approach that takes the nonlinear elastic dynamics into account, so that the stress stiffening is included in the dynamical model. Stress stiffening is proven to be a fundamental effect that arises in spinning space structures, for which the contribution of the centrifugal force is remarkable. In fact, incorrect predictions, associated with unrealistic dynamical behavior, i.e. structural instability for high spinning rates, come from neglecting this effect. Moreover, the error related to neglecting this physical phenomenon depends on the spinning rate, and kinematical conditions that make it negligible are identified, in relation to the systems fundamental deformation frequencies. Furthermore, attitude control is demanded to an arrangement of momentum exchange devices, used both for compensating payload spin-up and for performing slewing maneuvering. The dynamics of the actuators is included in the model, and a suitable steering law is adopted to drive the actuators, with the final objective of pursuing a nonlinear feedback control logic, designed for attitude tracking relative to the Earth. Numerical simulations point out the mutual influence between attitude control and elastic behavior, in different operational scenarios.