Paper ID: 70174
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IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures - Dynamics and Microdynamics (3)

Author: Mr. Paolo Iannelli
Sapienza University of Rome, Italy

Prof. Paolo Gasbarri
University of Rome “La Sapienza”, Italy
Dr. Marco Sabatini
Sapienza University of Rome, Italy

ROBUST SYNTHESIS AND PERFORMANCE ANALYSIS OF A POSITIVE POSITION FEEDBACK VIBRATION CONTROL FOR FLEXIBLE SPACE STRUCTURES

Abstract

Modern Earth Observation (EO) satellites are required to full high demanding stability and pointing performance to benefit by the high-resolution capacity of their scientific instruments. However, such spacecraft are currently equipped with large flexible appendages (such as antennas and solar panels), introducing low and lightly damped flexible modes that have a significant impact on platform pointing accuracy and limit the performance of the classical Attitude Control System (ACS) architecture. Furthermore, novel SAR imaging techniques implemented on modern observation satellites might involve fast slew maneuvers to obtain multiple acquisitions of the same area of interest, enhancing acquisition density and observations' resolution. In this perspective, the article presents an active vibration suppression strategy used to augment the spacecraft attitude control allowing improved agility, settling times after the completion of the maneuver and pointing stability. In particular, a network of collocated and optimally placed piezoelectric sensors/actuators is distributed on the flexible appendages to implement a multivariable Positive Position Feedback (PPF) control. Unlike traditional tuning procedures, in this study the PPF compensators are designed concurrently with the attitude controller using a structured H_∞ synthesis approach, which is based on non-smooth optimization techniques and allows to solve H_∞ synthesis problems while simultaneously accounting for additional constraints on the controller's structure. The PPF parameters (i.e., gains, compensator frequencies and damping value) and the attitude PID gains are therefore tuned accordingly to weighting functions shaping the desired closed loop behaviour of the system. The proposed strategy is tested on a spacecraft equipped with two large solar arrays. The FE model of these structures is developed and validated by using a FEM commercial code before being reduced to obtain a plant that can be easily handled by control systems algorithms. As several system parameters are assumed to be uncertain, the dynamic plant is recast in a Linear Fractional Transformation (LFT) to separate the uncertain/unknown part of the system from the known part, with the aim of carrying out the robust synthesis operations. Structured singular value (μ) analysis is then used to assess the robust stability and performance of the attitude/vibration control strategy against the various system uncertainties. Furthermore, the effectiveness of the proposed approach is compared to that of a traditional PID control and a full-order H_∞ controller in both frequency domain with -analysis and in time domain non-linear simulations.