Paper ID: 41617
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MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures - Dynamics and Microdynamics (3)

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MODAL PARAMETER CHARACTERIZATION FOR A SMALL SCALE HELIOGYRO BLADE IN HIGH VACUUM CHAMBER

Abstract

All solar sails generate thrust from the reflection of solar photons, providing propellant-free thrust for long duration and high delta-V missions. A heliogyro is a specific type of solar sail that spins, using centrifugal forces to supplant stiffening structure mass to maintain sail shape. The resulting higher accelerations allow the heliogyro to attain previously inaccessible orbits. The key advantage of the heliogyro concept is its ability to scale to very large areas by increasing the length of the blades while maintaining a conceptually easy packaging and deployment scheme from simple cylindrical rolls. The heliogyro's maneuverability comes from pitching the individual blades at the root with cyclic or collective sinusoidal profiles. The blades are constructed from 2 microns thick Mylar sheets that can be hundreds of meters long by a few meters wide. This lightweight blade material has very little inherent damping making it necessary to include some other way of attenuating blade vibration caused by maneuvering. The most common approach is to incorporate damping through the root pitch actuator. Due to the small root pitch control torques required, on the order of 2 μNm, compared to the large friction torques associated with a root pitch actuator, it is challenging to design a root control system that takes friction into account and can still add damping to the blade. However, with the use of classical control theory in conjunction with impedance control techniques, a position-source root pitch controller was designed to dominate friction with high gains, wrapped with an outer control loop that adds damping to the blade by sensing differential twist outboard of the blade root. The robustness of this control design depends on the accuracy of the blade damping model, since some amount of inherent damping at the higher frequency modes is needed to add damping to the larger magnitude low frequency modes. Experimental characterization tests were performed on a small-scale hanging blade in a vacuum chamber. Previous efforts relied on the System/Observer/Controller Identification Toolbox (SOCIT), which is generally used for well damped systems, to determine the percent damping ratio of the blade's first harmonic combined flap (out-of-plane) and twist (pitch) modes at 0.53 Hz, which was 0.028%. A new method uses incremental and reduced frequency response functions to calculate a flap percent damping ratio of 0.005%. This significant decrease in the damping estimate is critical to the control design's ability to add damping to the heliogyro blade.