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STRUCTURAL DYNAMICS AND CONTROL IMPLICATIONS FOR MODAL DAMPING OF A SIMPLIFIED TWO-BLADE HELIOGYRO MODEL

Abstract

Solar sails generate thrust from the reflection of solar photons, providing propellant-free thrust. A heliogyro is a specific type of solar sail that spins, using centrifugal forces to supplant stiffening structure mass. The key advantage of this concept is its ability to scale to very large areas by increasing the length of the blades while maintaining an easy packaging and deployment scheme from simple cylindrical rolls. Due to the large scale and difficulty of working with the thin blade material, much of the research has focused on individual blade structural dynamics, along with techniques for handling, and deployment of the blades. What is limited in the current heliogyro research field is a reduced order heliogyro dynamics model and a physically realizable root sensor/actuator/control system for space applications. This is due to the small root pitch control torques (2 μNm) compared to the large friction torques associated with a root pitch actuator. Only one approach currently exists for a single-blade twist-only model that mitigates friction and adds damping to the blade.

The existing single-blade twist-only analytic model is adapted to a two-blade heliogyro case. The heliogyro blade dynamics are simplified to a lumped parameter model with inherent blade damping and gyroscopic stiffness. This facilitates analysis of various affects on the structural dynamics and analysis of the root control designs for adding damping. Specifically, the affects of adding a second blade, varying central mass magnitudes and asymmetric blade mass properties were explored. A multivariable control design with a decoupled controller led to the analysis of the key loop gains, same blade and cross blade. The two blade symmetric mass properties case resembles the single blade with collocated modes in both the same and cross blade loop gains, allowing the same control to be implemented at each blade's root. A larger magnitude central mass results in the single and multi-blade modes coalescing into the same frequency mode, simplifying the control design further. Asymmetric blade mass properties have a negative affect on the structural dynamics and root control design, causing a non-collocated multi-blade mode. Therefore, different root controllers are needed for each blade, complicating the control design. Therefore, it is not beneficial to add asymmetry to the blades for control purposes, but a root control design for added blade damping is still feasible in asymmetric cases. The analysis of this simplified two-blade heliogyro model lays the foundation for future multi-blade heliogyro analytical models.