SPACE PROPULSION SYMPOSIUM (C4)
Advanced Propulsion Systems (8)

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STEERING CONCEPT OF A HELIOGYRO SOLAR SAIL SMALL SPACECRAFT

Abstract

Solar sails enable long term multi-mission capability and an extended operational lifetime because they do not require consumable fuel, instead deriving their velocity/direction from solar photons. Steering of solar sails is complicated because solar sails tend to have a larger moment of inertia than conventional spacecraft, due to the large sail area required to receive a significant amount of solar photon pressure. Moreover, the physics of a thin flexible sail membrane (2μm) imposes difficulties in controlling the sail at increasing distance from the spacecraft. Out of two solar sail configurations: masted and heliogyro, MacNeal[1] theorized that the heliogyro-like architecture would be a lighter, easier to stow, less costly, and less risky approach to deploying a large sail area than using a masted sail. With a rotating heliogyro, the sail membrane is stowed as a roll of thin film that forms a blade when deployed, and each blade can extend up to kilometer[1-4]. The masted-configuration requires booms to rigidize the sails, and therefore has a fixed sail area and geometry, unlike a heliogyro[2-3]. Hence, a masted-configuration limits options and increases the complexity required to maneuver.

This paper introduces a simple concept to steer the 2-bladed heliogyro-configuration by extending/retracting the blades to adjust the center of mass with respect to the spacecraft's center of pressure. The solar sail area is varied by simultaneously alternating the extension/retraction of the sail blades, during half of the spacecraft's rotation, thereby steering the spacecraft with respect to a defined turning axis. The times needed to turn the spacecraft at various degrees (10, 20, 30 and 40°) relative to the sun-facing angle, and return to its original orientation travelling on a new linear vector, are calculated. In this calculation, the blades are retracted/extended from 1–50 m. The solar photon incident angles are assumed to be 1-50° with respect to the sails at 1 astronomical unit. These calculations predict that the times needed to turn the spacecraft at 10° and 20° are 7 and 11 days for the blade retraction/extension of 10 m and with 10° solar photon incident angle. The time is reduced to 4–5 days if the blades are retracted/extended by 50 m.

[1] MacNeal R.H. et al., NASA CR-1329, (1969).

[2] Wiwattananon P. and Bryant R.G, Heliogyro-Configuration Solar Sail Spacecraft, 66th International Astronautical Congress, IAC-15-C4.8.3.x27468, pp.1-20.

[3] https://icubesat.files.wordpress.com/2015/05/icubesat-2015_org_b-4-2_heliogyro_wiwattanamon.pdf (accessed January-21-2016).

[4] Wilkie K.W. et al., Heliogyro Solar Sail Research at NASA, ISBN-978-3-642-34907-2, pp.631-650.