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EXPLOITING CORIOLIS ACCELERATION TO REDUCE LIBRATION OSCILLATIONS DURING RETRACTION OF TETHERED SATELLITE SYSTEMS

Abstract

Tethered Satellite Systems (TSS) enable formation flying missions by providing a physical connection between satellites. This physical connection may transfer data, ease formation length control, generate power, and even assist in orbit keeping for small systems. The presence of tethers couples the attitude and orbital dynamics of a TSS, significantly raising the complexity of dynamic modelling. Moreover, system retraction, which may be required for end of life or collision avoidance maneuvers, is an unstable process. In the literature, multiple controllers have been implemented to stabilize the retraction process by driving the tether libration angles to zero. In recent work, we aimed to simplify the retraction control by only reducing the libration angles during retraction to a small amount. This was achieved by introducing periods of extension during the retraction process, thereby exploiting the Coriolis effect.

The Coriolis acceleration experienced by the system during tether retraction or extension can either amplify or reduce libration angle oscillations. In this paper, the contributions of the Coriolis effect to tether libration angles are studied for a large three point-mass tethered system in low earth orbit. Equations of motion of the system are derived with the Lagrangian formulation and are simulated in MATLAB. Speeds of cyclic retraction and extension are selected by a control algorithm such that the corresponding shift in libration acceleration reduces the libration angles toward zero. Simulations show that instantaneous changes from retraction to extension, if performed at appropriate times, reduce the libration acceleration of the tethers and consequently the libration angles experienced by the system during retraction. If performed at improper times, the same maneuver would instead increase libration angles, further destabilizing the retraction process.

In previous work, exploitation of the Coriolis effect allowed reducing libration angles to near 1 degree using multiple cycles of extension and retraction at constant speeds. In this work, based on knowledge of the magnitude of the Coriolis contribution to libration acceleration, the speeds of tether retraction and extension are varied throughout multiple simulations. As a result, we achieve libration oscillation amplitudes near 0.5 degrees with up to half the previous Delta-V requirements during retraction. It is found that speeds of retraction and extension contribute greatly to the libration motion of the tethers, and that proper speed selection is especially critical when the formation is near its equilibrium state. Results additionally show that tether retraction rates have significantly greater effects on smaller length systems.