Attitude Dynamics of Orbiting Gyrostats

Christopher D. Hall

Virginia Tech,
Blacksburg, Virginia, USA. E-mail:chall@aoe.vt.edu

Equilibrium attitudes of a rigid satellite with N rotors in a central gravitational field are investigated. Over the past century, an understanding of the torque-free motion of gyrostats has been developed in cases with freely spinning rotors or with rotors constrained to spin at constant speed relative to the platform. Equilibrium motions of orbiting gyrostats, where the gravity gradient torque is included, have been studied for circular orbits. The gravitational moment used in most studies is obtained by truncating the gravitational potential in an inconsistent manner. In previous work by the author and colleagues, the inconsistency has been shown to be negligible for "ordinary" asymmetric, rigid, gravity-gradient spacecraft, but the relevance of this work for gyrostats has not been investigated thoroughly. Furthermore, most results are for spacecraft with free or constant-speed rotors. During rotational maneuvers, the rotors satisfy neither of these conditions. Although many have studied problems of maneuvering gyrostats, virtually no one has used information about equilibria to develop reorientation control laws. Herein, we attempt to unify the various cases, while taking into account more accurate approximations of the potential. The equations of motion are written as a noncanonical Hamiltonian system, where the Hamiltonian includes the potential, a volume integral over the body of the gyrostat. In practice, the Hamiltonian is approximated to partially decouple the position and attitude equations. The equilibria of this system of equations represent the steady motions of the body as seen in the body frame, and correspond to stationary points of the Hamiltonian constrained by the Casimir functions. This defines an algorithm for computing equilibria. In contrast to other approaches, this algorithm provides stability information directly, since the calculations required to solve the constrained minimization problem are also involved in computing the positive definiteness of the Hamiltonian as a Lyapunov function.