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RELATIVE ORBITAL MOTION OF A CHARGED OBJECT NEAR A SPACEBORNE RADIALLY-DIRECTED ROTATING MAGNETIC DIPOLE

Abstract

This paper studies the relative orbital motion of a charged object near a spaceborne magnetic dipole, which indicates that the Lorentz force acting on the charged object is taken into consideration. Assuming that a space station in a Keplerian circular reference orbit is capable of generating a rotating magnetic dipole (the axis of the dipole is in the direction of the orbital radius vector) and a constantly charged object moves nearby in the artificial magnetic field, a nonlinear dynamical model of the proposed relative orbital motion, which is similar to the scenario of satellite formation flying, is established based on the Hill–Clohessy–Wiltshire (HCW) equation. Moreover, we suppose that the Lorentz force acts on the charged object only and does not affect the circular reference orbit of the spaceborne magnetic dipole. Based on the system parameters such as the charge-to-mass ratio of the charged object, magnetic dipole's moment and rotating rate, and the angular velocity of the circular reference orbit, we firstly derived system's equilibrium points and analyzed their stabilities. Based on the stability characteristics, all of the equilibrium points in this dynamical system are classified into ten cases and the structure of the submanifold as well as the stable and unstable behaviors near the equilibrium points are described. Subsequently, the necessary and sufficient conditions for the equilibrium points belonging to any one of these ten cases are deduced according to the characteristic equation about the equilibrium points. The periodic orbits near the equilibrium points, determined by the structure of the submanifold, are also depicted in details. Finally, an integral constant and the zero-velocity surfaces of the dynamical system are derived, and it is clear to show the existences of bounded orbits around the magnetic dipole and transient orbits through equilibrium points. The flight mechanics of presented relative orbital motion, including equilibrium points, periodic orbits, bounded orbits, and transient orbits, reveals prospects of potential applications for proximity operations to a wide range of charged space objects in circular orbits.