Equilibria of a Multibody Connected System with Rigid and Tethered Elements in a Circular Orbit

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Abstract

The recent NASA plans of formation flying implementation, including benchmark tetrahedron formation, attracted attention of the researchers to the problems of satellite dynamics that are in scope of investigations since four decades ago.

To study spatial equilibria of a multibody connected system we use the well-known model of n + 1 material points connected by n light rods. The junctions are spherical hinges. The centre of mass of the system moves along a circular orbit.

We use “satellite approximation” for the gravitational potential to study spatial equilibria of an n-link open chain and describe all the possible equilibrium configurations. We prove that there exist a number of three-dimensional equilibria that can be used to maintain a tetrahedral satellite formation. It is shown that some rigid links can be substituted by tethers. Stability of tetrahedral configurations is also discussed.

We also discuss the relative equilibria of a symmetric tetrahedral structure in a circular orbit. It turned out that the use of the second approximation is not sufficient to describe dynamical behavior of the system, since all principal inertial moments of the structure are equal. Therefore, the terms of the third order are to be taken into account. This fact prescribes the principal difference of the considered case compared to the classic results on the equilibrium orientations of a satellite in a central Newtonian field in a circular orbit. In particular, these equilibria are not isolated, but form three classes of orientations. These classes differ in dimension of the geometric element which points to the Earth. Equilibria of each class can be obtained one from another by a rotation about the local vertical. The possibility of the use of tethers to provide the formation flights for such systems is discussed.

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