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EFFICIENT ATTITUDE CONTROL OF TETHER-CONTROLLED SPINNING SOLAR SAIL USING C.M.-C.P. OFFSET TORQUE AND VIRTUAL STRUCTURE METHOD

Abstract

Solar sail is a new spacecraft that deploys a large membrane and gets accelerated by solar pressure from the Sun using the membrane. One of the authors has proposed a tether-controlled spinning solar sail where multiple satellites are allocated at each corner of the membrane and connected by tethers. The formation, attitude and behaviour of the membrane can be controlled by the satellites by controlling the tethers' lengths and tensions. This paper deals with the attitude maneuver of the tether-controlled spinning solar sail. A common requirement of the attitude maneuver rate of solar sails is 1 degree a day. As one of the common methods for the attitude control of solar sail, the use of the vanes is considered. Then the authors investigate the unique method using the center of mass (C.M.) and the center of pressure (C.P.) offset torque generated by changing the lengths of tethers, which is proposed by the authors. A numerical model is developed to study the behaviour of the solar sail, where the membrane is modelled as multiple mass points connected with springs and dampers, and the satellites are expressed as rigid bodies. The paper introduces the results of the numerical simulation of proposed methods and possible problems such as in-plane vibration of the system, nutation, and out-plane vibration of the membrane. One of the authors investigated the former two problems and proposed a method to reduce them, but its feasibility was partially achieved and further study is necessary. In this paper, the authors consider the virtual structure method for formation control. The model is assumed to be single rigid body and is used to obtain reference information for the control of numerical model. The feedback control loop is configured so that the numerical model follows the behaviour of the virtual structure. The attitude maneuver method of the proposed solar sail using the virtual structure is proposed and its detailed algorithm is introduced. Numerical simulation results show that the stability of the membrane is improved by applying the quaternion feedback in reference to the virtual structure's satellites, and that the nutation is reduced by controlling the positions of the satellites. Based on these results, the feasibility of the attitude maneuver is discussed. The simulation shows that the attitude maneuver of 1 deg/day requires a large vane for each satellite, and the use of C.M.-C.P. offset torque is helpful to meet the requirement.