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ANALYSIS OF THE ATTITUDE MOTION AND STRUCTURAL VIBRATION COUPLING FOR SOLAR POWER SATELLITE

Abstract

In recent decades, the solar power satellite (SPS) has received much attention due to its potential for generating a large amount of clean electrical power. Different concepts have been proposed by NASA, JAXA, ESA, CAST and other organizations. While most research focuses on the system concept design, very few deal with the technical issues that surround the on-orbit operations of solar power satellites. To achieve stabilized on-orbit operations, the dynamic behaviour of a SPS should be thoroughly investigated. Unlike traditional satellites, the SPS has a very large area-mass ratio and an ultra-low fundamental frequency. The torque generated by solar radiation acting on the surface of a deformed SPS will therefore have a significant influence on the attitude motion, which is zero for a rigid model. Besides, the generalized force generated by the gravitational gradient will affect the structural vibration. It is therefore paramount to accurately analyze the dynamic characteristics of a SPS.

The coupling between attitude motion and structural vibration of the Sun Tower SPS, which is here considered as an unsupported (free-free) Euler-Bernoulli beam, is studied in this paper. Under the small deformation assumption, the vibration of the SPS is described by the approach of the assumed modes, and the equations of attitude motion and structural vibration are firstly proposed. Then the models of the torque and the generalized force caused by solar radiation and gravitational gradient, which is expanded to the second order of a Taylor series in the small size/orbital ratio, are then respectively developed. Through analyzing the structural vibration equation, a divergent vibration of the structure of the SPS could be occurred under the excitation of the gravitational gradient if the fundamental frequency of the SPS is below a certain threshold, and the condition to guarantee the stabilization of the vibration of the SPS is then derived. Numerical simulations are finally presented to assess the proposed model and the coupling effect, and to analyze the influence of solar radiation torque on the attitude motion of the SPS.