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Space Elevators and Tethers (4)

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THE EFFECT OF DISTURBANCES ON SPACE ELEVATOR DYNAMICS WITH FLEXIBILITY

Abstract

The space elevator, which consists of a long ribbon stretching from the Earth's surface to beyond geostationary altitude, has been considered as one of useful space transportation systems. Discovery of carbon nanotube that possesses high-intensity makes the system feasible. Dynamical behavior of the system that is an extreme version of a tethered satellite system has not been clarified. The lumped parameter system is occasionally used as a long tether model, i.e. the tether is divided into a large number of discrete masses that are connected by viscoelastic springs. The model, however, is not suitable for a space elevator system because the system should take space environment, atmospheric disturbances, and the effect of climber transit into account for its dynamics.

The purpose of this study is to propose a fundamental dynamic model of the space elevator system that is assumed to be a very long tethered system. The equations of its motion considering flexibility of the tether are expressed by using the distributed parameter system. The tether length is more than the geostationary altitude due to necessity of counterweight in equilibrium. The taper function that would provide constant stress throughout the tether is treated to determine the diameter of the cross-sectional area. Firstly, the effect of initial displacement and orbital perturbation as a disturbance on dynamics of the space elevator system is investigated by numerical simulation. The system under study hire is a 10,000-70,000 km long tether with a 1,000 kg climber. The results are generated using 10,000 elements to model the tether. Numerical result shows that the period of first mode of 10,000 km tether is about 7 hrs. The effect of the solar radiation pressure on the system can be negligible. The impulsive force by collision of space debris with the system causes vibrational and translational motion. It is noted that a orbital station should have enough mass to avoid this problem. We also study the effect of a climber transit with constant speed on the system. Although the vibration of the tether during ascent and descent of the climber is attenuated, the translational motion of the system is caused similar to the case of the impulsive force. Results of numerical simulation show that the effect of disturbances on the space elevator system should be fully taken into consideration when designing the system.