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CONSIDERATION OF TETHER ELASTICITY IN THE DEPLOYMENT PHASE OF A SPACE ELEVATOR SYSTEM

Abstract

It is known that deployment of the ribbon (tether) is a vital phase during the construction of the space elevator. Dynamics of the space elevator during this stage has been studied by several researchers with the aid of rather simple models. So far, elasticity of the tether has not been considered in the analysis. In this paper, it is aimed to study the effects of the tether elasticity on the dynamics of the system in its deployment phase as well as on the energy cost of the system. In an earlier study, Keshmiri and Misra (2012) concluded that enforcing the center of orbit of the system to move on the geostationary orbit leads to a near optimal deployment as far as energy cost and fuel consumption are concerned.

To perform the analysis, a more detailed model of the space elevator is developed, considering both lateral and longitudinal elasticity of the tether. Motion of the system is described by four generalized coordinates corresponding to the system rigid body motion r, α, φ, and l and two sets of elastic modal coordinates ξ and η. Here r and φ describe the main-satellite position, l denotes the deployed length of the space elevator, α corresponds to the librational motion of the whole system, ξ characterizes the longitudinal oscillations, and η describes the lateral elastic oscillations of the tether. Considering all the radial and tangential components of the control forces applied on the main-satellite (or ballast mass) and the sub-satellite (or spacecraft) and the above mentioned constraint, equations of motion are derived through the Lagrange's method.

Using the constrained equations of motion for a space elevator system with an elastic tether, this paper attempts to carry out the following by means of numerical simulation:

1. Evaluation of the near optimal deployment strategy, using the rigid body model and Legendre's orthonormal polynomial expansion for the unknown functions.
2. Evaluation of the excitation of elastic motion both in the absence and presence of the librational motion.
3. Evaluation of the effect of the tether elasticity on the system energy cost and an appropriate strategy for reduction of the corresponding energy cost