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ELASTIC OSCILLATIONS OF A DEBRIS REMOVAL TETHER IN AN INCLINED TOWING CONFIGURATION

Abstract

One of the possible applications of tethers in space in the near-term is the towing of space debris for its disposal. After the debris is captured by using a tether-net, or some other mechanism located at the end of a tether deployed from a service spacecraft (space tug), it can be towed to a graveyard orbit or to the upper atmosphere. A thrust is usually applied to the space tug during the debris removal procedure. It has been observed in earlier studies that the dynamical behavior of the tug-tether-debris system is strongly dependent on the magnitude and direction of the thrust applied. Furthermore, these two quantities also determine the nominal configuration of the tether. The tether configuration during the debris removal process is closer to the local horizontal than the local vertical configuration used in earlier tether missions.

Studies conducted so far on the dynamics of tug-tether-debris systems have focused on the librational motion of the tether and its stability. Although some of these studies have considered the tether to be extensible, elastic oscillations of the system have not received sufficient attention. However, one would expect that the design of a suitable controller for debris removal using a tug might require a good understanding of the frequency-content of the system. The objective of this paper is to analyze the longitudinal and transverse elastic oscillations of a tether in an inclined towing configuration. If a tether has a nominally inclined configuration, and additionally if a thrust is applied, then the tension along the tether can be very different from the previously studied cases and the elastic oscillations can be significantly altered by that.

This paper considers a tug-tether-debris system with a specified thrust acting on the tug. Nominal equilibrium configuration of the tether is determined for this scenario. Elastic displacements of the tether are considered in both longitudinal and transverse directions. Equilibrium longitudinal deformation and tether tension, which vary along the length, are determined. Small elastic oscillations about the equilibrium configuration are considered. The partial differential equations associated with the two types of elastic oscillations are solved with appropriate boundary conditions. Frequencies of oscillations are calculated for different values of thrust magnitude and direction (and hence for different inclined configurations). It is noted that these frequencies can be very different from those for a tether deployed nominally along the local vertical.