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DYNAMIC ANALYSIS OF SPACE ELEVATOR SYSTEM AFTER TETHER BREAKAGE

Abstract

Space elevator is a new-type transportation system capable of sending payloads from Earth to space, consists of a ground station and an apex anchor that are connected by a huge tether with a length of over 10,000km. During normal operations of a space elevator system, most of tether segments, especially ones at higher orbit, are flying around Earth with a very high linear velocity, so the tether is likely to be broken possibly by space debris, in-orbit spacecraft, wind, lighting, and even material corrosion. The tether breakage will not only terminate normal operations of space elevator, but also potentially do a great harm to the valuable space and ground assets and human safety. By virtue of this, it is necessary to analyze the dynamic behavior of space elevator system after tether breakage and effectively predict the broken tether motions.

To this end, this paper firstly formulates a discrete flexible dynamic model for the tether of a space elevator system by discretizing it into a series of lumped mass points, where the dynamics of any two adjacent mass points are described by a mass-spring-damp model to capture the flexibility and viscoelasticity. The impact from various environmental perturbations in space (including sun/earth gravitational perturbations, sun light pressure and Earth oblateness) and endoatmospheric wind disturbance are also considered, resulting in a non-uniform distribution of mass points along the tether to ensure a low computational complexity. Based on this dynamic model, different cases with a group of altitude points that tether breakage occurs (including 80km, 600km, 2000km, 8000km, 15000km, 30000km, 60000km, 90000km) are investigated via numerical simulations to study the broken tether motion. The simulations results indicate that 1) after breakage, the tether below the breaking point will fall on the ground with a fall time of over 500s; moreover, for cases with altitudes higher than 200km, the fall time is almost linearly related with the altitude that breakage occurs; 2) the distribution of falling points for different cases concludes that the motion of the tether below the breaking point no longer remains in the original orbit and thus the geocentric latitude of falling point will be deviated; furthermore, the distance between the falling point and the ground station increases first and then decreases, as the altitude that breakage occurs increases. Especially, the largest distance will reach the maximum of 296km when the tether is broken at the altitude of 8000km.