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Modern Day Space Elevators Customer Design Drivers (3)

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A LARGE-SCALE TETHER DEPLOYMENT CONTROL SCHEME FOR SPACE ELEVATOR CONSTRUCTION

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 100,000 km. Stable deployment of the huge tether is the key to the construction and operation of space elevator. Different from conventional tethered satellites, the tether deployment for space elevator has to face extremely flexible features and much complex external disturbances suffering from atmospheric effects and various space environmental perturbations due to the effects of the third celestial bodies, solar pressure and the gravity of Earth. These challenges necessitate an appropriate control scheme for the huge tether of space elevator ensuring a stable deployment in the presence of above complex disturbances. 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 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/moon gravitational perturbations, sun light pressure and Earth gravity) and atmospheric disturbance are considered, leading to a non-uniform distribution of mass points along the tether to ensure a low computational complexity. Three tether deployment schemes are then considered, comprising a unidirectional deployment with constant velocity, a bidirectional deployment with constant velocity, and a bidirectional deployment with non-constant velocity. The control algorithms for the spacecraft involved in these schemes mainly consists of a PD plus control law for position stabilization and an active disturbance rejection control law for attitude stabilization. Numerical simulations verify the effectiveness of the proposed deployment control schemes. The comparisons of simulation results indicate that 1) the unidirectional deployment strategy cost the most fuel; 2) the bi-directional deployment strategy with non-constant velocity ensures the least fuel and time consumption; 3) the proposed scheme enable to attenuate various disturbances, but requires more extra fuel cost compared with nominal cases; and 4) no matter what the scheme is, the total fuel cost for a complete tether deployment possess a huge value of at least several hundreds of tons, which requires inevitably on-orbit refueling. Finally, viewing current available carrying capacities provided by worldwide launch vehicles, a feasible refueling strategy is introduced to ensure a stable tether deployment of space elevator within 1 year.