Paper ID: 77954
oral
student

21st IAA SYMPOSIUM ON VISIONS AND STRATEGIES FOR THE FUTURE (D4)
Modern Day Space Elevators Customer Design Drivers (3)

Author: Mr. Ryo KUZUNO
Tohoku University, Japan, ryo.kuzuno.q1@dc.tohoku.ac.jp

Mr. Shuonan DONG
Tohoku University, Japan, dong.shuonan.p5@dc.tohoku.ac.jp
Mr. Yuya TAKAHASHI
Tohoku University, Japan, takaxaci@dc.tohoku.ac.jp
Dr. Keisuke Otsuka
Tohoku University, Japan, keisuke.otsuka.d6@tohoku.ac.jp
Prof. Kanjuro MAKIHARA
Tohoku University, Japan, kanjuro.makihara.e3@tohoku.ac.jp

HIGH-PRECISION MULTIBODY MODEL FOR SPACE ELEVATOR INCLUDING TORSIONAL DEFORMATION

Abstract

A space elevator is a promising technology for future space transportation. The main component of a space elevator is a tether deployed from a geostationary orbit toward the Earth and into deep space. Payloads are transported using climbers that move on the tether. However, understanding the precise dynamics of the system is a challenging task on a space elevator. The tether could have various deformations such as stretching, bending, and twisting due to the flexible nature of the tether and the low level of vibration damping in space. These deformations and motions can have a significant impact on the mission. Therefore, understanding those effects on the tether is essential for the mission design of a space elevator. It is difficult to reproduce those behaviors of space tether systems on the ground. Thus, high-fidelity numerical analysis methods are needed to analyze the dynamic response of space elevators precisely. Previously proposed analysis models of space tether systems with climbers have not argued the effect of torsional deformation of the tether; these models have only considered elongation, bending, and rigid body motion of the tether. However, a tether can be twisted easily due to its low torsional stiffness. This study adopts a nonlinear finite element method to establish high-precision numerical simulation models for space elevators that can consider large deformation that includes elongation, bending, torsion, and rigid body rotation of a tether. The analysis of a space tether system requires a lot of element divisions due to the length of the structure, which can result in a lengthy analysis time range. Therefore, it is desirable to reduce unnecessary computational costs by simplifying the model by excluding negligibly small deformations. This study developed Absolute Nodal Coordinate Formulation with 14 degrees of freedom (ANCF14) that allows efficient dynamic analysis with a few degrees of freedom using a moving frame. A moving frame is a coordinate system defined along the geometry of a curve. The torsion angle represents the deviation angle between the moving frame and the material coordinate system attached to the element. This study formulates a flexible multibody model and analyzes the motion and deformation of the space elevator that includes nonequatorial anchors. Based on the obtained results, we discuss the realistic design criteria for designing space elevators.