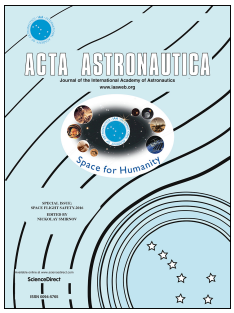
Accepted Manuscript



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PII: S0094-5765(17)30312-0

DOI: 10.1016/j.actaastro.2018.01.031

Reference: AA 6661

To appear in: *Acta Astronautica*

Received Date: 28 February 2017

Revised Date: 25 August 2017

Accepted Date: 14 January 2018

Please cite this article as: Y. Ishikawa, K. Otsuka, Y. Yamagiwa, H. Doi, Effects of ascending and descending climbers on space elevator cable dynamics, *Acta Astronautica* (2018), doi: 10.1016/j.actaastro.2018.01.031.

67th International Astronautical Congress (IAC), Guadalajara, Mexico, 26-30 September 2016.

IAC-16-D4,3,2

Effects of Ascending and Descending Climbers on Space Elevator Cable Dynamics

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Abstract

Based on a mass-point model, the cable dynamics of a space elevator during a climber's travel motion are examined. The cable response during a single operation of one ascending or descending climber is analyzed first, and then, based on the results, the cable dynamics for simultaneous operation of an ascending and a descending climber are evaluated. For the single operation, bending is significant when the climber is traveling near the Earth's surface. The cable also inclines with periodic oscillation as a result of a Coriolis force corresponding to the climber velocity. However, simultaneous operation of ascending and descending climbers can suppress the inclination of the cable by almost a factor of ten. In simultaneous operation, compared to single operation, a descending climber has a smaller amplitude of libration angle and less cable bending, while an ascending climber has a smaller amplitude when the climber is traveling at a higher altitude with climber velocities of 200 km/h and 400 km/h. The phase of the oscillation of the overall cable is found to be close to that of the descending climber. Cable bending is suppressed for any examined climber velocity, but the dependency of this suppression of displacement on climber velocity is not found. In summary, simultaneous operation can surely suppress the inclination of the cable via the cancellation of Coriolis forces by the two climbers.

Keywords: space elevator, cable, climber, dynamics, libration, simultaneous operation.

1. Introduction

The effects of traveling climbers on the cable dynamics of space elevators have been studied in detail by Lang [1-5], who used a discrete mass-point system to examine oscillating behavior of the cable. Lang studied the oscillation mode of the cable, stress, and tension during the movement of climbers, and cable response during gusty environmental conditions, such as hurricanes. Cohen and Misra [6] also researched cable dynamics by adopting a rigid-body model and formulated theoretical equations for cable oscillation when climbers ascend and descend and examined countermeasures against oscillation caused by multiple climbers.

Here, we examine in detail the cable response characteristics during the travel motion of climbers using Lang's discrete mass-point model. Based on the equations of motion that we have formulated, the cable response during the motion of a single ascending or descending climber, or the effects of climber velocity and mass on cable displacement and oscillation, are evaluated. In addition, based on the results for single climber operation, the cable dynamics during simultaneous (dual) operation of an ascending and a descending climber are analyzed.

2. Analytical method

In this study, a space elevator cable is considered as a combination of divided elements, for which the equation of motion is numerically solved to analyze the movement of the cable. The analytical model is the same as the one developed by Tao et al. [7] for simultaneous deployment of the cables from GEO Station at the space elevator construction.

2.1 Cable model

The numerical model of the cable is shown in Fig. 2-1. A rotating system of coordinates that rotates with the Earth's angular velocity, ω, is adopted, with the origin being located at the center of the Earth. The cable is divided into a number of elements $N = 925$, each of which is composed of a spring of natural length $l_0 = 100$ km and a mass of $m_i = \rho A_i l_o$, where ρ is the cable density and A_i is a cross section of the ith element.