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Space Elevator Critical Technology Verification and Validation Testing (3)

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SPACE ELEVATOR CABLE'S OSCILLATION CAUSED IN SPACE THERMAL ENVIRONMENT

Abstract

Severe space environment influences a space elevator cable to make it move and oscillate, which is a focus of this study. In space thermal environment, the cable absorbs solar radiation, exchanges infrared heat with space and the earth atmosphere, exchanges sensible heat with the earth atmosphere, and conducts heat in the cable itself. Assuming that the cable is 96,000 km long with tensile stress up to 65 GPa and density of 1300 kg/m3 which corresponds to the Obayashi Corporation Space Elevator Model, we have numerically solved the three-dimensional equations of motion for the model that considered the thermal effect on the cable. It is assumed that Young's modulus depends on temperature. The results show that the cable oscillates between the east and west directions whose amplitude reaches around 40 km. The period of the oscillation is found to be 12 hours, which exactly equal to the period of thermal cycles of many thermal events in space. It is concluded that the oscillation is caused by the periodical temperature change which longitudinally expands and contracts the cable, creating Coriolis force that then forcibly oscillates it. From the engineering point of view, resonance where the natural frequency (eigenfrequency) coincides with that of the temperature change, should be avoided. The natural frequency of the cable with the length of 96,000 km and tensile stress of 65 GPa is calculated to be 1.6 day-1, which is equivalent to 0.62 days in period. Since the period of the temperature change is 0.5 days, resonance might occur. This leads to the conclusion that to avoid resonance in a design stage we should increase the length of the cable or lower the tensile stress to lower the natural frequency of the cable away from the frequency of the temperature change, 2 day-1; or vice versa.