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LUNAR SKYLIFT: CABLE OSCILLATIONS AND THEIR TREATMENT

Abstract

The lunar elevator concept is a long cable loaded under tension by terrestrial and lunar gravity, with one end anchored on the Moon and the other end free. Such a cable can now be built inexpensively and greatly reduces cislunar transportation costs. A car rolling along the cable expereinces Coriolis force, which excites transverse waves in the cable. This effect has not been studied to date. The wave propagation speed puts a fundamental limit on the car velocity. As in aerodynamics, a sufficiently high speed results in a shock wave in front of the car and eventually rupture of the cable. Even Mach ¡ 1 may generate unacceptable wave amplitudes. Natural damping in the cable is negligibly weak, so repeated runs of the car can bring the cable to prohibitive irregular oscillations. Confining the allowed velocity to a few meters per second is not a solution because it restricts the traffic to a tiny part of the skylift's capability and yet it does not prevent the cable against the extraneous oscillations. This necessitates a technique for active suppression of oscillations. There are few ways to influence the transverse vibrations. The simplest solution is rocket propulsion. A rocket mounted on the car allows easy compensation of its Coriolis acceleration, aC; thus preventing excitation. For Magellan M5 fiber, aC = 1 mm/s2 at Mach =0.5, so a low thrust system with high specific impulse will suffice. However, the total characteristic velocity necessary to compensate Coriolis during a one-way run is 0.5 km/s. It may be too much for regular operation. Other possible solutions are movement of the lower part of the cable in east-west direction, controllable variation of Coriolis force by variation of car velocity a combination of the previous two. The cable is a system with infinite DOF, so synthesis of the control laws is non-trivial. Two methods are used: finite-DOF approximations (e.g. eigenmode decomposition), and the method of Lyapunov's functions, which does not distinguish between the cases of finite and infinite DOF. Along with the semi-analytical study based on eigenmode analysis, a numerical algorithm using finite elements was developed and extensively exercised to test the quality of the proposed control laws.