The Journal of the Astronautical Sciences, Vol. 42, No. 3, July-September 1994, pp. 301–318

Effects of Aerodynamic Lift on the Stability of Tethered Satellite Systems[1]

M. Keshmiri,[2] A. K. Misra,[3] and V. J. Modi[4]

Abstract

Dynamics and stability of a two-body tethered system are investigated considering the aerodynamic lift on the subsatellite in addition to the aerodynamic drag. The *free molecular flow model* is used to calculate the aerodynamic forces on the subsatellite. Equilibrium configurations of the system are obtained numerically. Equations of motion are linearized analytically about the equilibrium configuration through a symbolic manipulation language, Maple V, and stability behavior of small oscillations about the equilibrium configuration is analyzed. An extensive parametric study is done to understand the effect of aerodynamic forces (lift and drag) on the stability of the uncontrolled system. It is shown that the stability behavior changes significantly if the subsatellite is changed from a body with no lift to a body with lift. Hence, an unstable system with a spherical subsatellite can be stabilized if appropriate aerodynamic surfaces are added. It is concluded that consideration of the aerodynamic lift in addition to the aerodynamic drag on the subsatellite is indispensable for proper design of a tethered subsatellite system deployed in a low altitude orbit.

Introduction

The vast potential of tethered satellite systems (TSS) has led to many investigations on their dynamics and control [1]. Typical operation of a TSS involves the deployment of a subsatellite to the desired altitude, followed by the station-keeping phase, and subsequent retrieval of the subsatellite. Normally the station-keeping phase is stable (at least, marginally stable) and the effects of the aerodynamic forces have been presumed to provide damping and hence enhance the stability. However, Beletskii and Levin [2] have stated that in-plane swinging motion can become unstable due to the combined effects of air drag gradient, attitude motion, and elasticity of the tether, but gave no details. Onada and Watanabe [3, 4] studied

[1]Presented at the AIAA/AAS Spaceflight Mechanics Meeting, Pasadena, California, February, 1993.
[2]Graduate Student, Department of Mechanical Engineering, McGill University, Montreal, Canada H3A 2K6.
[3]Professor, Department of Mechanical Engineering, McGill University, Montreal, Canada H3A 2K6.
[4]Professor, Mechanical Engineering Department, University of British Columbia, Vancouver, Canada V6T 1Z4.