ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics (1) (3)

Author: Mr. Andreas Borggräfe
University of Strathclyde, United Kingdom

Dr. Jeannette Heiligers
University of Strathclyde, United Kingdom
Dr. Matteo Ceriotti
University of Glasgow, United Kingdom
Prof. Colin R. McInnes
University of Strathclyde, United Kingdom

ATTITUDE CONTROL OF LARGE GOSSAMER SPACECRAFT USING SURFACE REFLECTIVITY MODULATION

Abstract

Gossamer spacecraft are essentially spacecraft which deploy large, thin membranes. This type of spacecraft achieves very low mass and small stowage volume and thus enables various space-based applications such as scientific telescopes, solar power collection, communication antennas and solar sails. Since the on-board attitude control systems of such spacecraft need to be high-performing, lightweight and reliable, this work investigates the attitude dynamics of such large structure, and in particular the use of thin-film reflectivity control devices across the membrane surface for attitude control.

These coating elements consist of an electro-active material that changes its reflectivity according to an applied electric potential to modify the surface reflectivity, which modulates the solar radiation pressure acting on the surface. Consequently, the total force and torque acting on the structure can be controlled 'optically' without using additional mechanical systems or thrusters. Therefore, this concept of optical attitude control may contribute to reduce the overall system mass and therefore reducing launch costs.

The membrane is modelled using discrete reflectivity elements (as in a dot matrix) across the surface of the membrane, which is ideally assumed to be flat and rigid. The elements can maintain two states: either high (power on) or low reflectivity (power off) and are varied in number and surface position during the analysis. The aim is towards finding the optimal reflectivity pattern in terms of number, position and activation state of the coating elements to create a required control torque.

The control problem is addressed under consideration that the system is underactuated, since through the concept of surface reflectivity modulation presented here, torques can be created only in the membrane plane. Further, the two in-plane torque components both depend on the distribution and activation state of the coating elements simultaneously, thus they cannot be controlled independently. In addition, also the available torque magnitude decreases with increasing cone angle, which is the light-incidence angle between the Sun-membrane line and the surface normal. Therefore, the torque magnitudes vary with changing spacecraft attitude, and this constitutes a challenging attitude control problem.

Consequently, the available in-plane torque directions and magnitudes are derived first, as a function of number, position and activation state of the coating elements as free control parameters. Secondly, a nonlinear control framework for manoeuvring the spacecraft is established, taking into account that the proposed optical attitude controller can deliver a control torque with two components only for controlling three rotational degrees of freedom.