Euromech Colloquium n. 541 - New Advances in the Nonlinear Dynamics and Control of Composites for Smart Engineering Design - Senigallia, Italy, 3-6 June 2013

Optimal control of the deployment and retrieval of a tethered satellite under small disturbances

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We investigate the time-optimal deployment and retrieval of a tethered satellite. In previous investigations ([1,2]) we assumed, that the space station moves on a circular orbit and that the motion of the sub-satellite is restricted to the orbital plane. In this talk we consider the stabilization of the planar configuration and we also consider the case, that the orbit of the main station moves on an elliptic orbit with small eccentricity. For both cases we assume for simplicity, that the motion of the sub-satellite does not influence the orbit of the main station and that the mass of the tether can be completely neglected. The control of the motion is performed by pulling at one end of the tether.

We first study the simultaneous controllability of the in-plane and out-of-plane deviations from the straight down-hanging equilibrium by the intended control. While for the planar motion the variation of the tether's length acts like an external excitation, which can be used to steer the satellite into the desired position in finite time, it acts similarly to a parametric excitation for the out-of-plane disturbances. Therefore the control can at best be used to force the out-of-plane oscillations to decay algebraically slowly. The main obstacle for the stabilization of the radial position is the simultaneous control of both motions by applying the tension force as single control variable.

Second we consider the case, that the orbit of the main station is not perfectly circular. In this case the preferred steady motion of the sub-satellite is periodic with small amplitude close to the vertical position. We search the time-optimal transfer of a sub-satellite on a periodic solution to another periodic solution with a different tether length.

For this task we expect a bang-bang control with a number of switching points, which depends on the ratio of the initial and final tether length. For small eccentricity this solution should be close to that for the circular orbit of the main station. The solutions are obtained numerically ([3]) by solving a boundary value problem for the Hamiltonian differential equations derived by Pontryagin's Maximum Principle.

[1] A. Steindl, H. Troger, Optimal control of deployment of a tethered subsatellite, *Nonlinear Dyn.*, 31 (2003) 257-274.

[2] B. Barkow, A. Steindl, H. Troger, G. Wiedermann, Various methods of controlling the deployment of a tethered satellite, *J. Vib. Control*, 9 (2003) 187-208.

[3] H.J. Oberle, W. Grimm, E. Berger. *BNDSCO. Rechenprogramm zur Lösung Beschränkter Optimaler Steuerungsprobleme. Benutzeranleitung* M 8509, Techn. Univ. München, 1985.