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PROPELLANT–FREE STATION KEEPING DESIGN OF A SOLAR SAIL AROUND THE SUN–EARTH COLLINEAR EQUILIBRIUM POINTS

Abstract

This paper investigates the design of propellant–free station-keeping maneuvers for a solar sail spacecraft moving around the Sun–Earth collinear equilibrium points. Due to the unstable character of the libration point orbits, as well as the errors in the execution of maneuvers, the spacecraft will gradually move away from a reference libration orbit, so a station–keeping control is required for this kind of missions. There are mainly two kinds of station–keeping strategies: the first one requires the definition of a nominal orbit, according to the mission requirements, and when the spacecraft deviates from it perform a control maneuver to pull it back into the nominal orbit (within a certain tolerance); the second strategy only requires the spacecraft to follow quasi-periodic orbits within a certain region around the libration point. The paper is mainly based on this second strategy.

The dynamical model used is the Sun–Earth restricted three-body problem, including solar radiation pressure written as a perturbation and depending on three solar sail parameters: the reflectivity, the cone angle, and the clock angle of the sail with respect to the Sun. In the libration zone, solar sail maneuvers performed changing the values of the sail parameters can be seen as "jumps" in position instead of in velocity. This is due to the fact that changing the sail parameters the position of the libration point changes; in this way, keeping a reference frame centered at the equilibrium, the relative position of the spacecraft with respect to the origin changes with the solar sail maneuver. The paper uses this fact to systematically analize the impact of a maneuver (instantaneous sail reorientation) on a spacecraft moving along a libration point Lissajous orbit.

The station keeping procedure designed performs a maneuver periodically to prevent the sapcecraft to escape from a certain Lissajous orbit following its unstable manifold. The maneuver is computed in order to cancel the unstable component of the state and it is assumed that there is a random error in the execution of the maneuver. Performing the maneuvers every month, it is shown that the spacecraft can remains near the artifial libration points for, at least, 5 years, which shows that this multiple impulse design of the station keeping control by means of sail reorientations can be effective.