Spacecraft Relative Dynamics and Control Using Geomagnetic Lorentz Force

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In this thesis, we investigated dynamics and control aspects of a charged satellite using the Lorentz force. The concept of the Lorentz-augmented charged satellite realizes propellant-less electromagnetic propulsion, using the interaction between an electro-statically charged satellite and the Earth's magnetic field. Charging of satellites can be controlled by devices like ion or electron gun. The devices are smaller and lighter than conventional chemical thrusters and suitable to be carried by small-size satellites.

We investigated relative dynamics of two satellites orbiting around the Earth. One is a non-charged satellite called a target satellite, and the other is a charged satellite located near the target satellite on a circular orbit. We study the effect of the Lorentz force on the relative motion of the chaser satellite with respect to the target satellite on an elliptic orbit or on a circular orbit as a special case. We consider the general elliptic reference orbit for the target satellite using a tilted dipole Earth magnetic field. We derive the equations of the relative motion based on the Tschauner-Hempel equations. The circular orbit case can be given by substituting the condition of the circular orbit based on the Clohessy-Wiltshire equations.

Next, we investigated the conditions for transfer between two arbitrary positions using linearized equations when the target satellite lies in the plane of the Earth equator as a reference case. We derived the relation between the periodic orbit conditions of the chaser satellite. The condition for realizing transfer trajectory of the chaser satellites was also provided. Moreover, it was found that, if the inclination of the target satellite orbit is non-zero, the chaser satellite is able to move between any two positions on the target satellite's orbital plane.

Finally, by introducing a non-linear optimization method, called sequential quadratic programming method, we examined the possibility to control the chaser satellite position, when the target satellite orbit has non-zero inclination in the tilted dipole magnetic field moving on an elliptical Earth orbit, and various orbits were successfully proposed by controlling the charge of the chaser satellite.

References

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