Minimum Time Orbit Raising of Geostationary Spacecraft by Optimizing Feedback Gain of Steering-law

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Keyword : Orbit raising, geostationary orbit, low propulsion thruster, optimal control

In recent years, low propulsion thruster such as ion-thruster or hall thruster is becoming a hopeful propulsion system for a spacecraft transferring from a low earth orbit (LEO), a geostationary transfer orbit (GTO), or a supersynchronous orbit (SSTO) to a geostationary orbit (GEO). Conventionally, geostationary spacecraft is just putted in the GTO by a launcher and in order to complete the orbit transfer, the spacecraft employs an on-board high chemical propulsion thruster called apogee kick motor at the apogee of GTO so that the orbit semi-major axis, eccentricity, and inclination correspond with those of GEO. Although GEO insertion by the chemical propulsion thruster completes in a short period of time (less than one week), low specific impulse of the thruster results in much fuel consumption (almost half of the wet mass is occupied by the fuel). In order to overcome this disadvantage, a spiral orbit raising by the low propulsion electric thruster, which has almost ten times larger specific impulse than the chemical propulsion, is getting a lot of attention as an alternative transfer orbit. In case of the spiral orbit raising, it takes several months to complete the orbit transfer but it can save a lot of fuel.
In this study, the minimum time orbit transfer problem by the low propulsion thrusters is considered. This problem is equivalent to how to determine appropriate thrust directions during the orbit raising. This study proposes a feedback-like thruster steering law that determines the thrust directions based of the difference between the current orbital elements and the target ones (i.e. those of GEO). In detail, the feedback gains of the steering law are assumed to be the functions of orbital elements, and they are optimized by the meta-heuristic method such as particle swarm optimization. As an independent variable for expressing the gains, the orbital semi-major axis, eccentricity, and inclination are considered. Numerical simulations show that whatever orbital elements of these are selected for the independent variable, the same performances are obtained as shown in Table 1 and Fig. 1. This guarantees that regardless of the initial orbital elements, by selecting the independent variable appropriately, the minimum time orbit transfer problem can always be solved by the proposed method.

Table 1. Comparison of transfer time

Initial Orbit	Independent Variable		
	semi-major axis	eccentricity	inclination
GTO	99.20day	99.36day	99.12day
SSTO	101.44day	101.28day	101.36day

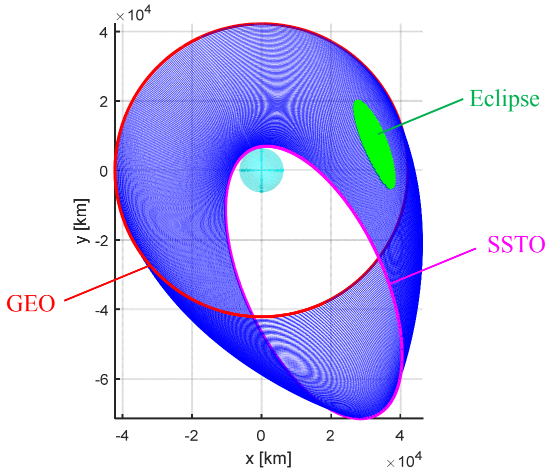

Fig. 1. Minimum time transfer orbit from SSTO to GEO