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OPTIMAL CONTROL OF SPACECRAFT WITH AN AIR-BREATHING ELECTRIC PROPULSION IN ULTRA-LOW ORBITS

Abstract

As previous studies have shown, to ensure the long-term existence of spacecraft (SC) with air-breathing electric propulsion (ABEP) in ultra-low orbits (ULO) with a perigee altitude of 120-250 km, elliptical orbits are preferable compared circular ones in conditions of energy shortages due to the possibility of using in areas with a high atmosphere density the energy, accumulated during the SC flight at high altitudes. In this case the problem of the ABEP thrust control is to compensate for the influence of aerodynamic drag not only during the ABEP operation, but also in sections of passive SC flight, taking into account the following factors:

- the gas concentration in the ionization chamber must be sufficient for the ABEP operation,
- increasing the area of solar arrays (SA) to provide the required power to create the ABEP thrust leads to an increase in aerodynamic drag,
- with an increase in the angle between the longitudinal axis of the air intake and the speed of the oncoming flow (angle of attack), the ABEP efficiency decreases,
- the influence of the Earth's nonsphericity increases on ULO.

Solving the problem of ABEP thrust control in view of listed above factors is proposed in the basis of the Pontryagin maximum principle for a dynamic model of osculating orbital elements with the ABEP thrust control due to an optimal change in the exhaust velocity (the Problem I) or at a constant exhaust velocity with optimal placement of active sections on the SC trajectory (the Problem II) with minimizing the energy consumed to create ABEP thrust.

To define the ABEP thrust control in Problem II, an analytical synthesis was developed, with the use of which a parametric study was carried out on the possibility of compensating the SC drag with the ABEP thrust for a wide range of orbital parameters and solar illumination conditions in contrast to previous works, which considered the SC with ABEP motion in the most favorable conditions: in sun-synchronous orbits in the terminator plane. The ranges of parameters of such orbits, configurations of SC with SB and ABEP, for which a long-term SC flight can be ensured, have been obtained.