IAF ASTRODYNAMICS SYMPOSIUM (C1)
Interactive Presentations - IAF ASTRODYNAMICS SYMPOSIUM (IP)

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THE THRUST VECTOR CONTROL OPTIMIZATION OF THE AIR-BREATHING ELECTRIC PROPULSION TO MAINTAIN SPACECRAFT IN ULTRA-LOW ORBITS

Abstract

The development of ultra-low (150-250 km) altitudes to improve the efficiency of applied tasks (communications, remote sensing, etc.) requires the solution of a number of problems related primarily to the significant impact of increased aerodynamic forces on the motion of spacecraft (SC). The compensation of such perturbations by the thrust of the existing engines will lead to an exponential increase in the propellant mass, which will limit the SC active lifetime. The factor limiting the SC lifetime at these altitudes is also the power of the energy sources (ES) (solar and storage batteries) used to create thrust, an increase in which to compensate for the increasing aerodynamic drag will lead to its additional enlargement and to an appropriate growth in the required thrust.

One of the ways to ensure the long-term SC existence at ultra-low altitudes is the use of an air-breathing electric propulsion (ABEP), which uses the gases of the surrounding atmosphere as a propellant. The efficiency of such engines significantly depends on the angle of attack due to changes in the gas flow through the air intake and a drop in the relative gases' concentration in the ionization chamber (IC).

The optimization of the ABEP thrust vector control, taking into account the dependence of thrust and aerodynamic drag on the SC angle of attack and the restriction on the minimum allowable level of gases' concentration in the IC under conditions of limited ES power, made it possible to determine the existence areas of SC with ABEP in the space of parameters of the orbit, SC and ES.

The problem solution is based on the use of osculating orbital elements and the Pontryagin maximum principle, taking into account the smallness of aerodynamic drag and thrust accelerations. The developed models of thrust and aerodynamic drag were verified by comparison with experimental data.

Estimates of the effectiveness of optimal control programs for the ABEP thrust vector depending on: perigee and apogee altitudes, ABEP specific impulse, SC layout parameters, and ES power, are obtained. In particular, it has been shown that the use of elliptical orbits in conditions of limited energy makes it possible to significantly increase the existence region of SC with ABEP at the expense of the energy accumulated during the passive SC flight.