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COMPARATIVE ANALYSIS OF SPACECRAFT INSERTION PROFILES TO THE MARS SATELLITE ORBITS

Abstract

One of the most effective ways to explore Mars and other planets of the Solar system along with the use of a descent probe is the use of orbital spacecraft. The goal of the present work is comparative analysis of the known and prospective insertion profiles of spacecraft into the orbits of Mars artificial satellite. Different modifications of combined profiles are researched including all-propulsive maneuvers in conjunction with aerodynamic deceleration of a spacecraft in the atmosphere as well as the profile consisting in propulsive orbit shaping. The minimum of total power consumption and the maximum of physically realizable spacecraft reentry corridors are considered as the main evaluation criteria of the alternative profiles. The tasks of spacecraft optimal control are solved with the use of necessary optimality conditions of Pontryagin's maximum principle. The new methods of accelerated calculation of spacecraft optimal trajectories are developed on its basis including transformation of initial systems of differential equations. The formulae for determination of control functions and trajectory parameters of spacecraft flight are obtained as a result. The areas of rational application of profiles are detected with the preliminary aerodynamic deceleration of a spacecraft in the atmosphere and accelerating burns in the apocentre of a transfer orbit, shared control by aerodynamic and propulsive forces in the atmosphere, multiple passage of Mars upper atmosphere by a spacecraft. It is shown that the use of a combined profile for shaping orbits with atmospheric maneuvering is high efficient as the power consumption with its use is 3-3.5 times less in comparison with the propulsive profiles. It is determined that during spacecraft reentry near the lower bound of the corridor it is reasonable to conduct propulsive trajectory correction maneuver. It allows reducing 1.5-2 times total required energy consumption or expanding of physically realizable reentry corridor by 10-15% in comparison with the profile without a correction burn. The energy consumption can be more considerably reduced for the profile with a spacecraft multiple passage of upper atmosphere. However the time for satellite orbit shaping considerably increases with the use of the given profile. The obtained results are of practical importance and may be used for deep space

missions such as “Expedition-M”, “Mars-Surveyor”, “Mars Science Orbiter”, “Hundred Year Starship”. The general principles of the methodological approach are adjusted for the solution of other tasks of spacecraft optimal control.