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TRAJECTORIES WITH MULTIPLE ATMOSPHERE RE-ENTRIES AND ANISOTROPIC HEAT-SHIELDING MATERIALS: ANALYSIS OF IMPACT ON THE TEMPERATURE REDUCTION ON THE SURFACE OF A RE-ENTRY MODULE

Abstract

A feature of the spacecraft return trajectory from the Moon's orbit is the proximity of the speed of its entry into the Earth's atmosphere to the parabolic one. This fact, due to very high convective and significant radiative heat flows, results in an increase in the temperature on the surface of the re-entry module (the recovery module). If the temperature exceeds the permissible values for the heat-barrier coating material, this will lead to the destruction of such material, which greatly complicates the task of creating and operating such modules.

One of the possible ways to reduce the thermal exposure intensity is related to multiple atmosphere re-entries of the re-entry module into the dense layers of the Earth's atmosphere. With this approach, the orbit after the first entry into the atmosphere represents an ellipse whose apogee is lowered rapidly during new entries into the atmosphere. The results of a preliminary analysis showed that, due to a rational choice of the perigee of the spacecraft's flight trajectory to the Earth, we can obtain acceptable apogee values of the elliptical orbit, where it is possible to carry out the subsequent descent to the Earth's surface with significantly lower entry speeds into the dense atmosphere and, accordingly, a lower surface heating.

In addition, it is appropriate to consider the possibility of using anisotropic coating material that features a significantly higher thermal conductivity factor in the tangential direction to the coating surface, as compared with the thermal conductivity factor in the direction normal to this surface. The use of anisotropic material can reduce the surface temperature in the area of the maximum heat flow density by redistributing the thermal energy in the heat-shielding coating in the tangential direction.

It follows from our calculations that, during the first entry of the re-entries module into the Earth's atmosphere, it is possible to choose a trajectory where the heat transfer intensity on the coating surface does not significantly exceed the permissible value. In this case, the use of modern anisotropic and promising heat-shielding composite materials can limit their heating to a level that does not results in their thermal destruction, whereas intermediate extra-atmospheric sections of the trajectory allow, through thermal radiation, to significantly cool the heat-shielding coating prior to the next entry.