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Author: Dr. Victor Leonov
Bauman Moscow State Technical University, Russian Federation, lv@bmstu.ru

Prof. Vladimir Zarubin
Bauman Moscow State Technical University, Russian Federation, zarubin_vs@mail.ru
Mr. Vladimir Zarubin
Bauman Moscow State Technical University, Russian Federation, vszarubin@gmail.com

ANISOTROPIC HEAT-SHIELDING MATERIALS: PROSPECTS FOR APLICATION IN THE RE-ENTRY MODULE HEAT SHIELD

Abstract

When a hypersonic flow passes around the surface of the hemispherical blunt-nosed cone of the heat shield of a reentry module, between the front of the detached head shock wave and the streamlined surface, a so-called shock layer is generated with rather high values of air pressure and temperature, which results in an intense convective and radiative heat transfer on the blunting surface. With an axisymmetric flow around the blunt-nosed cone and preservation of the laminar mode on its entire surface, the heat flow density is maximum at the front critical point, whereas in case of transition from the laminar mode to the turbulent one, the change in heat transfer intensity along the generatrix of the blunting surface is generally non-monotonous, and the heat flow density at the front critical point may not be the highest one.

The low thermal conductivity factor of heat-barrier coating material, due to uneven heating on the blunting surface, creates areas with a high temperature, which may exceed the permissible value for the material used. The negative effect of intense local heating on the performance of the heat-barrier coating can be reduced by using a layer of anisotropic material with a thermal conductivity along the heated surface exceeding the thermal conductivity in the direction normal to this surface. Modern methods for creating heat-barrier coatings from composite materials allow obtaining a material with a sufficiently high anisotropy of thermal conductivity. Quantitative estimates show that the use of nanostructured elements (including carbon nanotubes and graphene plates) for reinforcement allows increasing the composite anisotropy up to values of 100 order.

The paper discusses several model problems of unsteady heat transfer on the surface of the heat shield of a segmentally-conical reentry module, and assesses the effect of anisotropy on the temperature distribution over the surface and volume of the heat-barrier coating, both in the case of using single-layer and multi-layer coatings.