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RECOVERY OF INFORMATION ABOUT THE THERMAL PROTECTION OF A RE-ENTRY VEHICLE USING THE INVERSE PROBLEMS METHODOLOGY AND MACHINE LEARNING GAPPY POD

Abstract

When entering the atmosphere of the Earth, a re-entry vehicle is subject to significant non-stationary heat fluxes and extreme temperatures, and therefore they must be provided with highly reliable thermal protection. At the same time, thermal protection must not only be reliable, but also as light as possible, and sometimes reusable. Therefore, in the process of design and experimental work, it is necessary, firstly, to obtain sufficiently accurate information on heat fluxes and temperatures on the surface of descent vehicles, secondly, to correctly select the type of thermal protection system and its materials, thirdly, to carry out a sufficiently accurate calculation of this system. And, finally, to check the results of these calculations in experiments. As is known, research methods based on solving inverse problems of generalized heat conductivity (IPHC) are of great benefit in resolving these problematic issues. But such problems are usually solved only in relation to a few points on the surface and inside the thermal protection material. This means that in the case of flight or stand tests; to identify sufficiently complete information about the unsteady heat flux and temperature over the entire surface of the thermal protection system (TPS) of both destructible and non-destructible types along the entire descent trajectory, it is necessary to preliminarily install as many thermal sensors (TS) as possible in the TPS undergoing testing. All this complicates the preparation for testing. Thus, to solve the problem of restoring thermal information over the entire surface of the TPS of the re-entry vehicle during its re-entry, a new approach is proposed. This approach is based on solving the boundary IPHC in combination with machine learning algorithm—Gappy POD. The approach is implemented in two steps. First, a one-dimensional boundary IPHC is solved for a relatively small number of tiles equipped with internal TS. After that, the temperature and heat flux distribution over the entire surface is reconstructed using the Gappy POD algorithm, based on the known temperatures and heat fluxes obtained from solving the inverse problem in the first step for the locations with TS. In this study, all investigations were conducted for the bottom or the wind-ward side of the re-entry vehicle, consisting of multiple reusable thermal protection tiles. Finally, the results show that the new approach is quite successful in reconstructing thermal information on the TPS surface. Additionally, the number of thermal sensors required is also significantly reduced.