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MATHEMATICAL MODELING OF THIN ABLATING THERMAL PROTECTION COVERING

Abstract

The problem of thermal protection of different technical systems undergoing by extremely intensive thermal action belongs to the most important problems of thermal physics. Nevertheless the considered problem was known during practically all history of technologies since the industrial revolution, this problem attracted real attention only when the particular problem of thermal protection of re-entry space vehicles was arose. Active thermal protection systems were developed as the most effective relatively short-time thermal barrier for the last case. The quite simple main idea of active thermal protection supposes to use latent heat of phase transitions of thermal protection layer for compensation of external thermal flux. Existing mathematical models of active thermal protection systems are too simplified and cannot be used for complete calculations of them. The aim of the present work is to develop an alternative mathematical model, which can provide effective calculations of the relevant problems. The well-known asymptotic mathematical model of temperature field in thin layer is used as a base for developed approach. According to the mentioned model of thin layer, the is constructed as a series with respect to small parameter equal to ratio of reference scales of the thin layer (thickness) and the protected body. The evident advantage of the thin layer model is opportunity to calculate a temperature field in the protected body, what was extremely difficult for usual models of thermal protection. As a result, the solution for the active thermal protection layer is reduced to two series of boundary-value problems for ordinary differential equations for two different phase layers, correspondingly, with moving outer and interphase boundaries. Moving boundary propagations are described by Cauchy problems for first order ordinary differential equations like usual Stefan problem. It is necessary to note that for complex composite materials of the protective layer three-layer mathematical model usually arise, but it will be object for next investigations. The obtained boundary-value problems for ordinary differential equations can be solved analytically or numerically. Together with some computational algorithm for calculation of temperature field in protected body the obtained asymptotic model provide a very effective computational scheme. The proposed approach is illustrated by several examples of numerical calculations of active thermal protections of bodies with different shapes and properties under extreme thermal actions.