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FLOW-STRUCTURE-THERMAL INVESTIGATION OF BLUNT BODY IN HIGH-ENTHALPY FLOWS

Abstract

Design of TPS for hypersonic vehicles depends on accurate prediction of the structural temperatures. Significant coupling occurs between the aerodynamic flow field and structural heat transfer. A finite element approach is proposed to investigate the flow-structure-thermal interaction of blunt body in high-entropy flows based on a loose coupling algorithm. Nonlinear radiative-conductive heat transfer equations for the blunt body are solved in the commercial software ANSYS by iteratively modifying the thermal loads on the assumption that when the surface temperatures vary, the Newton heat transfer coefficient remains constant and the flow field is quasi-steady. The case employed in this paper was operated in an arc wind tunnel, and the blunt body experienced three stages in the arc wind tunnel in 72 seconds. In this case, the high-entropy inflows are steady, and it can be supposed that the flow field around the blunt body is quasi-steady. Thus, while the temperatures of the surface increase significantly in the high-entropy flows, the thermal loads decrease drastically, and they can be modified iteratively during the numerical process. The heat fluxes of the blunt body surfaces as the initial boundary conditions are obtained from the experimental measurements. 2-D and 3-D finite element models are employed to simulate the test, and changing the value of iteratively time step and the Newton heat transfer equation are applied to observe the differences. The obtained results show that the 2-D modified numerical temperatures are in good agreement with the experimental measurements compared with the 3-D modified and 2-D non-modified numerical results. The temperatures of the measured points increase to more than 900k at the end of the test, while the 2-D non-modified numerical results increase to 1700k in the first 40 seconds, and the relative error is more than 180% at the maximum point. The relative errors of the 2-D modified results rise up to 30% in the beginning, and then fall to 1% at last. The effects of the value of iteratively time step for numerical results are slight.The proposed approach offers a convenient and effective way to solve the similar problems, and can be used in the preliminary engineering designs.