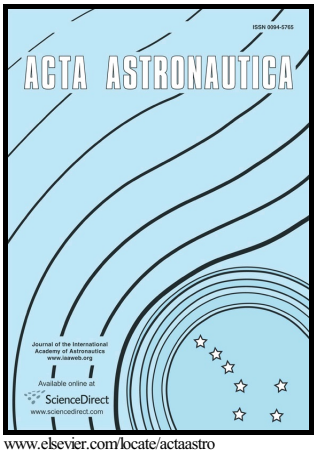

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Abstract

The inflatable aerodynamic decelerator (IAD), which allows heavier and larger payloads and offers flexibility in landing site selection at higher altitudes, possesses potential superiority in next generation space transport system. However, due to the flexibilities of material and structure assembly, IAD inevitably experiences surface deformation during atmospheric entry, which in turn alters the flowfield around the vehicle and leads to the variations of aerodynamics and aerothermodynamics. In the current study, the effect of the static shape deformation on the hypersonic aerodynamics and aerothermodynamics of a stacked tori Hypersonic Inflatable Aerodynamic Decelerator (HIAD) is demonstrated and analyzed in detail by solving compressible Navier-Stokes equations with Menter's shear stress transport (SST) turbulence model. The deformed shape is obtained by structural modeling in the presence of maximum aerodynamic pressure during entry. The numerical results show that the undulating shape deformation makes significant difference to flow structure. In particular, the more curved outboard forebody surface results in local flow separations and reattachments in valleys, which consequently yields remarkable fluctuations of surface conditions with pressure rising in valleys yet dropping on crests while shear stress and heat flux falling in valleys yet rising on crests. Accordingly, compared with the initial (undeformed) shape, the corresponding differences of surface conditions get more striking outboard, with maximum augmentations of 379 pa, 2224 pa, and 19.0 W/cm^2, i.e., 9.8%, 305.9%, and 101.6% for the pressure, shear stress and heat flux respectively. Moreover, it is found that, with the increase of angle of attack, the aerodynamic characters and surface heating vary and the aeroheating disparities are evident between the deformed and initial shape. For the deformable HIAD model investigated in this study, the more intense surface conditions and changed flight aerodynamics are revealed, which is critical for the selection of structure material and design of flight control system.

Keywords: inflatable aerodynamic decelerator; deformation; aerodynamics; aerothermodynamics; hypersonic

1. Introduction

When performing space transport missions, a vehicle deorbiting at ultrahigh speeds is strongly dependent on the aerodynamic deceleration in the atmospheric entry phase. While the vehicle attains substantial aerodynamic drag for deceleration, it also encounters severe heating from the planetary atmosphere, which leads to fairly heavy metal heat