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基于边界层转捩的高超声速进气道特性研究

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Study of Flow Characteristics of Hypersonic Inlet Based on Boundary Layer Transition

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摘要 为了探索边界层非强迫转捩对进气道性能的影响,采用数值计算的方法开展了边界层转捩对轴对称混压式高超声速进气道流场特性的研究。研究表明:随着进气道中心锥锥尖钝化半径增大,边界层转捩先推迟。当锥尖钝度大到一定程度时,边界层转捩位置前移。随着钝化半径进一步增大,边界层转捩再次推迟,转捩位置逐渐后移。来流湍流度越大,边界层越不稳定,边界层转捩越易发生。与湍流边界层相比,考虑边界层转捩时进气道的总压恢复系数及流量系数较高、热载荷及阻力系数较小,*Ma*=6.5时喉道处总压恢复系数最高上升17.3%,进气道阻力最大下降17.4%。边界层转捩对壁面热流密度分布影响较大,但对壁面压力分布影响较小。钝化影响进气道的自起动性能,随着钝化半径增大,自起动马赫数升高,而边界层转捩对进气道自起动性能影响较小。

关键词： 转捩 边界层 进气道 高超声速 推进系统

Abstract： In order to understand the influence of unforced boundary layer transition on the performance of a hypersonic inlet, a numerical study is performed in this paper. The results show that the bluntness of the leading edge of the inlet influences the boundary layer transition. The boundary layer transition is delayed first when the nose of the cone is blunted, and then the transition location moves upstream once the blunt radius is large enough, but eventually the boundary layer transition is delayed again when the blunt radius becomes larger. The turbulence intensity, which induces the boundary layer to become more instable, influences the boundary layer transition greatly. Compared with the turbulence boundary layer, an inlet can obtain higher total pressure recovery and capture more mass flow rate with lower thermal load and drag when the boundary layer transition occurs at the compression surface. Compared with the turbulence boundary layer, the total pressure recovery at the throat increases by 17.3% and the drag of the inlet decreases by 17.4% when the boundary layer transition occurs at *Ma*=6.5. The boundary layer condition influences the distribution of heat flux greatly but has little influence on the pressure distribution along the wall. The blunt radius of the nose influences the self-starting ability of the inlet, and the self-starting Mach number becomes larger when the blunt radius increases, but the boundary layer transition almost has no influence on the self-starting ability.

Keywords： transition boundary layers inlet hypersonic propulsion system

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