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新型一体化热防护系统热力分析与试验研究

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Thermal-mechanical Analysis and Test Study of a New Integrated Thermal Protection System

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摘要

高速飞行器对结构效率的苛刻要求使得热防护系统不断趋于向轻质化、集成化方向发展,新型的力热耦合一体化热防护系统(ITPS)极具发展潜力。首先阐释了一种新型一体化热防护方案的概念与特点,总结了一体化结构设计的基本原则,数值分析了结构参数对背面温度响应、屈曲临界载荷的影响,结果表明腹板厚度对背面温度以及屈曲临界载荷的影响最大。然后设计并加工制备了ITPS的面板与单胞试验样件,分别展开了800 ℃的高温防隔热性能试验考核和屈曲性能的力学试验研究;试验表明腹板结构是引发热短路效应和屈曲的关键因素,屈曲试验与模拟结果吻合,高温屈曲分析表明温度梯度对屈曲特征有较大影响。

关键词： 热防护系统 力热结构耦合 一体化设计 屈曲 防隔热性能

Abstract:

The demanding requirements of high-speed aircraft for structural efficiency lead to their thermal protection system to be lightweight and integrated. The new thermal-mechanical coupling integrated thermal protection system (ITPS) has great potential for development. Firstly, the concept and characteristics of a new integrated thermal protection structure design are explained and the basic design criteria are summarized. Numerical analysis is completed to study the impact of structural parameters on temperature response and the critical buckling load. The results show that web thickness has the greatest impact on the bottom temperature as well as the critical buckling load. ITPS panels and unit-cell test samples are designed and then manufactured in order to conduct insulation performance test at 800 ℃ and buckling performance mechanical tests. The experiments show that web structure is the key factor causing the thermal short circuit effect and buckling. The results of the buckling tests are consistent with finite element analysis, and high-temperature buckling analysis shows that the temperature gradient has great impact on the buckling form.

Keywords: thermal protection system thermal-mechanical structure coupling integrated design buckling insulation performance

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