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复合材料蜂窝夹芯结构单面贴补弯曲性能的分析模型与试验研究

李剑峰¹, 燕瑛¹, 廖宝华², 马健¹, 张涛涛¹, 刘波¹

1. 北京航空航天大学 航空科学与工程学院, 北京 100191;
2. 中国航空工业集团 成都飞机设计研究所, 四川 成都 610041

Analysis Model and Experimental Study of Bending Behavior of Composite Honeycomb Sandwich Structures with One-side Bonded Repair

LI Jianfeng¹, YAN Ying¹, LIAO Baohua², MA Jian¹, ZHANG Taotao¹, LIU Bo¹

1. School of Aeronautic Science and Engineering, Beihang University, Beijing 100191, China;
2. Chengdu Aircraft Design & Research Institute, Aviation Industry Corporation of China, Chengdu 610041, China

摘要

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摘要

复合材料蜂窝夹芯结构作为一种轻质结构已经被广泛应用于飞机舵面及各类整流罩等部件,而弯曲性能可以综合表征其力学性能。基于此,对复合材料蜂窝夹芯板单面贴补试件进行了试验研究及数值分析。首先对单面贴补试件进行了三点弯曲试验,得出结构的破坏载荷及强度恢复值,并分析了芯层压溃以及补片脱胶两种破坏模式及其机理。数值分析中,结合Hill准则、Hashin Fabric准则以及粘聚单元技术,以二次应力准则和能量释放率准则作为失效判据,建立了基于梯形本构关系的修补结构三维有限元分析模型。对蜂窝夹芯板单面贴补结构的弯曲强度及破坏机理进行计算与分析,计算结果表明,基于梯形本构关系的胶层模型可以较好地模拟实际脱胶情况,与试验结果能够较好吻合,验证了分析模型的正确性。最后,分析了补片直径以及补片厚度对修补效果的影响,结果表明,随着补片直径与厚度的增加,修补结构承载能力呈现先增加后减小的趋势。

关键词: 复合材料 蜂窝夹芯板 梯形本构关系 单面贴补 弯曲性能

Abstract:

Composite honeycomb sandwich structures are widely used in aircraft control surfaces and various fairing parts as a lightweight structural design, and their bending properties can be integrated to characterize their mechanical properties. In view of this, experimental study and numerical analysis are performed on one-side bonded composite honeycomb sandwich specimens. First, a three-point bending test is carried on damaged composite honeycomb sandwich panels with one-side bonded repair. The failure loads and strength recovery values of the structures are obtained, and the failure mechanism of the two failure modes of core crush and patch debond are analyzed. A trapezoidal constitutive relationship and failure criterion based on the quadratic stress criterion and energy release rate criterion are introduced with Hill failure criterion, Hashin fabric failure criterion and the cohesive element technique, by means of which a three-dimensional finite element analysis model of the repaired structures is established. The bending strength and failure mechanism of one-side bonded honeycomb sandwich structures are predicted and detected with the model. The numerical results show that the patch debond mode can be well simulated with the introduction of the trapezoidal constitutive relationship in the adhesive, and a good agreement is found between the numerical results and the test data, which demonstrated the validity of the proposed model. Then the effect of patch diameter and thickness on the repair is analyzed, which revealed that with the increase of patch diameter and thickness, the loading capacity of the repaired specimens first increased and then decreased.

Keywords: composite materials honeycomb sandwich panel trapezoidal constitutive relationship one-side bonded repair bending behavior

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Corresponding Authors: 燕瑛 Email: yingyan@buaa.edu.cn