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复合材料帽型筋条脱粘的失效机理分析

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Failure Mechanism Study on Omega Stringer Debonding

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摘要

复合材料加筋结构承受后屈曲载荷时,蒙皮局部屈曲会导致筋条承受面外弯曲载荷,极易引起蒙皮与筋条的界面脱粘,最终导致结构破坏。通过四点弯曲试验模拟加筋结构受后屈曲载荷时的蒙皮/筋条界面性能,建立渐进损伤模型,分别考虑筋条与蒙皮胶接界面以及复合材料层板的失效,并引入材料刚度退化模型,详细分析蒙皮/筋条界面的脱粘机理和失效过程。分析结果与试验结果一致,表明加载跨距对于结构的失效形式影响较大,90 mm加载时,胶层均首先失效于筋条与蒙皮内角处的胶接界面,且主要受Ⅱ型剪切模式影响;而150 mm加载情况下胶层均首先失效于翼缘自由端与蒙皮交界处。正向加载时胶层失效主要受Ⅰ型和Ⅱ型混合模式影响,反向加载胶层主要受Ⅱ型剪切模式影响。界面脱粘以后,随着载荷增加,筋条腹板与缘条转角外侧出现分层破坏,损伤模型预测结果与超声扫描检测结果一致。

关键词: 帽型筋条 蒙皮筋条脱粘 渐进损伤 虚拟裂纹闭合技术 能量释放率

Abstract:

In the post-buckling mode, fatal failure of a composite stiffened panel is easily induced by the separation of a skin stiffener interface,because the local buckling of the skin will cause the stringer to withstand an out-plane bending load. In this paper, four-point bending tests are performed to simulate the interface properties between the skin and the stringer after post buckling, and a progressive damage model is presented to study the interface failure mechanism and the failure process of the composite hat-stiffened panel structure which takes into consideration both the glued interface and laminate failure with a material stiffness degradation model. The numerical results are in good agreement with the experimental data, which shows that the loading span greatly affects the failure of the structure. In the 90 mm loading conditions, the adhesive layer initially failed near the inner chamfer of the web and skin, and it is mostly influenced by the Ⅱ shear mode. In the 150 mm loading conditions, the adhesive layer initially failed near the free edge of the flange, and it is mostly influenced by both the tensile mode and the Ⅰ and Ⅱ shear mode when the stringer is tensile, and influenced by the Ⅱ shear mode when the stringer is compressed. After the interface was debonded, delamination occurred on the tensile stringer chamfer between the web and the flange with increasing load, which is consistent with the ultrasonic B-scan results.

Keywords: omega stringer skin/stiffener debonding progressive damage visual crack closure technique energy release rate

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