EXPERIMENT STUDIES AND NUMERICAL SIMULATION OF COMPOSITE LAMINATES OPENING PLATES WITH ASYMMETRIC REINFORCEMENT

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ABSTRACT

Composite materials are being increasingly used in primary launch vehicle and space aircraft structures as they offer higher performance and efficiency. Many of these composite launch vehicle or space aircraft shell structures have cutouts or openings inevitably that serve as wave-transmission windows or equipment fixing holes and so on. However, these cutouts or openings will bring stress concentration around the cutout and local buckling when the structures experience compression loads. These cutouts or openings usually need for reinforcement design to control local structural deformations and stress concentration so that increase carrying capacity of the whole composite structures.

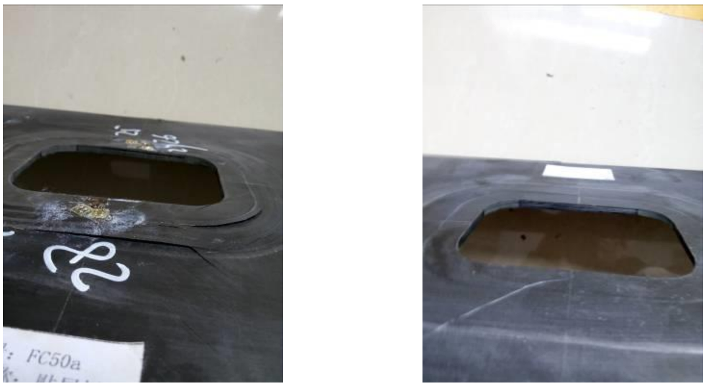
This paper designs three styles of rectangular opening plates with asymmetric reinforcement base on launch vehicle composite structures. The three different forms of asymmetric reinforcements are consisted of flanging configuration, sequential placement and intercalated placement which are easy to implement in engineering. Firstly, the responses to uniaxial compress loading of these cutout plates are analyzed by tested experimentally, and obtain carrying capacities and damage forms. The results have shown that (1) the average values of carrying capacity of the three styles asymmetric reinforcement plates increase 6.5%, 10.8% and 10.1% respectively compare to the plates without reinforcement. (2)The flanging configuration plates occur local buckling at the openings when they reached ultimate load, and this damage form is similar to the plates without reinforcement as shown in Fig.1. The carrying capacities of flanging configuration plates are not significantly increased; in addition, the flanging configuration brings serious eccentric effect, so this asymmetric reinforcement is not a good way in engineering. (3) The sequential placement plates and the intercalated placement plates have almost the same carrying capacity, and they have excellent efficiency to raise local buckling load. The experimental results show that the fiber and matrix around the opening boundary have damaged before local buckling. Owing to the influence of eccentric, the phenomenon of delamination appears in the transition zone of the sequential placement plates, while intercalated placement plates have not delamination damage in the same zone as shown in Fig.2. Consequently, the intercalated placement is a better way in engineering.

Secondly, the finite element simulation is implemented with the arc length method taking into account progressive failure. Ply damage modes such as matrix damage, fiber damage, and fiber-matrix shear damage are modeled by degrading material integration point stiffness. The cohesive element is applied to simulate the propagation of delamination at the reinforcing region. Calculation results show that out-plane damage must be considered when the sequential placement and intercalated placement plates are analyzed while in-plane damage is considered only when the flanging configuration plates are analyzed. Simulation

result accorded well with experiment result. According to the simulation and experimental results, the original damage zone of all the reinforcing opening plates focus on rectangular opening corner, and the damage propagates along the plate width direction. In addition, the numerical simulation result of delamination damage is similar to the experiment result; the delamination damage occurs at the opening boundary of the intercalated placement plates and the transition zone of the sequential placement plates.

Finally, research achievements offered by this paper have reference for the composite designer.

Figure 1: The damage zone of the flanging configuration plate



a. The sequential placement plate   b. The intercalated placement plate

Figure 2: The delamination damage of the sequential placement and intercalated placement plate

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