Effect of cutouts or low-speed impact damage on the performance of CFRP laminate under shear load

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1. Introduction

Carbon Fibre Reinforced Polymer (CFRP) composites, which offer an attractive potential for weight saving, have witnessed the increasing application in aerospace engineering on account of their higher stiffness and strength to weight ratio compared to conventional materials. During the manufacture and service process, aircraft structures inevitably have various types of damage, such as defects in the production, cutouts for functional requirements, and impact damage caused by external objects in repairing operation. The existence of damage may lead to significant reduction in the loading capacity and remains a longstanding challenge in design and analysis of damage tolerance for aircraft structure [1].

However, understanding the post-buckling behavior and failure mechanisms of laminated panels with cutout or low-speed impact has been considered difficult due to the non-linearity or anisotropic effects. Comprehensive experimental investigation about the effect of cutout or low-speed impact damage on the structural mechanical performance is still very few. Moreover, most existing researches[2-11] mainly focus on the investigation of the influence of impact damage on the residual properties of these structures and prediction of residual tension/ compression strength after impact. So it is of great practical importance to understand their performance of CFRP laminate with cutouts or low-speed impact damage in detail, and evaluate the residual strength of damaged structure for ensuring the structure safety and reliability.

2. Body of abstract

The aim of this paper is to systematically explore the effect of cutouts or low-speed impact damage on the performance of CFRP laminate under shear load. Here, five sets tested shearing panels of CFRP laminate in the presence of different cutout shape or low-speed impact damage were designed and tested. For inducing visually invisible damage (BVID), some specimens were prior to be impacted at three different initial impact energies (55J, 57.5J and 60J) using a specially designed drop weight test rig. Then low-velocity impact damage characteristics were descried using ultrasonic C-scanning and the relation between the levels of impact energy, penetration depth and damage area were investigated. The following shearing test was performance on the buckling and post-buckling, up to collapse behavior of CFRP composite panels with different shaped cutout or low-speed impact damage. The impact-damaged results reveal that the main damage characteristics of the impact zone are delamination, matrix cracking and fiber damage, etc. These laminated panels with cutout or low-speed impact have their respective damage evolution and different final failure mechanisms under the following quasi-static shear load. As expected, the experiment observations and results are presented in sufficient details and the effects of different cutout shape or low-speed impact damage on the stress concentration, buckling resistant, postbuckling bearing capacity have been be quantified systematically. These constructive conclusions and suggestions should contribute to future design and analysis of composite aircraft structures in similar shape and loading conditions.

Keywords: Shear-loaded composite panels; Cutout; Low-velocity impact damage; Failure mechanisms; Buckling and Post-buckling

3. Equations, figures, and tables

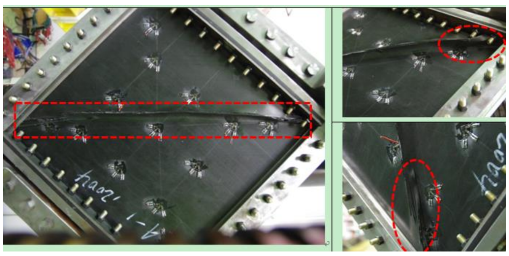
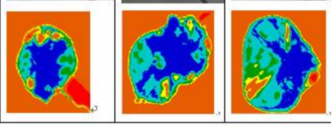


Fig.1 Ultimate failure appearance of NSP

Table1 Damage and failure appearance of the test beam under impact load

	(55J)	(57.5J)	(60J)
Indentation depth			
Frontal view			
Back view			
ultrasonic C-scanning			

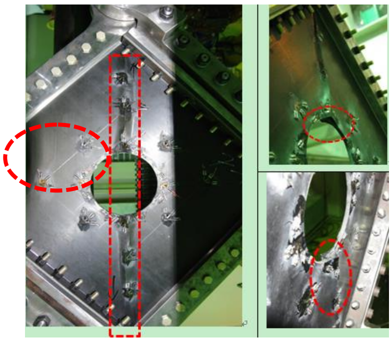


Fig. 2 Ultimate failure appearance of CSP1

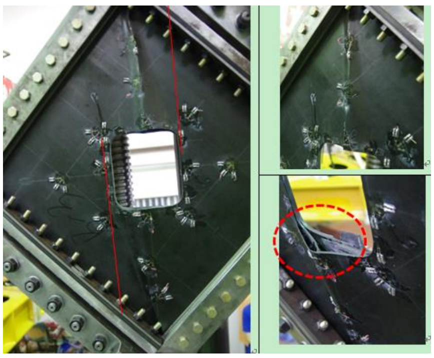
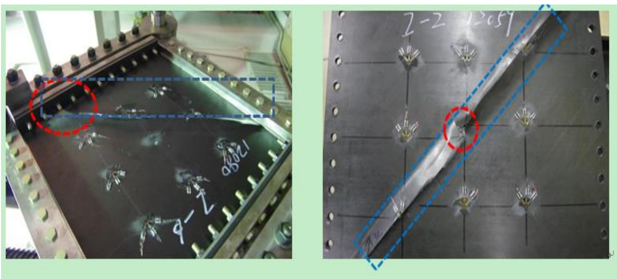


Fig. 3 Ultimate failure appearance of CSP2



(a) ISP1 (b) ISP2

Fig.4 Ultimate failure appearance of ISP1 and ISP2

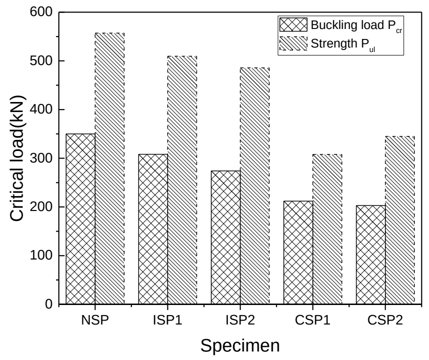


Fig.5 Buckling load and final failure load

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