SANDWICH T-JOINT STRUCTURES WITH AND WITHOUT CUTOUT UNDER SHEAR LOADS

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Introduction

In previous research, numerical and experimental studies have been conducted to determine the failure modes of both composite laminate and composite sandwich T-joint structures [1-11]. The effect of cutouts in sandwich panels and cutout reinforcement around the free edges has also been the attention of many studies [12-14]. However the focus of these researches has been either on the structural modelling and failure analysis or experiment, especially for monolithic composite joints. The aim of this current paper is to extend the analysis for the sandwich T-joint structures, together with experimental work, to design improvements and simpler manufacturing processes without compromising the overall strength.

Sandwich T-joint under Shear Load

The T-joint Structure Design

The sandwich T-joint structure consisted of two panels joined at a right angle to each other reinforced with composite cleats. Fig. 1 shows the dimensions of the structure in mm.

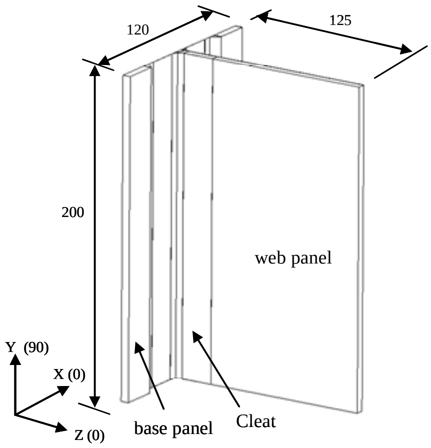


Fig. 1 T-joint structure geometrical details

Fig. 2 (a) shows the load and boundary conditions set in the FE model: the two sides of the base panel were fully clamped and the shear load was applied in the *y*-direction along the free edges of the web. The applied shear load however, induced an in-plane bending moment on the web panel which was simulated by applying opposing forces in the z-direction at the top and bottom edges of the web panel.

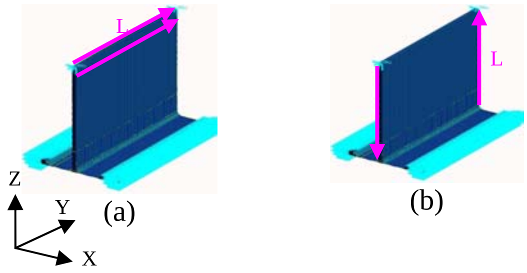
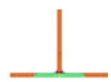


Fig. 2 FE loads and boundary conditions (a) shear load, (b) induced bending moment

The T-joint under Shear Load

Initially a traditional design for the sandwich composite T-joint structure with the base foam drop off region was analysed. However, a sandwich T-joint without dropping the base panel core would need simple and low cost manufacture process and result in a greater bending stiffness. Three alternative designs were therefore proposed and modelled by using the FE method to analyse the improved design. Table 1 presents a summary of the different design cases.

Table 1 Summary of the design cases.

Case	Description	
1	T-joint with central monolithic panel: baseline model with the foam drop off in the sandwich base	
2	T-joint with foam core: both web and base are made of sandwich composite panels with a foam core	
3	T-joint with honeycomb central insert: the core of the central part of the sandwich base is made of a honeycomb material (green region) instead of foam	
4	T-joint with localised honeycomb insert: the sides of the sandwich base core is made of a honeycomb material (green region) instead of foam	

For case 1, when the shear force was applied, a local bending of the upper half of the base panel occurred. This caused high tensile stress in off-fibre direction in the 90° ply. As the stress exceeded the material allowable of 33.9 MPa, failure of the structure was inevitable. When the shear load was applied on the T-joint web panel in cases 2, 3 and 4, the base panel deformed in an asymmetrical manner. This deformation made the right hand side of the base panel in tension whereas the left hand side was under compression. The structural failure was therefore caused by the high tensile stress in the off-fibre direction of the 90° ply on the right hand side of the joint. The structural failure load for cases 2-4 was much lower than that for case 1, however the buckling load was higher for cases 2-4., as shown in Table 2.

Table 2 Failure and buckling load

	Failure Load (kN)	Buckling Load (kN)
Case 1	120	98
Case 2	60	103
Case 3	66	102
Case 4	60	103

The effect of asymmetrical bending and the consequent web deformation could be reduced by modifying the way the shear load and bending moments are applied in the FE model. This would increase the overall failure load and make the alternative design a more appealing option.

Test Results and Comparison with FE

For the design case 1, three samples without cutout and two samples with cutout were manufactured and tested under shear load. Two samples without cutout, the actual failure mode of the joint was not reached as severe damage around the bolting position occurred. The other sample without cutout failed due to off-fibre fibre failure and web buckling. The samples with the cutout failed due to web buckling around the cutout. Table 4 shows the test and FE strain comparison and the.

Table 4 Shear test and FE failure load and strain

	T-joint without cutout		T-joint with cutout	
Test Sample	Sa	Sb/ Sc	Sd	Se
Test FL(kN)	41.7	27.4/35.4	35.1	35.7
FE FL(kN)	43	-	37	37
Test ε (με)	-2772	-	-577	-391
FE ε (με)	-2895	-	-329	-329

***FL = Failure Load, ε = Strain**

The FE analysis for sample Sa showed that the T-joint web panel buckled at 40.5 kN. The web composite face, however, failed at 43 kN. At this loading level, the tensile stress of the outer ply in off-fibre direction was 34.8 MPa, which exceeded the material allowable strength of 33.9 MPa.

For the T-joint with a cutout, the predicted failure load was 37 kN. The structure failure was caused by both web buckling and stress concentration around the cutout. High stress concentration also occurred around the cutout where the maximum tensile stress of the outer ply in off-fibre direction was 36 MPa.

Conclusion

In this investigation, stress and buckling analysis and experiment of a composite sandwich T-joint under shear load were conducted. The results show that the traditional T-joint configuration has advantages in both strength and stiffness at the cost of manufacture complexity. Improved design options for lower cost and simpler manufacture process were also proposed and analysed. Although the current design options have not yet achieved the same strength as the traditional T-joint design, the design case 3 is very competitive and has potential to be improved for higher strength. Experimental tests for the traditional T-joint structure with and without cutout were conducted to validate the FE model. Good agreement between FE and test results was obtained.

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