Mechanical Properties Study of Advanced Pultrusion Epoxy Composites

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Introduction

Stiffener is one important form of aircraft material structures, having access to maximum rigidity of structure, capacity of against post-buckling, high efficiency of structure; deck floor type link also accounts for a large proportion in aircraft structures. For composite stiffener, co-curing and bonding with composites wallboard can make full use of structure advantage of composites, which is very important to improve quality, reduce cost and improve airworthiness. There are many methods to manufacture composite cross beams and stringers, including 3D braided RTM, directly hand layup, thermal deformation after automated tape laying, advanced pultrusion(ADP), etc [1~4]. Compared to other methods of forming, ADP has the following advantages: 1) Laminated construction is devisable. 2) Straightness & steadiness of quality. 3) llimit-free fabrication in logitudinal direction 4) Degree of cure is controllable.5) High production efficiency, Low cost. This paper chooses epoxy matrix prepreg to produce π structural section with ADP. Mechanical properties of ADP epoxy composites are studied by comparing with the bending property and in-plane shear property of molded product in the same process parameters.

Experimental

Materials

π shape blank and panel are all laid up with GuangWei company 12,500 unidirectional carbon fiber/epoxy prepreg and W3021 carbon fiber fabric prepreg. Laminated construction $[(0,90)/02/(0,90)/02/\overline{(0,90)}]_S$.

Apparatus and Procedures

π shape blank is preformed on the punch by hand and produced by pultrusion with the hot pressing device and traction device of the trial-produce ADP machine. Unlike traditional pultrusion, the processing method of π shape blank is intermittent rather than continuous. The flow of uncured π shape blank stops at the pressing device where heated, segmented metal molds close onto the preform to complete the consolidation and cure the resin at pressures around 0.3 Mpa/43.5psi, temperatures up to 130 ℃/250 ℉, intermittent heat preservation time 37.5s(the total curing time is 30 min), step distance 10mm. The panel is mould pressing on the XLB-50Z flat vulcanizing machine with curing temperature 130℃, curing time 30 min, pressure 0.3MPa.

The π shape parts are sampled along the lengthways (fiber 0° direction) at web and the panels are sampled along fiber 0° direction. The bending test is according to GB/T3356-1999 *Test method for flexural properties of unidirectional fiber reinforced plastics*. And the in-plane shear test is according to ASTMD5379/D5379-05 *Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method*.

Results and Discussion

The π shape parts are smooth in surface, well-distributed in fiber arrangement, and fine in straightness and perpendicularity. There is little resin pulled out on the outside surface at the corner, and none on the inside surface (shown in Fig. 1).

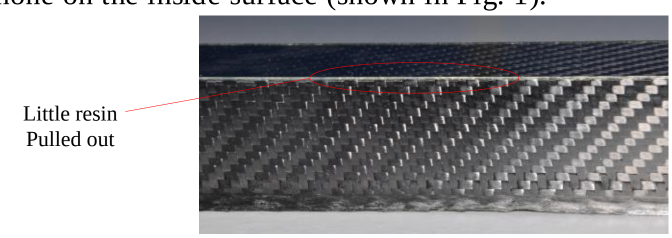

Fig. 1 The π shape part

The flexural properties and the in-plane shear properties of the π shape parts, are shown in Table 1:

Tab. 1 The result of flexural properties and in-plane shear properties tests

Parts	π shape parts	Molded panels
Average of flexural strength/MPa	1374.8	1378.8
Coefficient of variability/%	1.34	4.11
Flexural modulus /GPa	88.5	89.1
Coefficient of variability/%	3.75	5.26
Average of in-plane shear strength /MPa	111.4	105.4
Coefficient of variability/%	6.62	6.85

As shown above, the properties of molded panels are barely better than the ones of π shape parts, according to the results of two different tests. Compared to π shape parts, the flexural strength of molded panels exceeds only by 0.29 % , and the in-plane shear strength by 5.21%. Typical failure mode of flexural properties test is that the surface being stretched cracked, and the surface being compressed buckled. To make comparison of the results, three groups of stress-strain curves of the samples are shown in Fig. 2. The failure mode of both the π shape parts and molded panels is brittle failure(show in Fig 3), and the cracks existed in the surface on which directly contacts with the indenter. And this is not its typical failure mode. The deflections the samples are more than the 1/4 of its thickness. Thus, the in-plane tension emerges in the inside the parts, except for flexural stress in the cross section. The in-plane tension, which is called the membrane stress, can bear a portion of the horizontal load. The thickness of the samples made by ADP each is about 2mm larger than the molded panels. The selected spans (32 times of the thickness) of ADP samples are larger for the different thickness. Therefore, the deflections of the π shape parts are larger, although the flexural modulus of them are quit close.

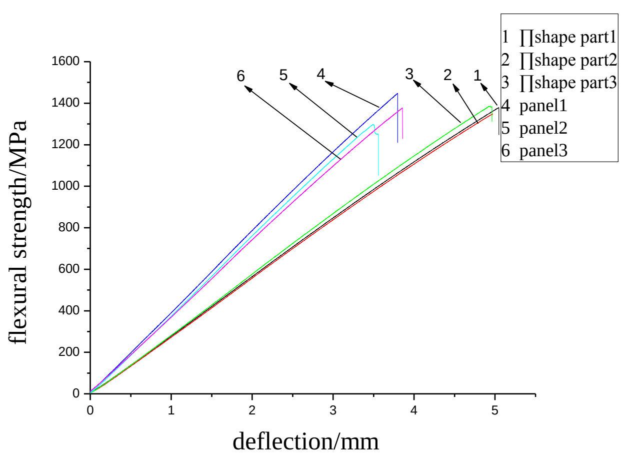

Fig. 2 Stress-strain curves of the samples

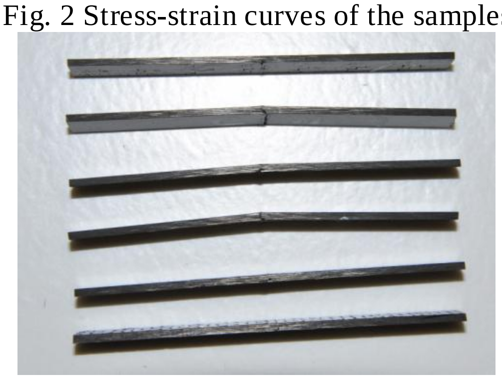

Fig. 3 Bending failure samples

In-plane shear stress-strain curves of the samples are shown in Fig. 3, and the samples all failed in typical failure mode. The results showed that the shear strength of the π shape parts are better than the molded panels, therefore the ADP products possess good quality in the in-plane properties.

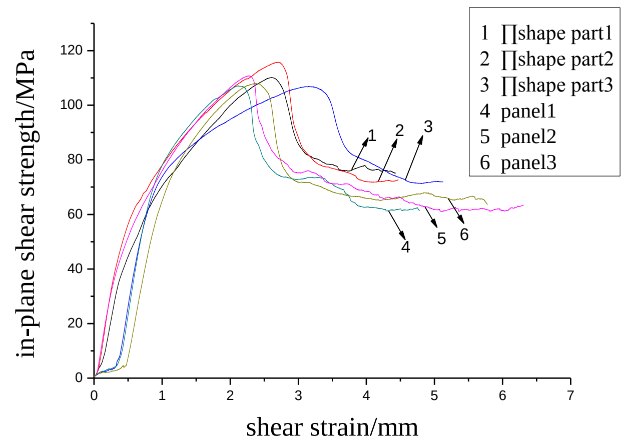

Fig. 3 in-plane shear stress-strain curves

Conclusion

The results revealed that the components manufactured by ADP possess smooth surface, well-distributed fiber arrangements, fine straightness and perpendicularity and stable mechanical properties, which almost equal the ones made by molded panels. The achievements acquired recently demonstrated the feasibility and advantages of the ADP process, and made contributions to the application of composites in large aircrafts manufacture.

Reference

1. Vernon M. Benson, Jason Slack, Todd A. Rosevear, et al. Apparatus and methods for forming composite stiffeners and reinforcing structures. P. US: 20050056362A1.2005-03-17.
2. Toru K, Makoto O, Shuntaro K. Method and apparatus for continuous molding of fiber reinforced plastic member with curvature. P. US: 20050029707. 2005-02-10.
3. Dale B. Advanced Pultrusion Takes Off In Commercial Aircraft Structures. High-Performance Composites. 2003-09.
4. J.Xiao, Y.Li and L.Wen. Progress of Automated Placement Technology for Polymer Composites. J. Materials China. 28(2009)28-32.