

Abstract for American Society of Composites 21st Annual Technical Conference,
September 17-20, 2006, The University of Michigan-Dearborn, Dearborn, MI

Mode I Toughness Measurements of Core/Facesheet Bonds in Honeycomb Sandwich Structures

Alan Nettles

George C Marshall Space Flight Center
Huntsville, AL 35812

James G Ratcliffe

National Institute of Aerospace
100 Exploration Way, Hampton, VA 23666

Composite sandwich structures will be used in many future applications in aerospace, marine and offshore industries due to the fact that the strength and stiffness to mass ratios surpass any other structural type. Sandwich structure also offers advantages over traditional stiffened panels such as ease of manufacturing and repair. [1]

During the last three decades, sandwich structure has been used extensively for secondary structure in aircraft (fuselage floors, rudders and radome structure). Sandwich structure is also used as primary structure in rotorcraft, the most common example being the trailing edge of rotor blades.

As with other types of composite construction, sandwich structure exhibits several types of failure mode such as facesheet wrinkling, core crushing and sandwich buckling [2]. Facesheet/core debonding has also been observed in the marine and aerospace industry [3, 4]. During this failure mode, peel stresses applied to an existing facesheet/core debond or an interface low in toughness, results in the facesheet being peeled from the core material, possibly leading to a significant loss in structural integrity of the sandwich panel. In an incident during a test on a liquid hydrogen fuel tank of the X-33 prototype vehicle, the outer graphite/epoxy facesheet and honeycomb core became debonded from the inner facesheet along significant areas, leading to failure of the tank. As a consequence of the accident, significant efforts were made to characterize the toughness of the facesheet/core bond [4].

Currently, the only standardized method available for assessing the quality of the facesheet/core interface is the climbing drum peel test (ASTM D1781) [5]. During this test a sandwich beam is removed from a panel and the lip of one of the facesheets is attached to a drum, as shown in Fig. 1. The drum is then rotated along the sandwich beam, causing the facesheet to peel from the core. This method has two major drawbacks. First, it is not possible to obtain quantitative fracture data from the test and so the results can only be used in a qualitative manner. Second, only sandwich structure with thin facesheets can be tested (to facilitate wrapping of the facesheet around the climbing drum). In recognition of the need for a more quantitative facesheet/core fracture test, several workers have devised experimental techniques for characterizing the toughness of the facesheet/core interface [6-8]. In all of these cases, the tests are designed to yield a mode I-dominated fracture toughness of the facesheet/core interface in a manner similar to that used to determine mode I fracture toughness of composite laminates [9].

In the current work, a modified double cantilever beam [10] is used to measure the mode I-dominated fracture toughness of the interface in a sandwich consisting of glass/phenolic honeycomb core reinforced with graphite epoxy facesheets. Two specimen configurations were tested as shown in Fig 2. The first configuration consisted of reinforcing the

facesheets with aluminum blocks (Fig. 2a). In the second configuration unreinforced specimens were tested (Fig. 2b). Climbing drum peel tests were also conducted to compare the fracture behavior observed between this test and the modified double cantilever beam.

This paper outlines the test procedures and data reduction strategies used to compute fracture toughness values from the tests. The effect of specimen reinforcement on fracture toughness of the facesheet/core interface is discussed.

References

- [1] Saporito, J. "Sandwich structures on Aerospaciale helicopters," Proceedings of the 34th Int. SAMPE Symposium and Exhibition, Reno, Nevada, 1989. p. 2506.
- [2] Allen, G.H., "Analysis and Design of Structural Sandwich Panels," Pergamon Press, 1969.
- [3] Echtermeyer, A.T., and McGeorge, D., "Fracture Toughness of Core Skin Interfaces of Sandwich Materials," Proceedings of the 4th International Conference on Sandwich Construction, Stockholm, Sweden, 1998, pp.635-644.
- [4] Final Report of the X-33 Liquid Hydrogen Tank Test Investigation Team, George C. Marshall Space Flight Center, May 2000.
- [5] ASTM D1781-98 (2004) "Standard Test Method for Climbing Drum Peel for Adhesives," *2005 Annual Book of ASTM Standards*, Vol.15.06.
- [6] Cantwell, W.J., and Davies, P., "Study of Skin-Core Adhesion in Glass Fibre Reinforced Sandwich Materials," *Applied Composite Materials*, Vol. 3, No. 6, 1996, pp.407-420.
- [7] Cantwell, W.J., Scudamore, R., Ratcliffe, J., and Davies, P., "Interfacial Fracture in Sandwich Laminates," *Composites Science and technology*, Vol. 59, 1999, pp.2079-2085
- [8] Li, X and Carlsson, L.A., "The Title Sandwich Debond (TSD) Specimen for face/Core Interface Characterization," *Journal of Sandwich Structure and Materials*, Vol. 1, 1999, pp.60-75.
- [9] ASTM D5528-01 "Standard Test Method for Mode I Interlaminar Fracture Toughness of Unidirectional Fiber-Reinforced Polymer Matrix Composites," *2004 Annual Book of ASTM Standards*, Vol.15.03.
- [10] Prasad, S., and Carlsson, L.A., "Debonding and Crack Kinking in Foam Core Sandwich Beams-II. Experimental Investigation," *Engineering Fracture mechanics*, Vol. 47, No. 6, 1994, pp.825-841.

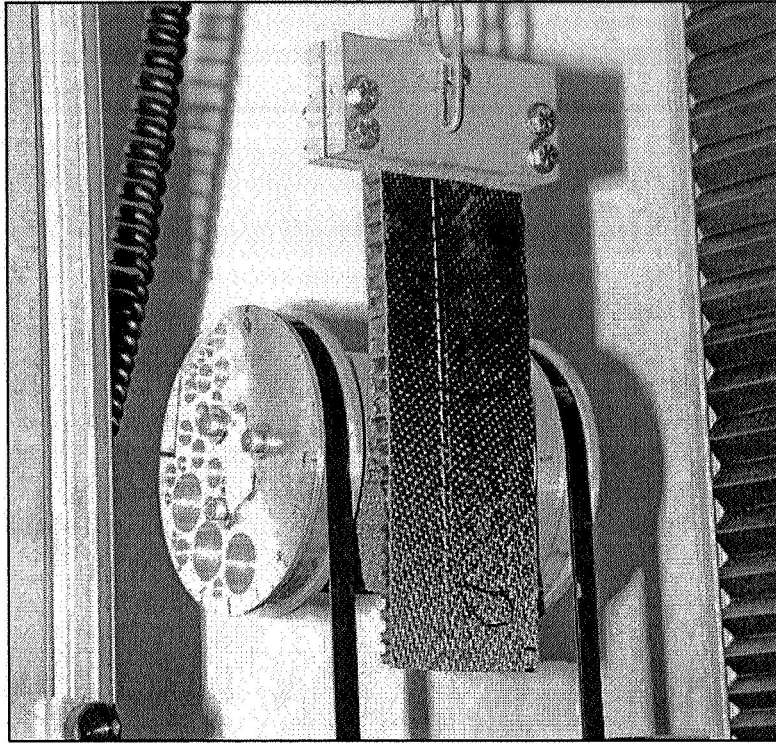


Figure 1 Climbing drum peel test fixture.

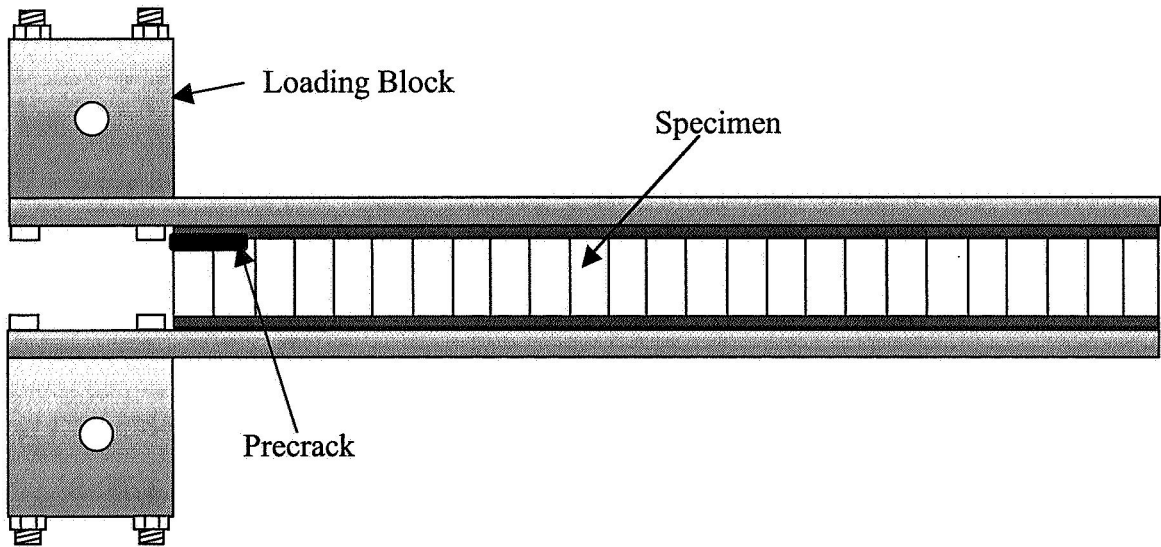


Figure 2a Schematic of reinforced modified double cantilever beam specimen.

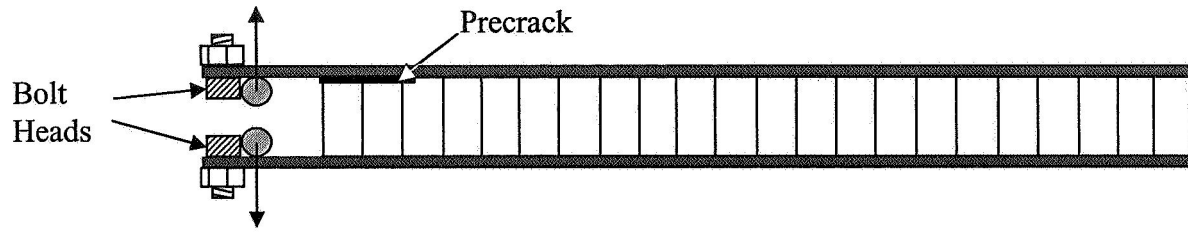


Figure 2b Schematic of unreinforced modified double cantilever beam specimen.