EXPERIMENTAL INVESTIGATION OF TAPERED EDGE CLOSEOUTS IN SANDWICH COMPOSITE PANELS

Elizabeth Fortin and Scott James
Department of Aerospace Engineering, San Diego State University

Introduction

Aircrafts traditionally are fabricated as semi-monocoque structures, made of metallic beams (stringers and ribs) and shells (thin curved sheets) assembled using mechanical fasteners. Aluminum has been the primary material used in fuselage and wing structures. As weight and fuel savings becomes increasingly important, newer airframe structures use of light weight composite materials are being explored. Composite sandwich construction is a potential concept being explored. The sandwich panel is constructed by affixing two thin yet rigid skins, usually a metal or fiber reinforced composite, to a lightweight but thick core, typically an aluminum or Nomex honeycomb (Refer to Figure 1 below).

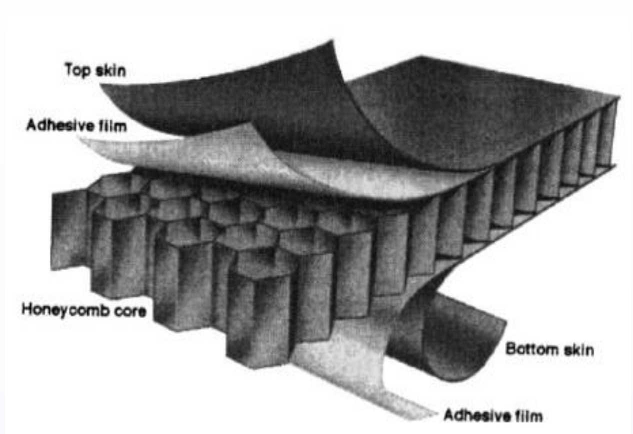

Figure 1: Traditional Construction of the Honeycomb Panel [1]

	Solid Metal Sheet (t)	Sandwich Construction (2t)	Thicker Sandwich (4t)
Relative Stiffness	100	700 7 times more rigid	3700 37 times more rigid!
Relative Strength	100	350 3.5 times as strong	925 9.25 times as strong!
Relative Weight	100	103 3% increase in weight	106 6% increase in weight

Figure 2: Stiffening Effects Due to Honeycomb [1]

Use of honeycomb cores to increase the plate thickness (Figure 2) dramatically increases the stiffness and strength of a structure with minimal material weight increase. However, sandwich composite laminates exhibit poor damage tolerance and possesses low transverse compression strength. Sandwich panels requires modifications such as rigid inclusions or tapered closeouts to be attached to frames using mechanical fasteners, such as rivets and bolts (Figure 3).

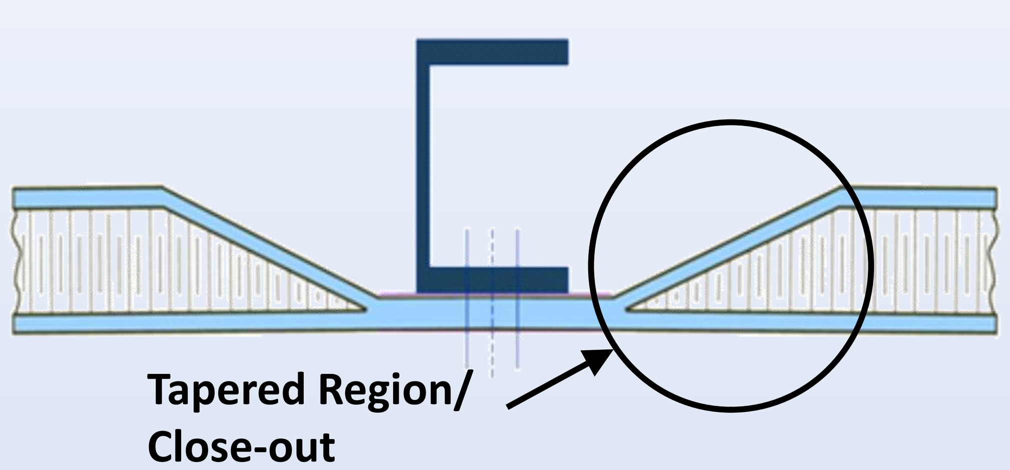

Figure 3: Sandwich Panel with Tapered Edge Closeouts [1]

The Goal

The goal of this research is to develop experimental methods to investigate and quantify the local deformation and failure mechanisms in tapered sandwich core closeouts using full field deformation and strain characterization methods. Such methods are needed for development of analytical models, and/or verification and validation of numerical models.

Methods

To mitigate the localized stress concentrations in the tapered close out region various design solutions such as using localized laminate thickness build up of facesheets [2], use of denser core inserts [3], and use of functionally graded cores [4] are being investigated. Modeling these design solutions require many simplifying assumptions and cannot always reveal effect of manufacturing processes. In this research, a digital image correlation (DIC) based full field displacement (and surface strain) measurement is used to study tapered closeouts in sandwich laminates. The ability to visualize and quantify full field strains enable understanding of the load transfer mechanisms and the initiation and progression of failure during testing. Data obtained are useful for direct validation of finite element analysis simulations.

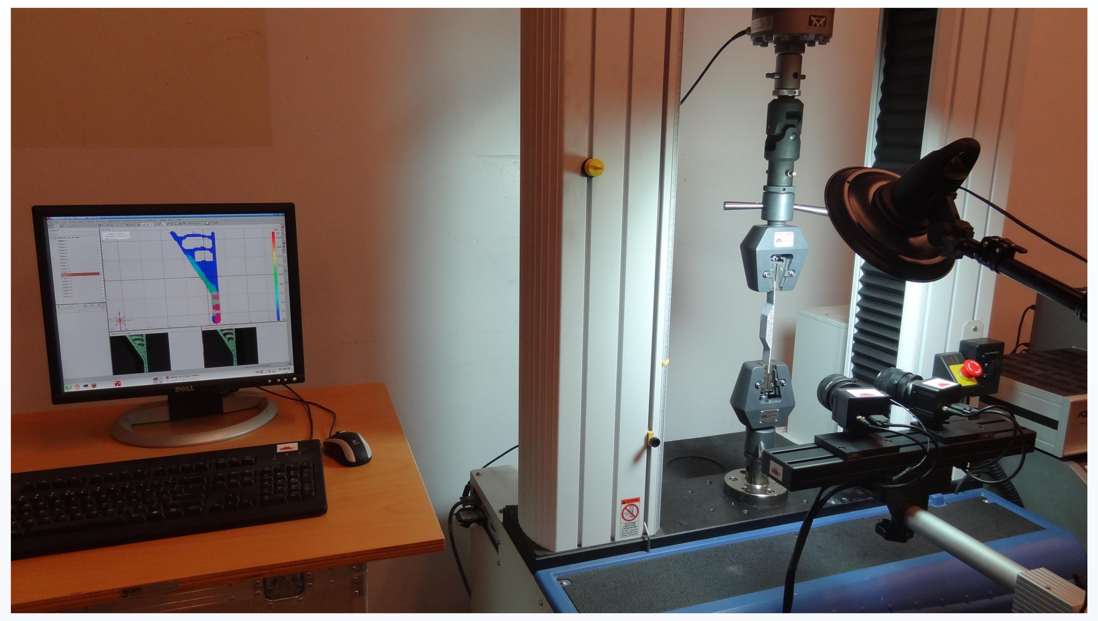

Figure 4: ARAMIS Digital Image Correlation System Test Frame Configuration.

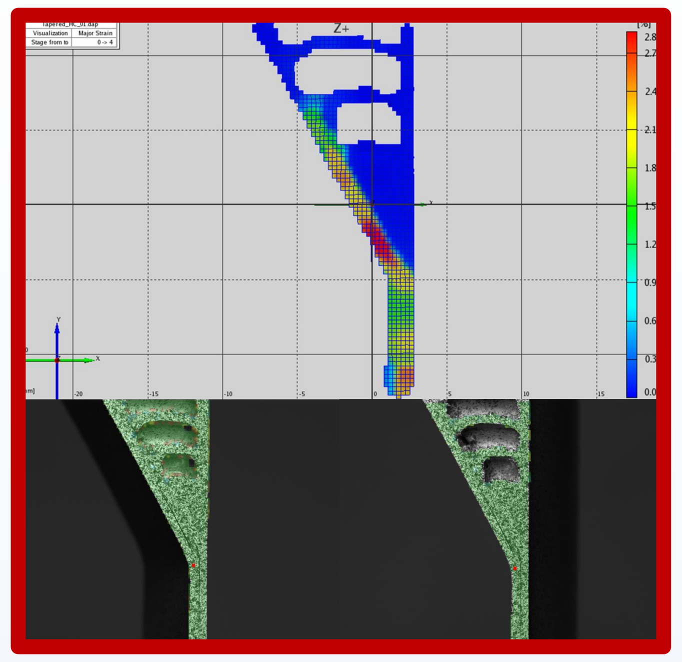

Figure 5: Real Time Full Field Strain Visualization.

Figure 4 shows a sandwich beam with end taper subjected to a tensile load with the imaging system used for full field displacement and strain measurement. Figure 5 shows the stereo images of the sandwich closeout with a fine speckled surface pattern applied to it and the computed strain distribution in the specimen after being loaded.

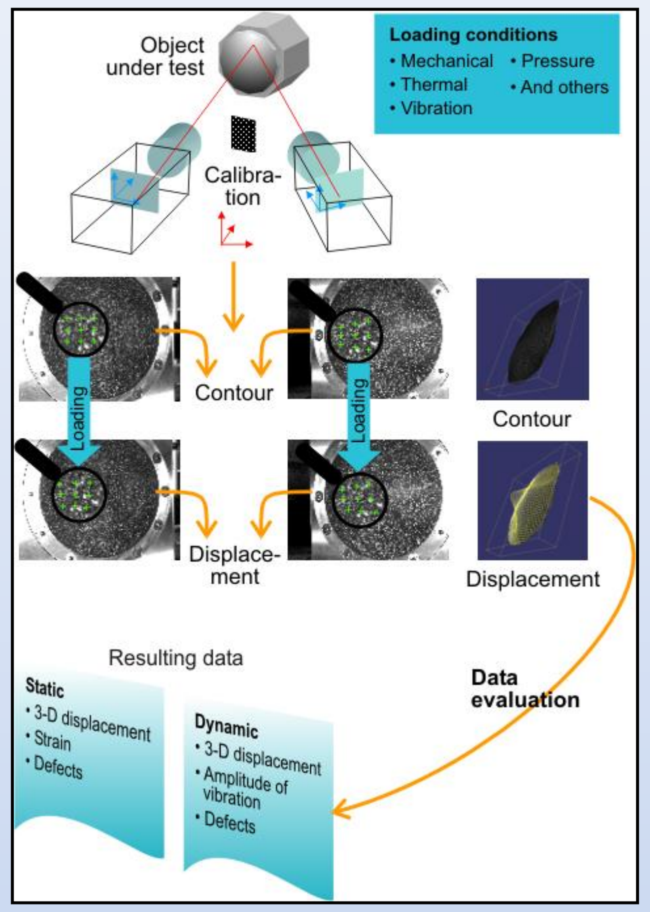

Figure 6: Digital Image Correlation Deformation Measurement [5]

In DIC, a high resolution stereoscopic camera system is used to image the surface the object that has been coated with a high contrast speckled pattern. The camera system is calibrated using a standard gauge or known image to establish the orientation of the sensors with respect to each other (extrinsic parameter), the position of object points in three dimensional space, the camera resolution, image noise and other intrinsic parameters. The camera system images and tracks each point of the speckled image pattern from one frame to the next. The image data together with the calibration data are used to compute the deformation and strains using an image correlation algorithm [5].

Progress

A group of researchers at San Diego State University are investigating various aspects of sandwich tapered closeouts. These finite element analysis simulations of sandwich tapered closeout behavior [2], modeling crushing of honeycomb cores to develop graded cores [6], design and fabrication of sandwich tapered closeout specimens for testing in tension and three/four point bending.

Efforts for producing functionally graded core using aluminum honeycomb panels (Figure 7) and the optimization of manufacturing process variables in the rolling process to achieve specified density profiled of the graded core were undertaken.

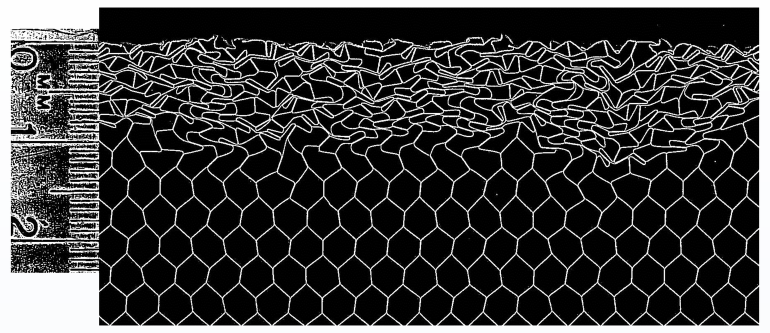

Figure 7: Graded Honeycomb produced by a edge crushing process

A small number of sandwich laminates with metallic facesheets and cores were produced and tested and the DIC system was used to perform strain visualization. The small volume of the taper region and the non flat surface of the honeycomb cores required gaining expertise in calibrating the imaging system to achieve high accuracy. With this experience and expertise gained we will soon test tapered sandwich closeouts with different core modifications and obtain data on full field deformation to investigate effectiveness of the proposed design solutions.

References

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