



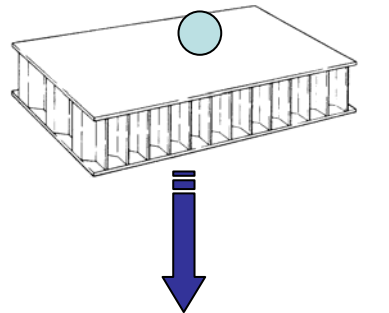
FULL-SCALE DAMAGE TOLERANCE OF COMPOSITE SANDWICH STRUCTURES



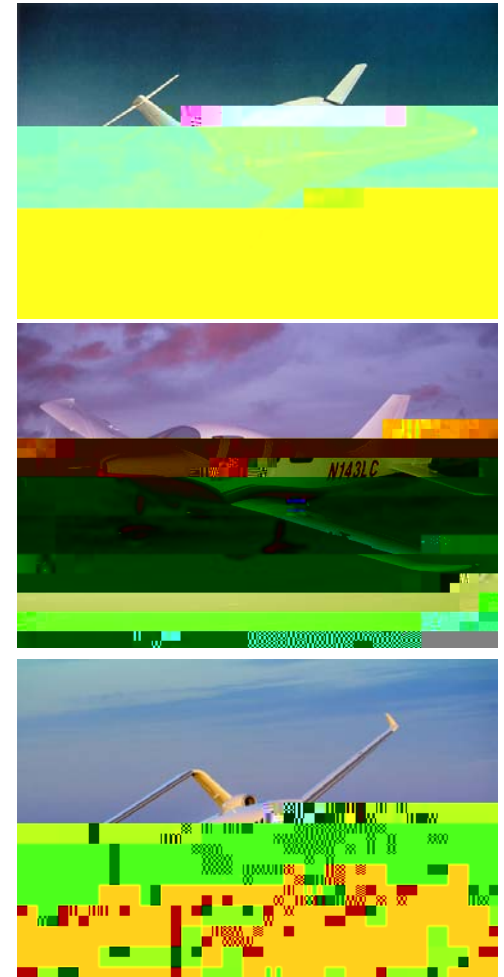
Background

- Literature Review
- Experimental Investigation of Damage Resistance & Tolerance
- NDI Techniques, Curvature effects, Fatigue
- Design of experiments, CAI modeling
- Scaling effects
- Open-Hole Testing
- Independent Review

1998
1999
2001
2004



- REPORTS-
- DOT/FAA/AR-99/49, 1999
 - DOT/FAA/AR-00/44, 2001
 - DOT/FAA/AR-02/80, 2002
 - DOT/FAA/AR-02/121, 2003
 - DOT/FAA/AR-03/75, 2004
 - DOT/FAA/AR-0?/??, 2005

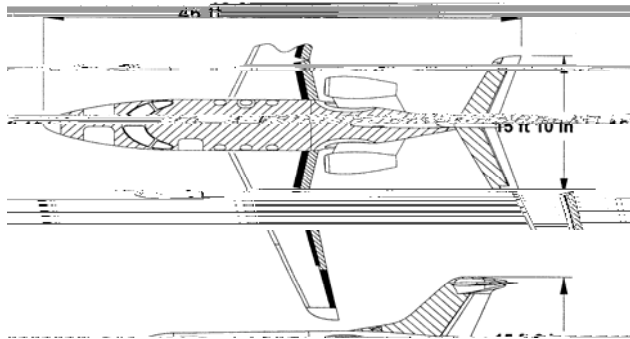


FULL-SCALE DAMAGE TOLERANCE OF COMPOSITE SANDWICH STRUCTURES



- **Critical Damage States**
 - **IMPACT DAMAGE** – Load transfer through damage region
 - **OPEN HOLE** – No load transfer through damage region

FULL-SCALE DAMAGE TOLERANCE OF COMPOSITE SANDWICH STRUCTURES



FULL-SCALE DAMAGE TOLERANCE OF COMPOSITE SANDWICH STRUCTURES



- Objectives

- Design, fabrication & Testing of sandwich test article(s) under combined loading at WJHTC test facility
 - Material Systems & Sandwich Configuration
 - Geometry
 - Load-introduction
 - Attachments, etc.
 - Damage configurations – notches, holes, impact damage, etc..
 - Instrumentation
 - Loading Scenarios
 - Failure load predictions
 - Testing

APP



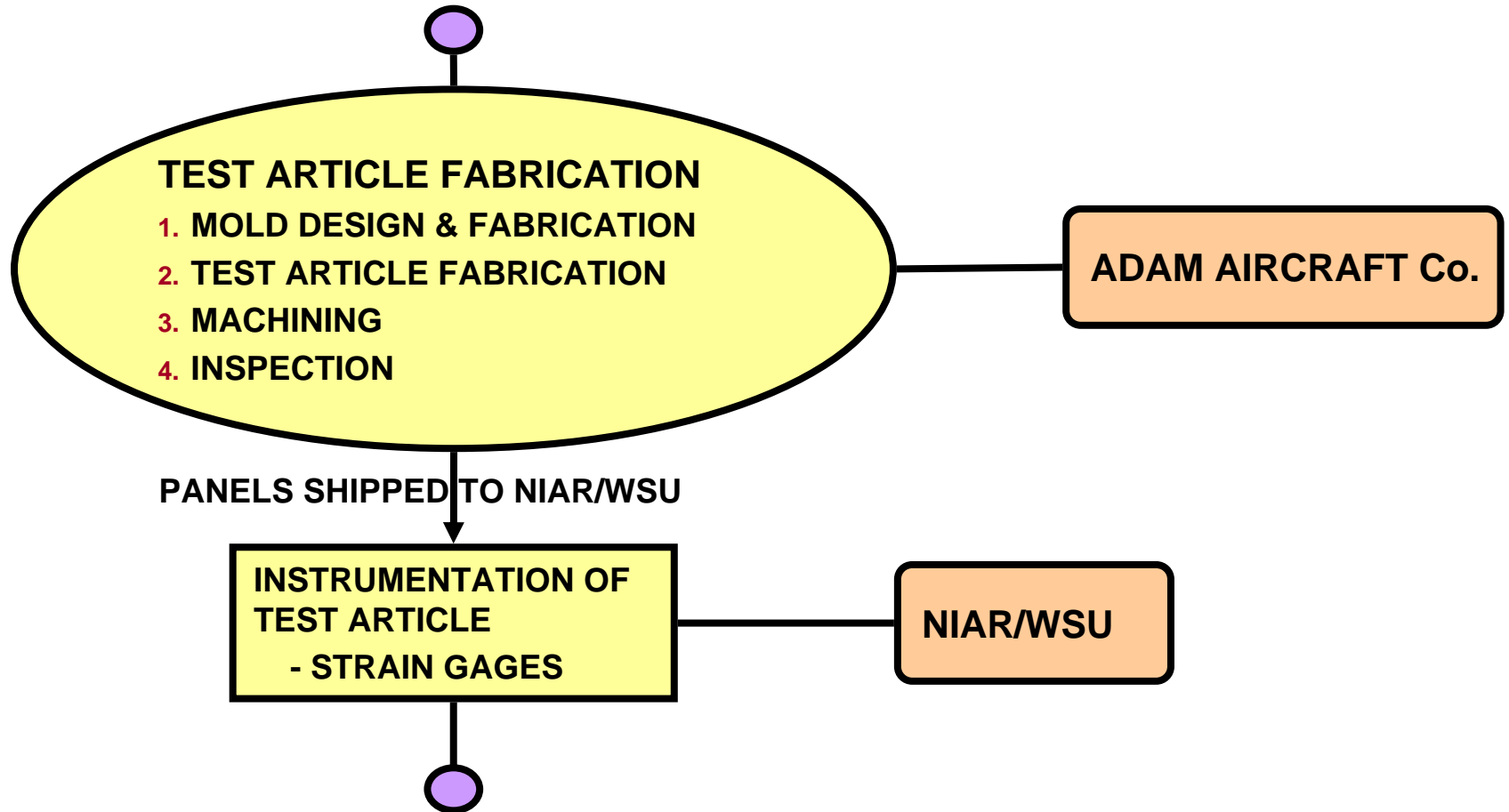
composites and advanced materials



**REVIEW PREVIOUS TEST
ARTICLES/REPORTS**

**ESTIMATE FAILURE
LOADS**

APPROACH



APPROACH



TESTING

3 TEST ARTICLE PREPARATION

- 3 Bonding of seals
- 3 Speckle pattern coating for DIC

DATA REDUCTION &
REPORT GENERATION

Full-Scale Aircraft Structural Test Evaluation & Research (FASTER) Fixture



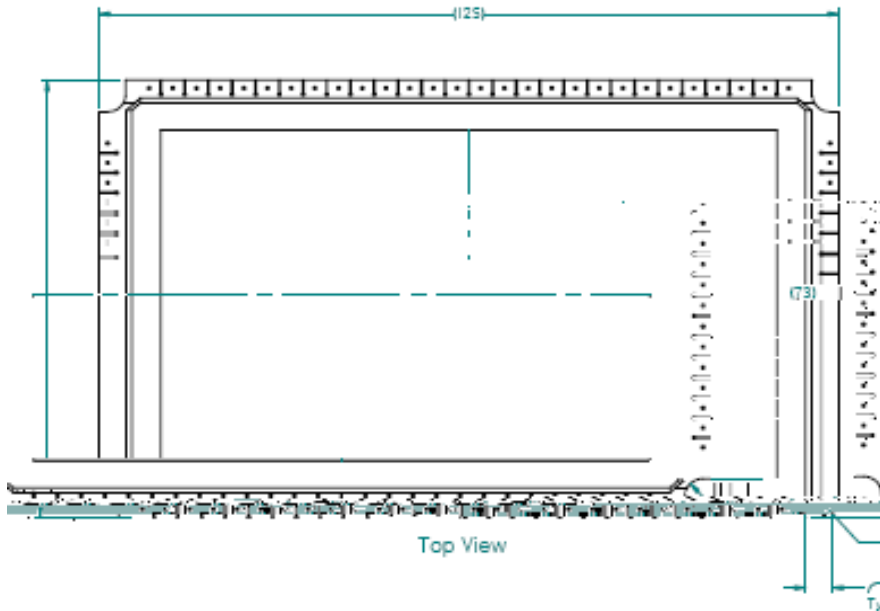
TEST FIXTURE SPECIFICATIONS^{Ref}



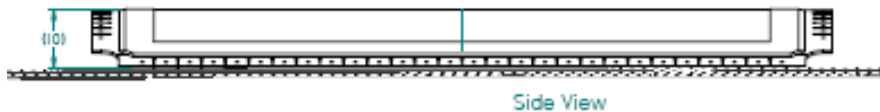
- **Longitudinal loading**
 - 1800 lbf/in
 - 16 load introduction points
- **Circumferential (Reactive) loading**
 - 1800 lbf/in
 - 28 load introduction points
- **Frame Loads**
 - 360 lbf/in
- **Pressurization loading**
 - 15 psi
 -

Ref. John Bakuckas, "Full-Scale Testing and Analysis of Fuselage Structure containing Multiple Cracks," DOT/FAA/AR-01/46.

TEST ARTICLE GEOMETRY

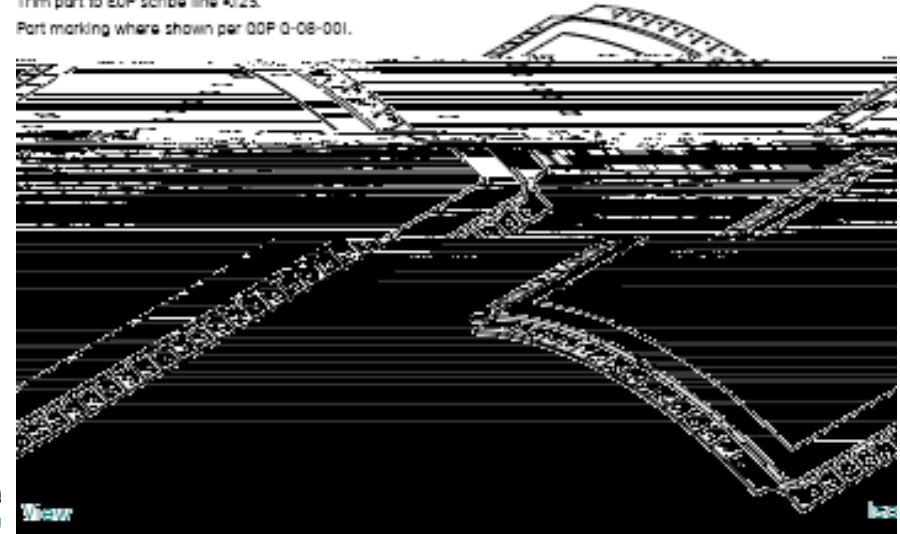


Top View



Side View

Trim part to EOP scribe line 4/25.
Part marking where shown per OOP Q-08-001.



Internal Radius : 74 inches

TEST ARTICLE



- Material Systems
 - Facesheet
 - TORAY COMPOSITES T700SC-12K-50C/#2510 PWCF
 - Core
 - Plascore Nomex PN2-3/16-3.0 honeycomb (0.75 in thick)
- Sandwich Configuration (test section)
 - [45/0/45/core/45/0/45]

TEST PLAN /STATUS



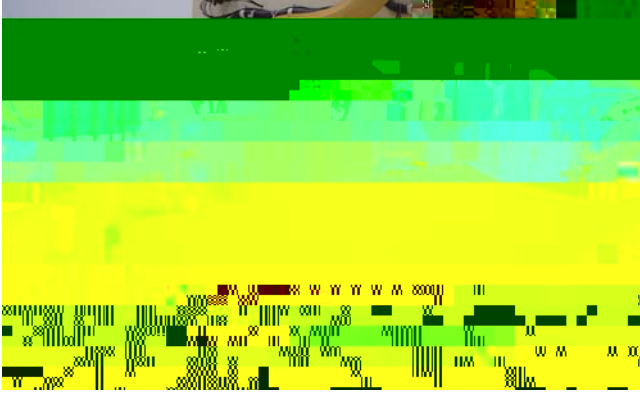
TEST NO	PANEL I.D	FLAW TYPE	LOADING	STATUS	comments
1	CP-1	NONE	Combined	completed	- Trial testing to exercise loading mechanisms, ARAMIS, etc.
2			Pressurization/hoop loading	completed	
3			Longitudinal	completed	
4	CP-1A		Longitudinal loading to 1500 lb/in	completed	
5	CP-1B		Combined loading (1:1) (495 lb/in)	completed	
6	CP-1B		Hoop loading to 495 lb/in	completed	
7	CP-1B		Longitudinal loading to 495 lb/in	completed	
8			Combined loading (1:1) (1050 lb/in)	completed	
9	CP-2		Longitudinal loading (1500 lbf)	completed	10" diameter hole on convex side facesheet

TEST PLAN /STATUS

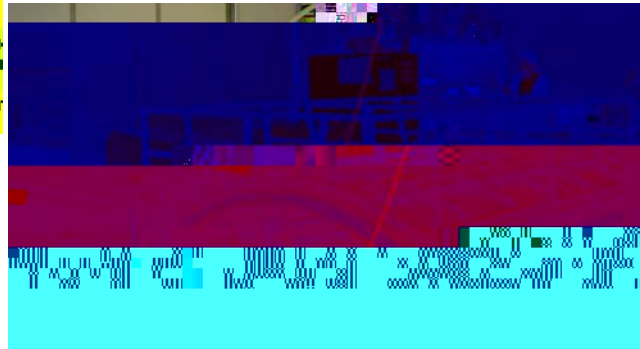


NO	SUBJECT	comments	NO	PANEL I.D.	FLAW	TYPE	LOADING
		STRAIN SURVEY					
		3 Longitudinal loading: 300 lb/in					Machining under progress
	4. Combined loading - Prestress						
	3.4psi Longitudinal 300						
	14	CP-5					
		10" notch at 45°					
							RESIDUAL STRENGTH

FABRICATION OF TEST ARTICLES



TOOLING FABRICATION



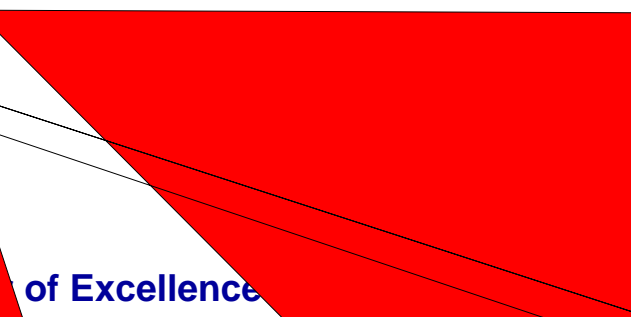
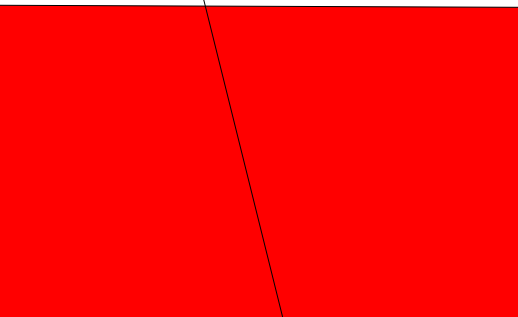
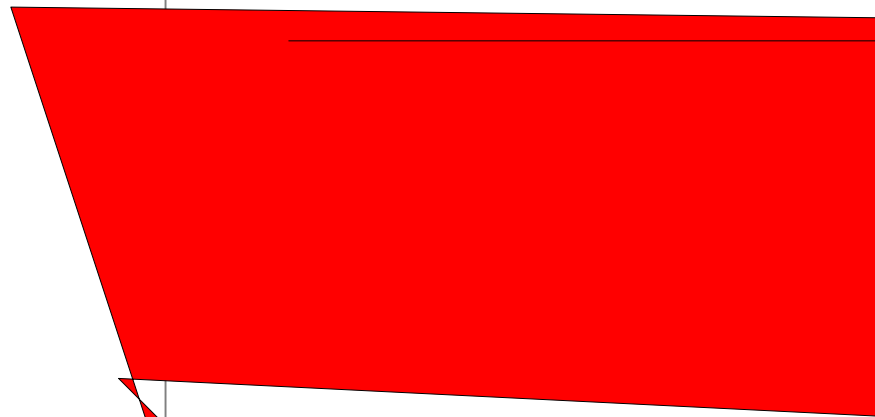
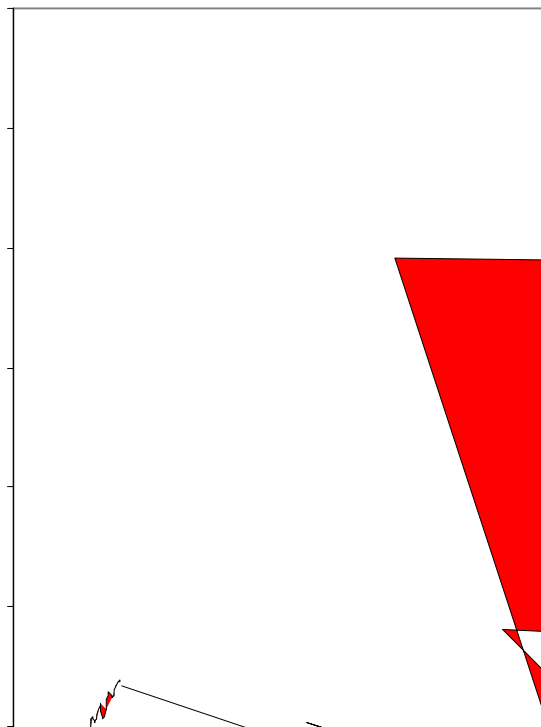
COMPLETED TOOLING

TEST RESULTS



- UNDAMAGED PANEL TEST(S)
 - OBJECTIVES
 - CHECK LOAD INTRODUCTION & UNIFORMITY OF LOADING
 - CHECK INSTRUMENTATION & PHOTOGRAMMETRY METHOD
 - LOAD CASES





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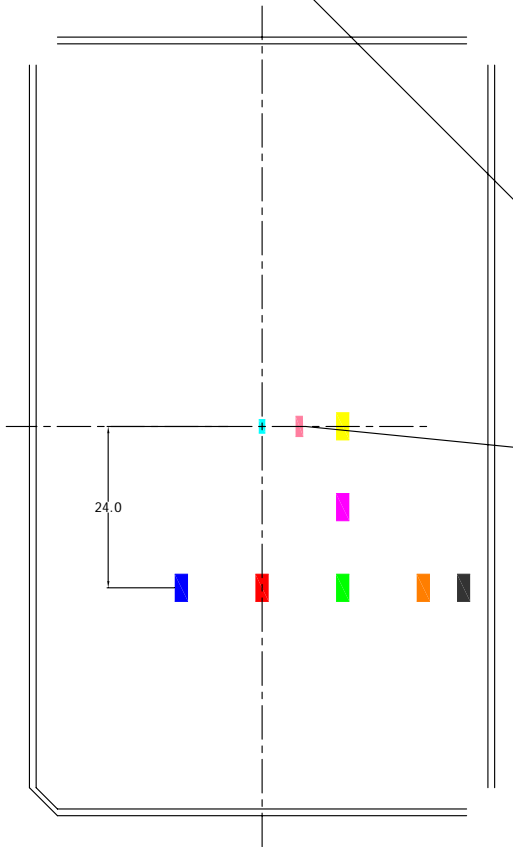
TEST RESULTS



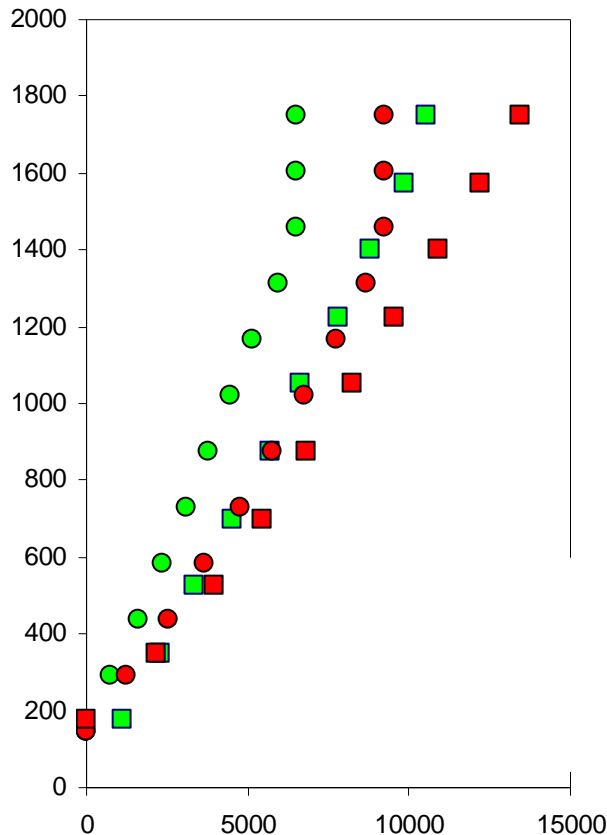
- PANEL GEOMETRY & INSTRUMENTATION



HOOP LOADING – Bending of panel

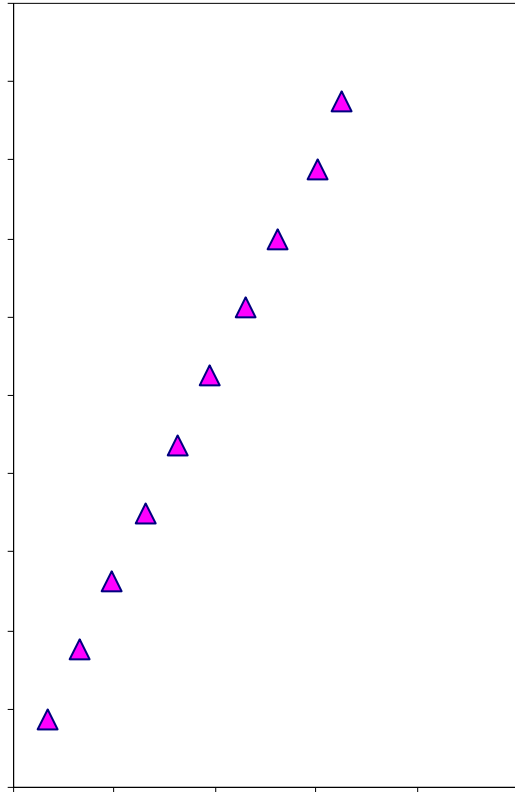


COMPARISON OF TANGENTIAL STRAINS



- 3 Tangential strains vary linearly with applied loading under pure longitudinal and hoop loading
- 3 Tangential strains under hoop loading was significantly higher than longitudinal & combined loading cases
 - 3 Failure initiated under hoop loading
 - 3 Bulging at hole edge adds to tangential component
- 3 Under combined loading, tangential strains along hoop & longitudinal directions are unequal
 - 3 Bulging effects

COMPARISON OF backside facesheet STRAINS



Comparison with coupon data



- **Hole in single facesheet is less severe as through holes or notches**
- **The failure load for single facesheet hole (pressurization) corresponds to failure initiation**

Ongoing Work



- Analysis of photogrammetry data and failure modes
- Testing of Specimens with notches
 - Longitudinal notch
 - Circumferential notch
 - Notch at 45° to longitudinal axis
- Two additional damage/loading configurations –TBD
- Analysis
 - Advatech Pacific : Failure prediction using GENOA program

A Look Forward



- Future needs
 - Longitudinal compression loading capability in the fixture
 - Inclusion of shear loading
 - Fatigue
 - Structural details – cut-outs, adhesive joints, etc.