PERFORMANCE OF BOLTED JOINTS IN DISCONTINUOUS CERAMIC CORED SANDWICH STRUCTURES

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INTRODUCTION

- Thick section composites using discontinuous ceramic tile arrays as a core represents a unique class of sandwich structures that has been developed to provide a balance of structural and ballistic performance at minimum weight.
- Mechanically Fastened Joints
  - Allow for easy installation, inspection, and repair
  - Cause large stress concentrations.
  - Catalyst for Failure modes:
    - Net Tension Failure
    - Bending/Shear Failure
    - Bearing Failure
    - Ceramic Tile/Facesheet bond line failure (at ultimate failure)

OBJECTIVE

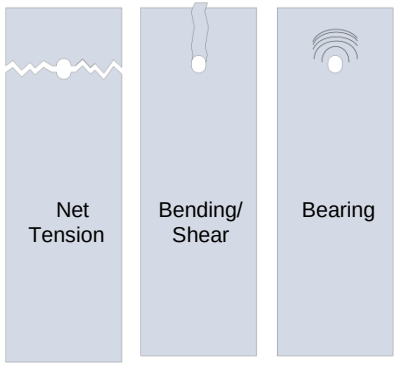
- Understanding the performance of bolted joints in discontinuous ceramic cored sandwich structures.
  - Failure modes for thick section composites due to bolted connections are unknown.
  - Develop design allowables based on experimental testing.
  - Experimentally test multiple scenarios to be able to quantify performance of DCCS Structures.
    - Static Tests of facesheet and DCCS Structures
    - Fatigue Tests of DCCS Structures
    - Residual Strength Static Tests to determine loss of strength in fatigued specimens.

DISCONTINUOUS CERAMIC CORED SANDWICH STRUCTURES

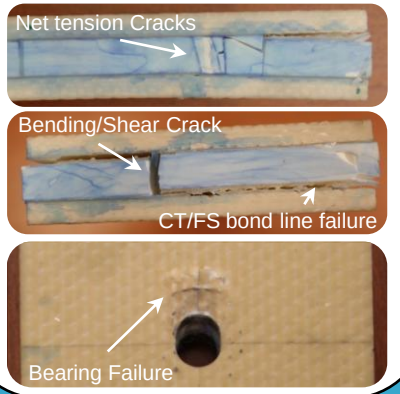
- Discontinuous Ceramic Cored Sandwich Structures (DCCS Structures)
  - Multifunctional Hybrid Composite
  - Balances Ballistic and Structural Performance
  - Manufactured using VARTM process
    - Facesheet
    - Interlayer
    - Ceramic Tile

DCCS Structure Cross Section (Not to Scale)

FAILURE MODES

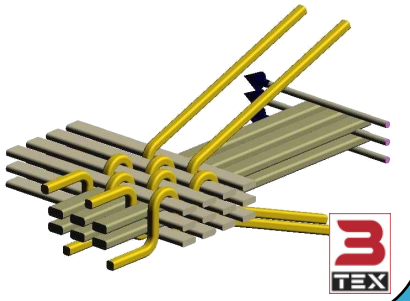


FAILURE MODES



FACESHEET

- 3TEX 3Weave S-2 Glass ZZ 100 oz
  - Each facesheet = 0.25 in. thick



CERAMIC TILE / INTERLAYER

- Alumina Ceramic Tile
  - Placed in aligned array
  - Individual Tiles = 4” x 4” x 0.4”
- Interlayer
  - Adhesive between Ceramic Tile and Facesheet
  - Comes in sheets that are laid in panel.
  - Each interlayer = .02 in.

PERFORMANCE OF BOLTED JOINTS IN DISCONTINUOUS CERAMIC CORED SANDWICH STRUCTURES

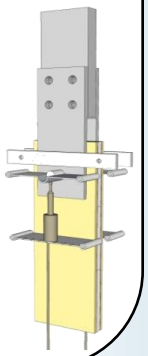
(Continued)

FATIGUE TESTING

- Understanding in fatigue performance is extremely important for materials that will be subjected to cyclical loading
  - 5 Stress Levels were selected
    - 1 – 560 lbs (20% stress level 5)
    - 2 – 1120 lbs (40% stress level 5)
    - 3 – 1680 lbs (60% stress level 5)
    - 4 – 2240 lbs (80% stress level 5)
    - 5 – 2800 lbs (90% first crack)
  - Each Specimen Tested to 1 Million Cycles
    - Hairline Cracks were detected

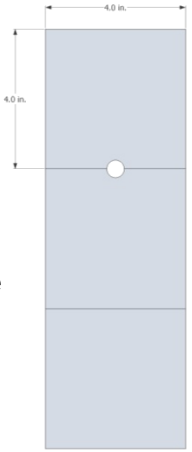
STATIC TESTING

- Tested a wide variety of geometric ratios for facesheet testing to create design charts.
- Statically Tested 3 variations in geometric ratios for DCCS Structures.
  - Baseline
    - width/Diameter (w/D) = 8
    - edge/Diameter (e/D) = 4
  - Reduced Edge Distance
    - w/D = 8
    - e/D = 3
  - Reduced Width
    - w/D = 6
    - e/D = 4



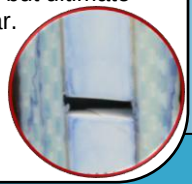
FUTURE WORK

- Pin on Gap Testing
  - The discontinuous ceramic core can alter the effects of a mechanical joint significantly.
  - Will the pin bearing directly over a region of discontinuity affect the failure modes or strength?
  - Does increased edge distance increase the load carrying capacity?

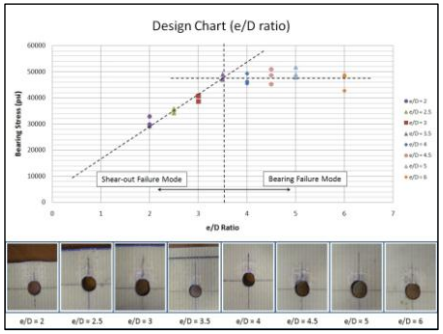


RESIDUAL STRENGTH

- Determine whether hairline cracks and cyclic loading has detrimental effects on strength
  - Stress Levels 1 – 3 show no change in strength
  - Stress Levels 4 – 5 show change in failure modes, but ultimate strength is similar.
  - Large crack displacement in stress levels 4 – 5.

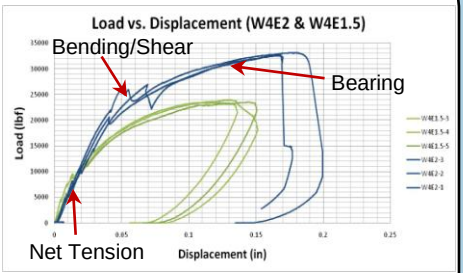


FACESHEET TESTING



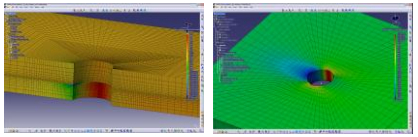
- Shows e/D ratios that cause failure modes to change from bearing to shear-out.

DCCS STRUCTURE TESTING



- Different regions of failure modes are visible on Load vs. Displacement Plot
- Green line is reduced e/D specimens. Shows reduced strength

FINITE ELEMENT ANALYSIS



- Finite Element Analysis using Abaqus in Catia (DCCS Left, Facesheet Right)
- Non-linear analysis to better understand failure mode progression (future work)