NUMERICAL PREDICTIONS OF THE PERMEABILITY OF COMPLEX FABRIC ARCHITECTURES

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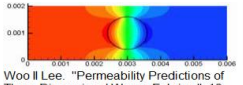
PROJECT OVERVIEW

- Research to involve permeability and processing predictions of three-dimensional fiber performs
  - 3-D fabrics used in structural and ballistic applications because of increased fracture toughness, damage tolerance, and impact resistance
  - Process modeling can be used to improve manufacturing processes as well as reduce the cost of wasted resources
- Thick cross-section composites difficult to infuse
  - Dual scale flow problem – tow impregnation
  - CFD modeling performed to study large scale flow as well as tow saturation
- CFD calculations to be carried out using ANSYS CFX 12.0
- Numerical predictions to be compared to experimental results

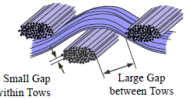
CFD MODELING

- Several fundamental problems were solved using ANSYS CFX to validate the resulting solutions
- Calculated values were compared to the governing constitutive equations, specifically Darcy's Law.
- Problems investigated include:
  - Viscous flow in a pipe
  - Flow between parallel plates
  - Chanel Flow with unsaturated porous fiber tow problems studied in Woo II Lee's report "Permeability Predictions of Three-Dimensional Woven Fabrics."

$$Q = \frac{-\kappa A}{\mu}\frac{(P_b - P_a)}{L}$$



Woo Il Lee. "Permeability Predictions of Three-Dimensional Woven Fabrics." 13 May 2010

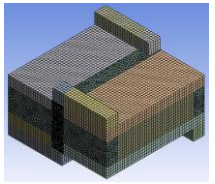


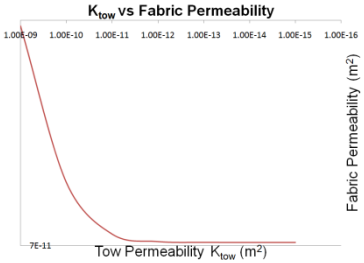
Woo Il Lee. "Permeability Predictions of Three-Dimensional Woven Fabrics." 13 May 2010

- Numerical results produced by CFX within 3% error of those given by the governing equations

3WEAVE 50 OZ. S2 ZZ

- Initial studies to investigate the directional permeabilities of 3TEX's 3WEAVE 50 oz S2 ZZ fabric (P3W-GS031)
- Model tow permeability varied to determine the effect on bulk fabric data

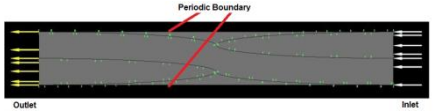




- As tow permeability decreases, bulk fabric permeability reaches an asymptotic level
  - Flow ceases to impregnate fiber tows, instead resin flows through open channels

PERMEABILITY STUDIES

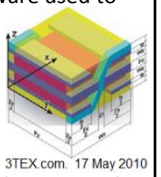
- Directional permeabilities of structural and ballistic grade fabrics to be analyzed to potentially aid in high volume processing of lightweight composite vehicle armor



- Study the effect that microscopic flow and tow permeability has on large scale fabric permeability and part quality

GEOMETRIC MODELING

- Fabrics infused with resin using VARTM process
- Images of cut cross sectional area taken
- ImageJ image analysis software used to measure unit cell geometries

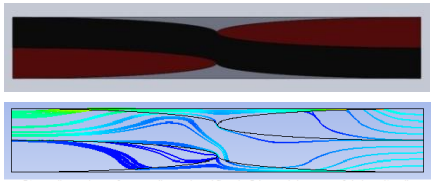


3TEX.com. 17 May 2010

- 3Weave fiber tows modeled as rectangles
- Measured geometries identical to those supplied by the manufacturer 3TEX, Inc.

BASELINE FABRIC

- Baseline fabric studied is 24 oz. S2 plain weave



Streamlines shown for one-dimensional flow in 24 oz. plain weave fabric unit cell.

- Simulation streamlines show tow impregnation
- Predicted permeability agrees with experimental values

MODEL & MESH DESIGN

- Geometric model created using Solidworks
- Meshing performed in ANSYS CFX Mesh
- Total of approximately 90,000 elements in 3-D mesh
- Fiber tows modeled as porous bodies
- Periodic boundaries defined to simulate large scale flow in fabric unit cell model

ACKNOWLEDGEMENTS

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