PROCESS AND PERFORMANCE EVALUATION OF THE VAP PROCESS

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Objectives

- To quantify the performance improvements of Vacuum Assisted Process (VAP) and compare them to the Seemann Composite Resin Infusion Process (SCRIMP), the most common variation of the Vacuum Assisted Resin Transfer molding (VARTM) process.
- To improve the repeatability and part quality of the VARTM process in order to replace conventional manufacturing methods, such as autoclave processing, used for aerospace-quality parts

Approaches

- Infusion characteristics
  - CCD – Camera records the flow front on the bottom of the preform
  - SMARTMolding system records the flow front on the surface of the preform
  - Electronic scales weigh the resin injected and vented versus. time
  - Laser Scanning to obtain the thickness variation along the panel
    - Resin Arrival Time
    - Resin Flow Weight
    - Thickness Gradient
- Mechanical properties
  - Fiber Volume Fraction (ASTM D 3171)
  - Void Content (ASTM D2734)
  - Short beam shear test (ASTM D2344)
    - Fiber volume fraction and void content
    - Short beam shear strength test
- Process robustness
  - CCD – Camera and SMARTMolding system detect the infusion status
    - L-shape scenario test

Experimental Conditions

MATERIALS

E-Glass Fiber (324-2407 Woven Roving)

Size: Length 80 cm (32 inch), width 20 cm (8 inch), thickness around 8.6 mm (15 layers)

In-Plane Permeability: $3.63 \cdot 10^{-7}$ cm^{-2}
Out-of-Plane Permeability: $7.00 \cdot 10^{-5}$ cm^{-2}

Applied Poleramics SC15 epoxy resin

Composition: 100% part A + 30% part B

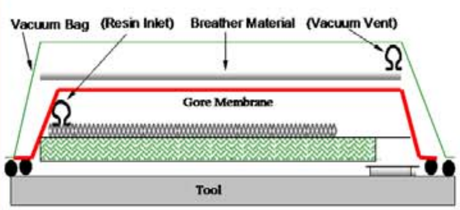
PROCESSING

The injection line will be closed after full infusion.

DATA

- Infused Resin Weight
- Resin Bleeding Weight
- Thickness variation
- 2-D Thru-Thickness Flow Analysis

Vacuum Assisted Processing (VAP)



Gore Membrane

— Permeable to Gas (Air),
Non-permeable to Fluids (Resin)

VAP (Continued)

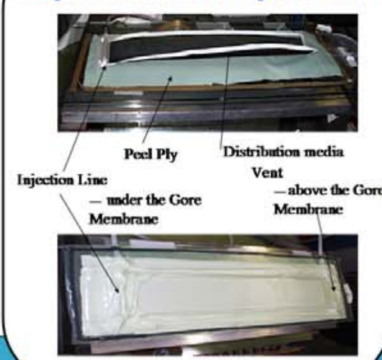
Advantages

- ✓ Uniform vacuum pressure on the part surface
  - ⇒ No Thickness gradient
  - ⇒ Allow no dry-spot development
- ✓ Potential of degassing during infusion and gelation
  - ⇒ Less voids in the final part
  - ⇒ No degassing prior to infusion required
- ✓ No resin bleeding

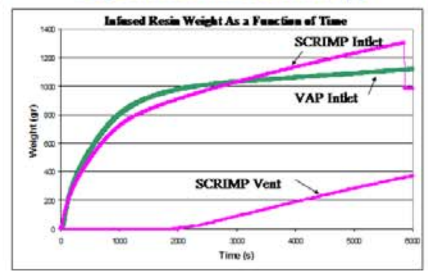
Limitations

- x Additional labor required for bagging
- x Cost for membrane
- x Excessive resin in part
- x Surface flow can not be visually observed

Experimental Set-Up for VAP



Experimental Results (I)



- Resin bleeding typical in SCRIMP process
- No resin bleeding in VAP process

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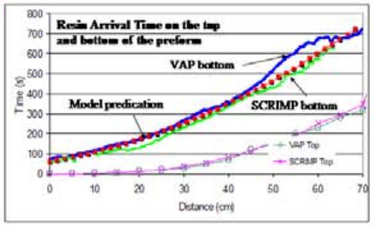
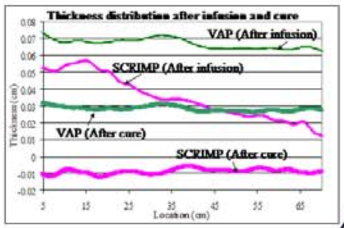
Experimental Results (II)



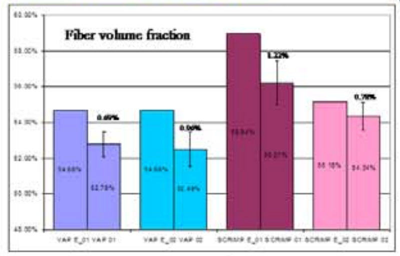
- The flow behavior of SCRIMP and VAP parts are similar
- Experimental data fit well with the model prediction

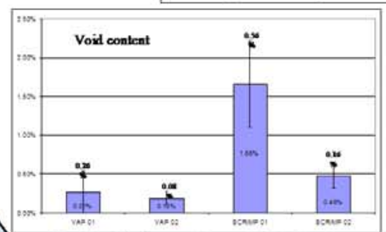
- VAP has smaller thickness gradient compared to SCRIMP parts after infusion
- Thickness change and final thickness in VAP depends on total infused resin weight
- SCRIMP parts are thinner due to allowable resin bleeding
- Large cure time of SC15 allows SCRIMP parts to have minimum thickness gradient after cure



Experimental Results (III)

- SCRIMP parts show higher fiber volume fraction, but also potential higher void content compared to VAP parts because of excessive resin bleeding

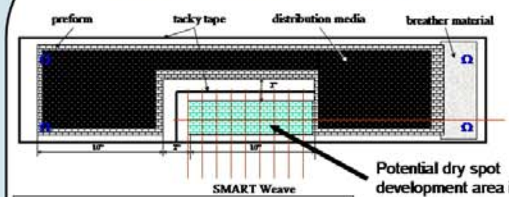




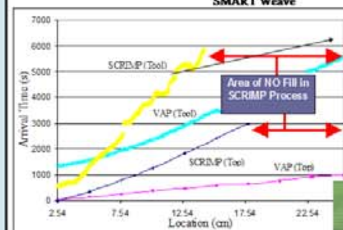
- SCRIMP parts show higher void content compared to VAP parts

• Degassing of the resin • Post cure of the infused panels

Experimental Results (IV)



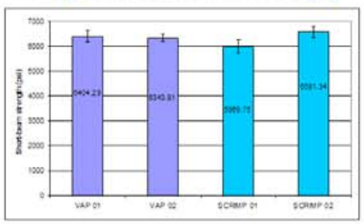
Potential dry spot development area in SCRIMP process, while full wet-out in VAP process



X Dry spot developed in SCRIMP process

⇒ Process robustness validation

Experimental Results (V)



• Degassing of the resin
• Post cure of the infused panels

- Two VAP parts have very similar short beam shear strength due to the more uniform fiber volume fraction and void content
- Despite the high fiber volume fraction in SCRIMP 01, it shows lower short beam shear strength due to the higher void content in the part

Summary

- **Flow Behavior**
  - The flow behavior of VARTM and VAP parts are identical, small flow variation are due to preform variation
  - No resin bleeding during VAP (small membrane breach near infusion line)
  - Resin bleeding in VARTM allows infusion shut-off when resin net-gain falls below zero
  - Continued infusion during VAP after complete fill increases thickness → IMPORTANT to understand optimum resin weight for full infusion in VAP process
- **Thickness**
  - VAP has smaller thickness gradient (almost zero gradient) compared to VARTM parts after infusion
  - Thickness change and final thickness in VAP depends on total infused resin weight
  - VARTM parts are thinner due to allowable resin bleeding
  - Large cure time allows VARTM parts to have minimum thickness gradient after cure

Summary (Contd.)

- **Fiber Volume Fraction and Void Content**
  - Weighting before injection and final part allowed determination of fiber volume fraction, again showing higher fiber volume fraction for VARTM, but potential dry-spot development because of excessive resin bleeding
  - VAP parts show lower standard deviation in fiber volume fraction and void content
- **Short beam strength**
  - Parts from VAP process have better mechanical property compared with SCRIMP process
  - Optimizing the fiber volume fraction during VAP processing will likely result in further improvement of the mechanical properties.
- **Process robustness**
  - VAP process allows for continuous application of vacuum through the membrane throughout the panel
  - The correct placement of the vent location is not critical to the successful infusion of the preform

Future Work

- Influence of VAP layer on opposite side of distribution media
- Vacuum gradient / level on the VAP layer
- Modeling of VAP process
- Automated Shut-Off of VAP Process to maximize fiber volume fraction
- VAP for elevated Temperature VARTM

Acknowledgements

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