MEMBRANE BASED VARTM VACUUM ASSISTED PROCESS (VAP)

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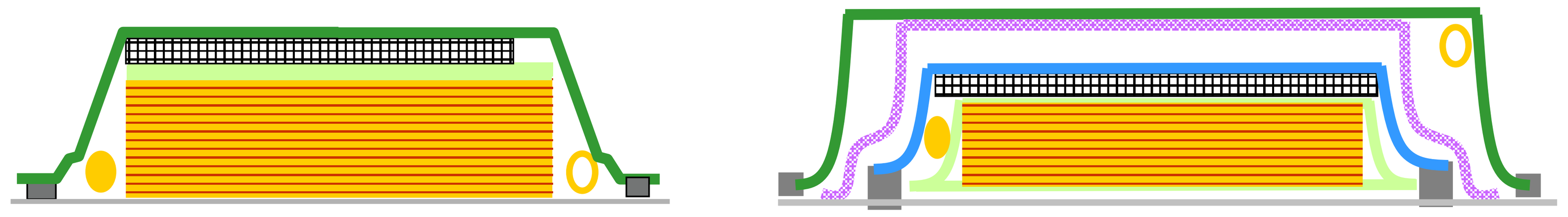
VARTM v. VAP

Distribution Media		Membrane		Sealing	
Peel ply		Breather cloth		Injection line	
Fabric lay-up		Bagging film		Vent	



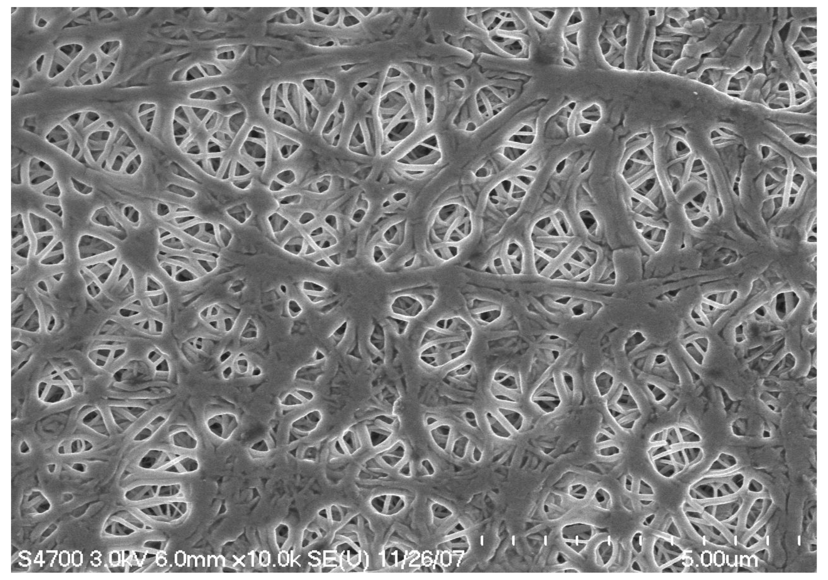
- Vacuum Assisted Resin Transfer Molding (VARTM) is a prolific composites manufacturing process.
  - A one sided tool is loaded with a dry fabric pre-form and covered by a bagging material.
  - Vacuum is applied to the vent line. It compacts the fibers and draws resin into the pre-form through the injection line.
- The Vacuum Assisted Process (VAP) incorporates an air permeable membrane into the setup.
  - The setup is identical to traditional VARTM except for the addition of the membrane and the bleeder cloth.
  - The membrane is impermeable to resin and permeable to air. Air bubbles only have to travel the thickness of the part greatly reducing voids and air bubbles; consequently increasing part quality.

MEMBRANE

- The membrane is composed of a porous Teflon ® membrane.
  - The membrane is approximately 50 – 100 nm thick and contains pores between 50 and 400 nm in diameter.
  - This extremely thin Teflon ® membrane is extremely delicate so it is typically adhered to a support material that is 200 – 400 nm thick.
  - Membrane and support properties differ so stretching becomes a complicated phenomenon since they are bound together.

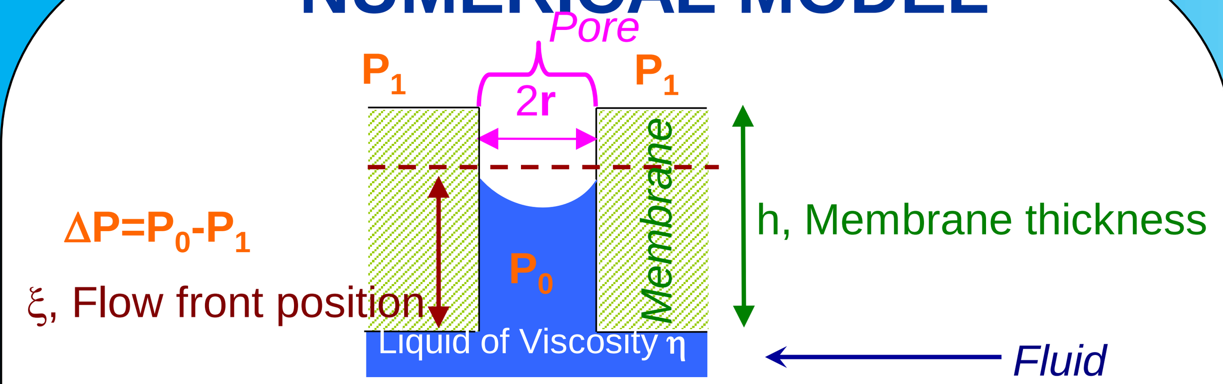
- Membrane performance is exceptional in controlled conditions, but application has found that stretching the membrane will initiate leaks and deleteriously influence the part quality.
  - The benefits of the membrane are currently limited to parts with simple geometry to mitigate the stretching issues of complex geometries.

Future Model and Validation

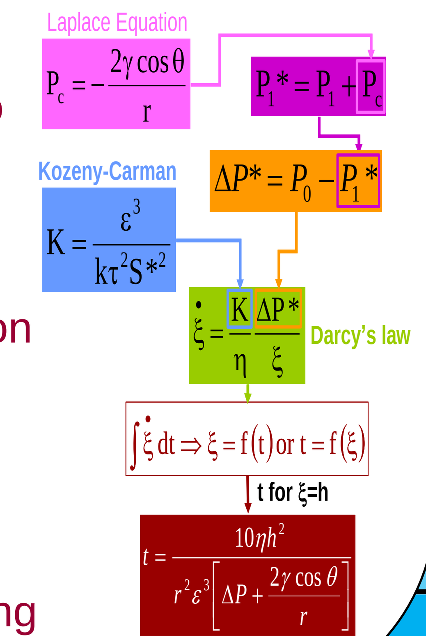


- SEM Images show a series of nodes connected by fibrils.
- The idealized numerical model works for the unstretched membrane, but exhibited limitations in stretched membranes.
- Characterization of the node size, fibril size, and fibril length will be used to generate a 2D or 3D CAD model. Fluid and multiphysics analysis can then virtually evaluate the permeability of candidate resins.
- Once the capillary pressure is determined in the virtual world with stretched and unstretched membranes, we will compare them to experimental values and adjust the model parameters accordingly.
- Experimental validation of the model will be performed with:
  - SEM
  - Porometry
- Membrane that has been stretched 0, 5, 10, 15, 20, 25, 30% will be examined. Gross tearing of the support occurs between 25 – 30%.

NUMERICAL MODEL

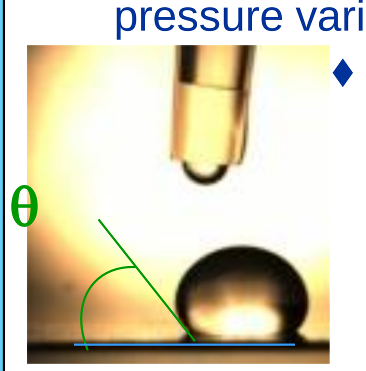


- Research has isolated the critical parameters of resin compatibility.
  - A numerical model was created to characterize the membrane as a pore.
  - Darcy's Law and the liquid properties showed great correlation between theoretical and experimental permeability.
- Production identified excessive stretching to cause leakage.
  - A model that includes the stretching influences is desired.



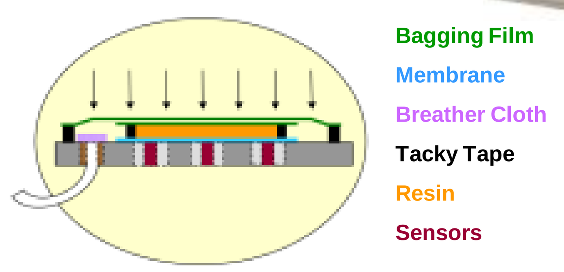
NUMERICAL MODEL VALIDATION

- Capillary pressure was determined to be the most influential parameter in the model. The 3 capillary pressure variables were evaluated and investigated:

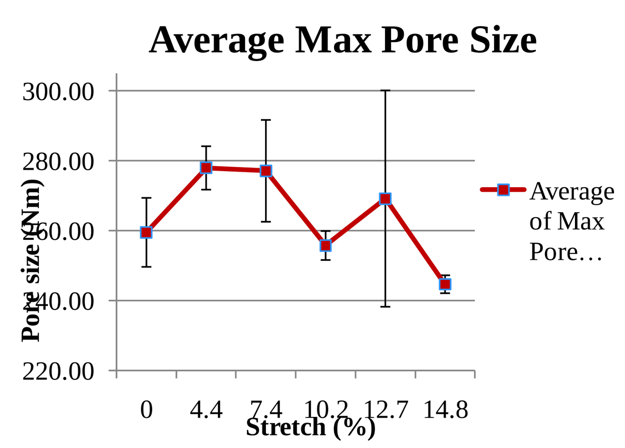


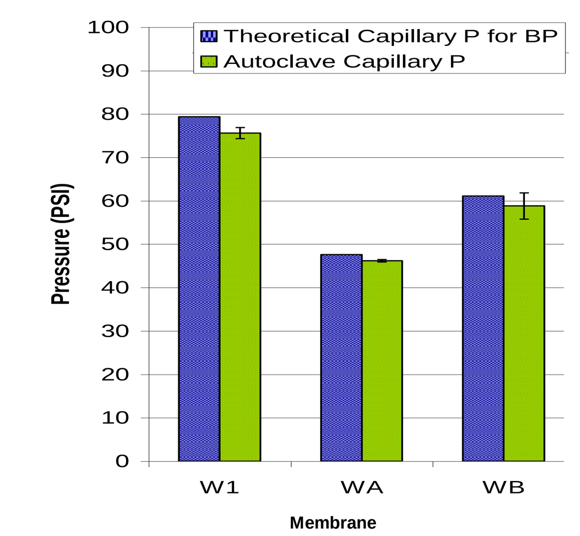
- Contact Angle
  - Contact angle was evaluated by dropping fluids onto the membrane, capturing images with a high speed camera (1000 fps) and using computer software to calculate the angle.
  - Contact Angles less than 90° would immediately wet the membrane.
  - Average for HPLC: 109.1°
- Pore Size
  - A Capillary Flow Porometer was used to measure the largest (bubble point), average, and smallest pore sizes in the membranes.
  - Bubble Point: 259.50 nm Average Pore: 88.93 nm

- Autoclave: Experimental Verification
  - The input parameters were used to validate the accuracy of the numerical model.



Current Stretching Experiments





- The model did not account for stretching. A model incorporating micromolecular mechanics is desired to predict resin compatibility and stretch capable before leakage.
- Un-stretched membranes had extremely close correlation between the theoretical and experimental values.

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