INFUSION DESIGN OF PREFORMS WITH SEMI-PERMEABLE BARRIER LAYERS

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PROGRAM OVERVIEW

- ♦ Problem Description
- ♦ Finite Element Model Implementation
  - ✧ Mesh Design
  - ✧ Material Data
  - ✧ Baseline Study
- ♦ Case Study
  - ✧ Number of holes in the core section
  - ✧ Hole size (diameter)
  - ✧ Influence on Flow media Permeability
  - ✧ Influence of the Preform Thickness
- ♦ Experimental Validation
- ♦ Discussions and Conclusions

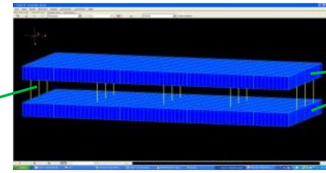
PROBLEM DESCRIPTION

Schematic Representation of the Problem

- ♦ The flow behavior depends on many materials and process conditions and are mainly Governed by:
  - ✧ Geometry (diameter and height) of the interconnecting flow channels
  - ✧ Spacing of the channels
  - ✧ Distribution and fabric permeability
  - ✧ Preform thickness
  - ✧ Resin viscosity

FINITE ELEMENT MODEL

Mesh Design



- ♦ A total of about 6000 elements
- ♦ Top and bottom layers connected with 1-D elements representing (15) channels in the core
- ♦ Flow media is modeled as 2-D elements on the complete top surface of the reinforcement
- ♦ Infusion line modeled as a 1-D channel located on the left edge of the top preform

MATERIAL DATA

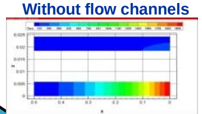
- ♦ Preform used is 24oz woven roving E-glass (324-407) from Mahogany
- ♦ Flow media is 50% shading material from Rockwell

Panel Length	0.5m
Panel Thickness (10layers)	0.005842m
Panel width	0.2m
Preform Fiber Volume Fraction	0.5
In-plane preform permeability	3.6e-11m^2
Through thickness preform Permeability	9.2e-13m^2
Core Thickness	0.0127m
Flow channel Diameter	0.003175m
Flow Channel Permeability	3.15e-7m^2
Distribution media Permeability	2.6e-9m^2
Distribution media thickness	0.0013m
Distribution media voulme fraction	0.1
Resin Viscosity	0.1Pas

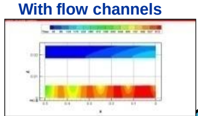
BASELINE RESULTS

- ♦ The top surface infusion of both scenario are identical
- ♦ A potential solution used in industry is to connect the two reinforcement sides through the core material using drilled out holes.
- ♦ The channels reduce the overall fill time from 2128s to 716s by virtually dividing the bottom Panel into smaller sections which are concurrently infused from the flow channels in the core.
- ♦ The flow times on the surface still depend on the distribution media properties while the bottom flow is influenced by the number and size of the interconnecting channels as well as the fabric material permeability.

Without flow channels

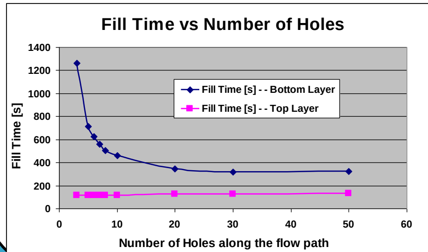


With flow channels

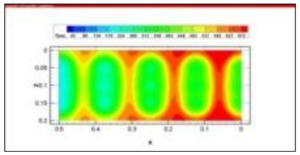


VARYING NUMBER OF HOLES

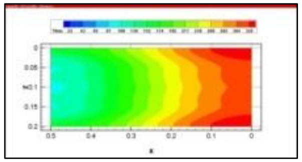
- ♦ More holes will reduce the required flow path and reduce overall fill time but not eliminate the final dry spot area
- ♦ Nevertheless, flow fronts converge and potentially create dry-spots when the void area is separated from the vent port



VARYING NUMBER OF HOLES



5 Holes



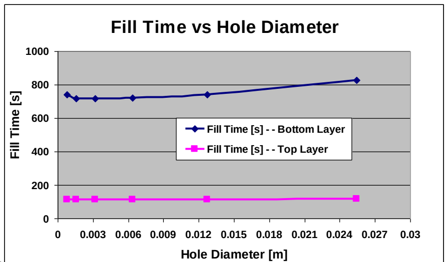
20 Holes

INFUSION DESIGN OF PREFORMS WITH SEMI-PERMEABLE BARRIER LAYERS

(Continued)

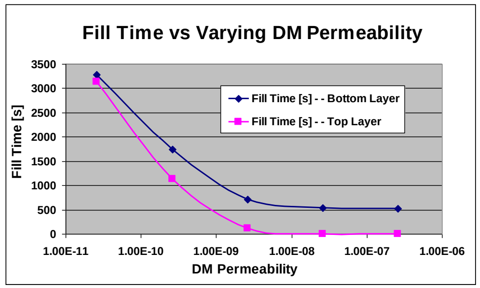
VARYING HOLE SIZE

- It can be seen that for diameters smaller than 0.0016m (0.0625in) the fill time increases as the pressure drop in the flow channel builds up
- Large diameter holes greater than 0.012m will increase the infusion time of the bottom layer as the channel volume has to be completely filled before resin can be transferred into the bottom layer
- An optimum diameter would try to reduce the resin uptake in the channel to reduce any apparent density increase of the core while providing minimum infusion times
- In this case a hole diameter between 0.0016m and 0.006 would be recommended

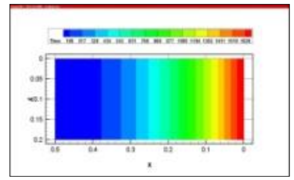


VARYING FLOW MEDIA PERMEABILITY

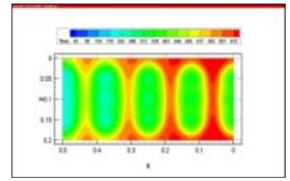
- For low permeabilities the fill time is equivalent to the RTM process setup
- The fill time of the bottom layer reaches a plateau where filling of the holes is almost instantaneous and fill time is governed by the in-plane Impregnation of the fabric in between holes
- The dry-spot development is affected by the selection of the distribution media permeability



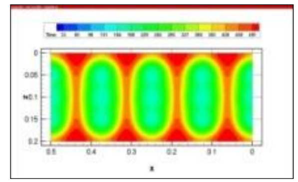
VARYING FLOW MEDIA PERMEABILITY



DM = 0



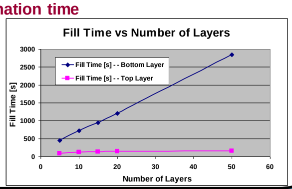
DM = 2.6e-9m^2



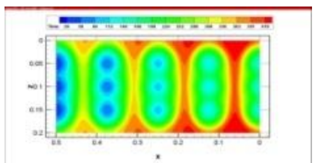
DM = inf

VARYING PREFORM THICKNESS

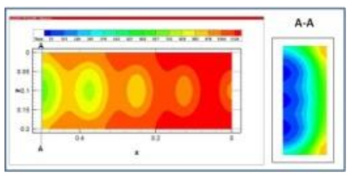
- The flow time increases from 447 seconds from 5 layers to 1204 seconds for 20 layers and shows an almost linear relationship with increasing number of layers
- This demonstrates that in the case study the flow on the bottom layer is limited by the flow rate coming through the holes.
- Thus an increase of fill volume due to more reinforcement leads to the linear increase in the impregnation time



VARYING PREFORM THICKNESS



5 Layers of Preform



20 Layers of Preform

DISCUSSIONS/CONCLUSION

- The study simulates various infusion scenarios using a partially impermeable core (SCRIMP process) with the LIMS flow simulation software .
- Holes integrated in the impermeable core results in non-uniform in- plane and out-of-plane flow behavior. This leads to potential dry spots formation in the preform and large differences in infusion times.
- It is important to optimize the number and geometry of the flow channels integrated into the core.
- Increasing the permeability of the flow media reduces the fill time of both top and bottom layer. Nevertheless, a very high permeability maximizes the potential dry-spot formation in the bottom layer.
- This work outlines a design methodology based on finite element flow simulation and can be applied to any material form (incoming fabric, core or resin) and used to optimize the layup.

FUTURE WORK

- Experimental Validation of all the simulation results

ACKNOWLEDGEMENTS

This work is supported by the Office of Naval Research through the Advanced Materials Intelligent Processing Center Program.

Thanks to Justin Alms for helping generate the mesh and Pavel Simacek for helping to understand the LIMS software