FABRIC PERMEABILITY TESTING AND THEIR USE IN INFUSION SIMULATION

Justas Sirtautas, Anthony K. Pickett
Institute of Aircraft Design, University of Stuttgart
Institut für Flugzeugbau, Pfaffenwaldring 31, 70569 Stuttgart, Germany
E-mail: sirtautas@ifb.uni-stuttgart.de, web page: http://www.ifb.uni-stuttgart.de
Keywords: Permeability, Infusion, Simulation, Composites

IFB Institut für Flugzeugbau
Institute of Aircraft Design

INFUCOMP *

SEVENTH FRAMEWORK PROGRAMME

Infusion process

RTM – Resin Transfer Molding
VARI – Vacuum Assisted Resin Infusion

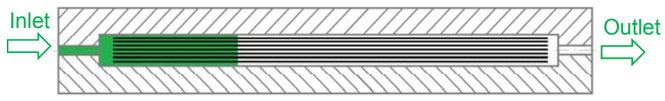
Darcy's law:

$$v = -\frac{1}{\phi\mu} K \cdot \nabla P$$

Continuity equation:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0$$

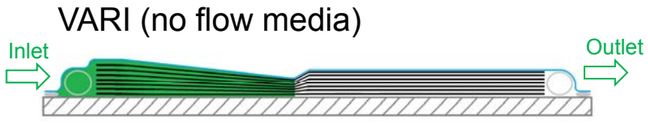
RTM



- 2D infusion
- V_f = const.

$$K = \begin{bmatrix} k_1 & 0 \\ 0 & k_2 \end{bmatrix} = const.$$

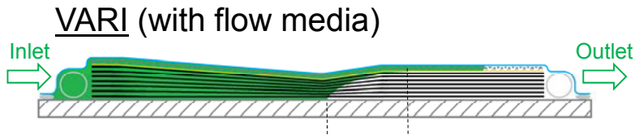
VARI (no flow media)



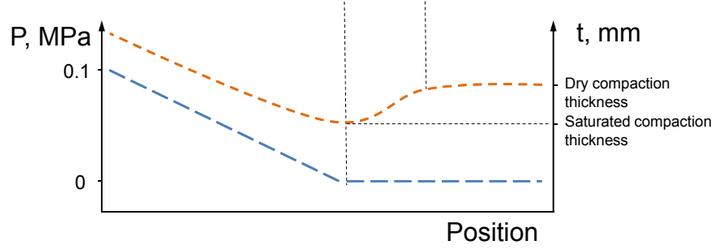
- 2D infusion
- $V_f \neq$ const.

$$K(V_f) = \begin{bmatrix} k_1(V_f) & 0 \\ 0 & k_2(V_f) \end{bmatrix}$$

VARI (with flow media)

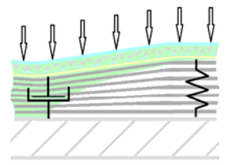


- 3D infusion
- $V_f \neq$ const.



$$K = f(V_f, t, P)$$

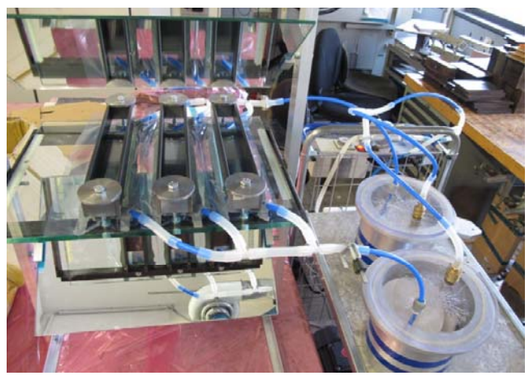
$$P = P_{resin} + P_{preform}$$

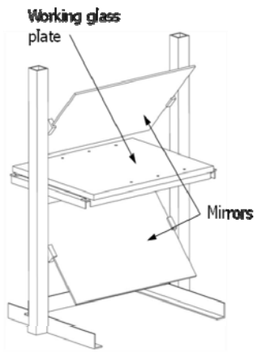


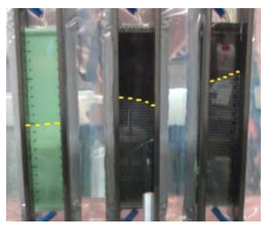
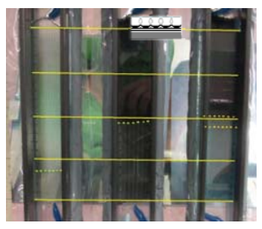
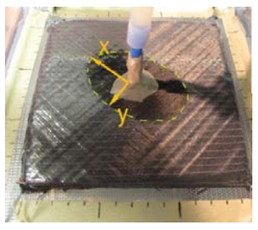
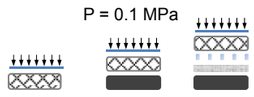
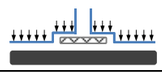
$$K(V_f) = \begin{bmatrix} k_1(V_f) & 0 & 0 \\ & k_2(V_f) & 0 \\ sym & & k_3(V_f) \end{bmatrix}$$

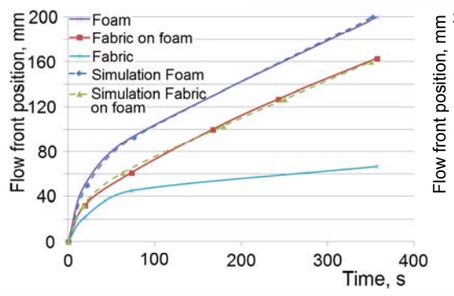
Figures adapted from [1]

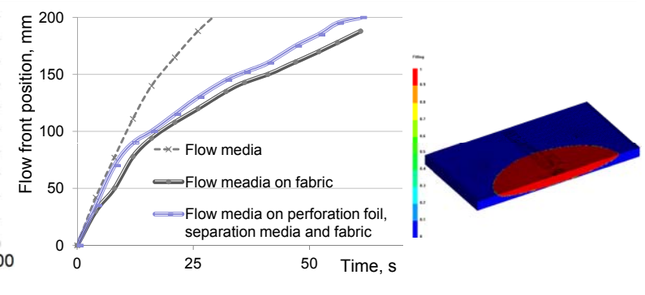
Permeability testing was performed on the *fabric* (quasi UD), *flow media* and several stacks' *interfaces*, namely *foam-fabric* and *flow media-fabric* (effective permeability of the corresponding interface is reduced due to nesting). Through-thickness fabric permeability was estimated via one point infusion test[2] and simulation fitting[3] (resin used was RIMR235-H237).



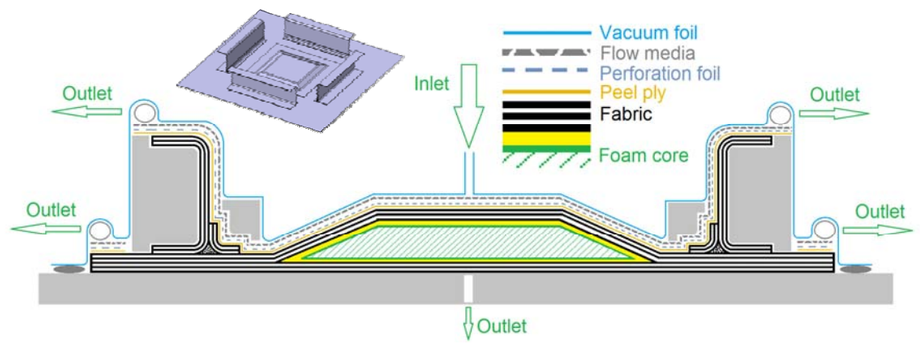


Foam-fabric interface	*Flow media-fabric* interface	*Fabric* through-thickness
		
P = 0.1 MPa	P = 0.1 MPa	P = 0…0.1MPa
		
7.1E-11 | 3.7E-11 | 2.3E-11	8.0E-10 | 3.5E-10 | 4.1E-10	5.0E-13
K_x, m²		K_z, m²

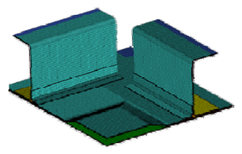




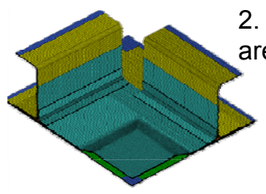
Demonstration module consists of four C-Spars molded to an outer skin. The central portion of the panel uses a sandwich construction filled with foam core.



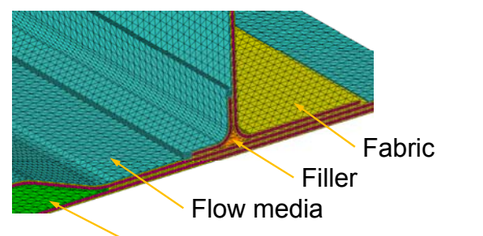
Simulation models represents a quarter of module, with separate FE layers for each fabric ply (~700 000 elements).



1. Flow media on all surfaces

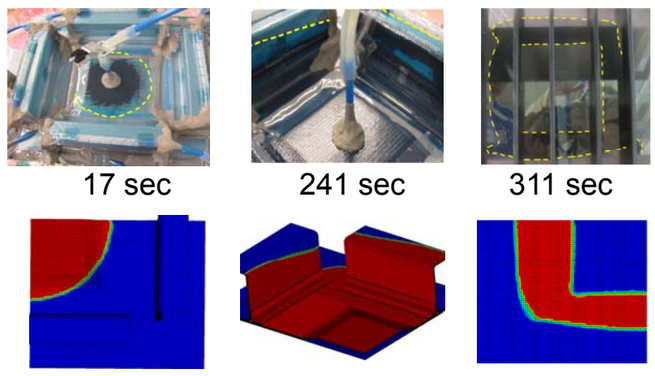


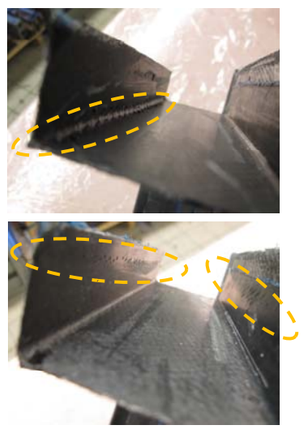
2. Flow media area reduced



Tests and simulations results comparison

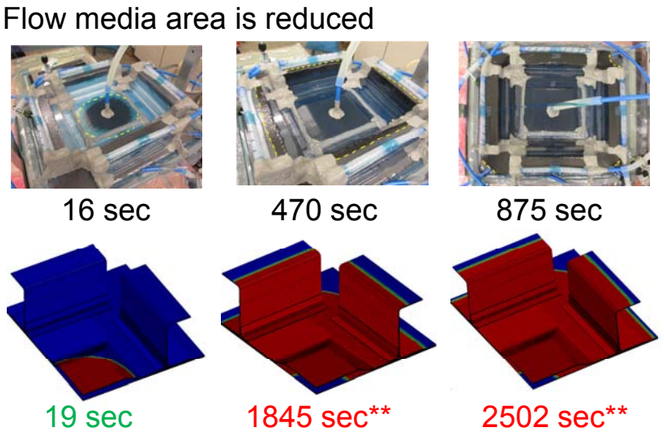
1. Flow media on all surfaces

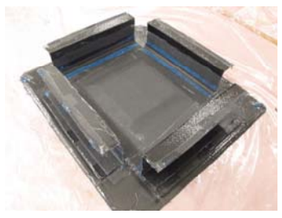




Filling defects

2. Flow media area is reduced





Cured module

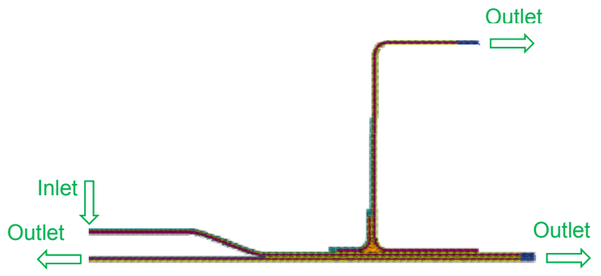
PAM-RTM™ software[3] was used for simulations.
** - pronounced disagreement between test and simulation filling times is due to VARI specific phenomena (e.g. thickness and permeability variation) which are not taken into account in the current simulation model

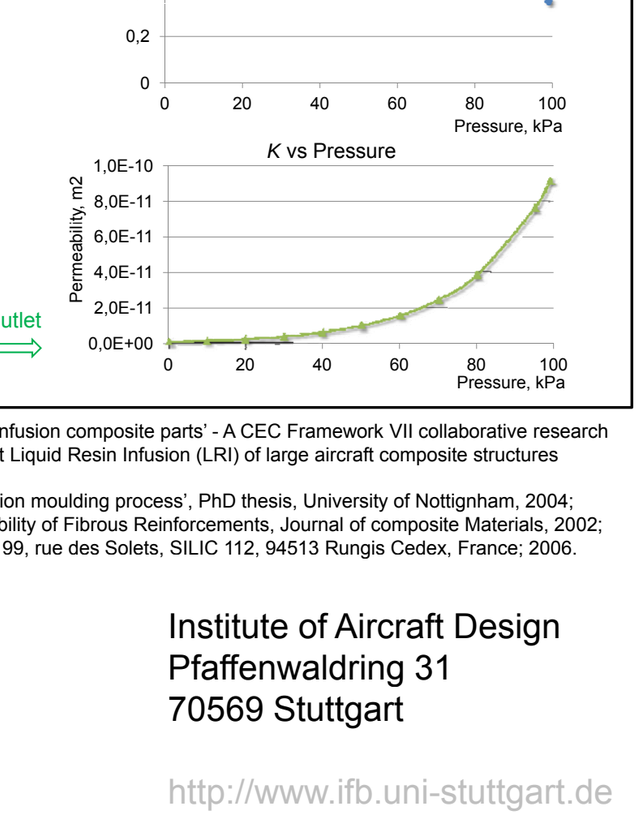
Conclusions

- boundary interface effects have to be taken into account
- changing pressure results in variable preform thickness (V_f) and permeability
- for accurate simulation the above effects have to be accounted for

Future work

- 2D and 3D simulation with permeability and fiber volume fraction as a function of pressure





Preform thickness change during VARI process (GOM-Aramis optical measurements system)

* - 'Simulation based solutions for industrial manufacture of large infusion composite parts' - A CEC Framework VII collaborative research project to develop new technologies and simulation tools to predict Liquid Resin Infusion (LRI) of large aircraft composite structures (Coordinator: Anthony Pickett (ESI GmbH, Germany);
[1] - Nuno André Curado Mateus Correia, 'Analysis of Vacuum Infusion moulding process', PhD thesis, University of Nottignham, 2004;
[2] - Nedanov P.B., Advani S.G., A method to determine 3D Permeability of Fibrous Reinforcements, Journal of composite Materials, 2002;
[3] - PAM-RTM™. ESI Software Engineering Systems International, 99, rue des Solets, SILIC 112, 94513 Rungis Cedex, France; 2006.

Universität Stuttgart
University of Stuttgart

Institute of Aircraft Design
Pfaffenwaldring 31
70569 Stuttgart

http://www.ifb.uni-stuttgart.de