REPEATABILITY OF THE VARTM PROCESS IN ORDER TO ACHIEVE AERONAUTICS REQUIREMENTS

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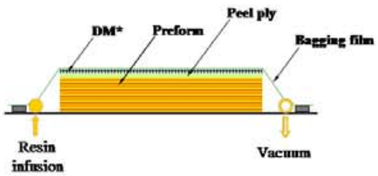
OBJECTIVE

➢Achieve a repeatable VARTM process by
- identifying,
- understanding,
- evaluating, and
- controlling

the sources of variation of the final parameters

➢For aeronautical grade composite parts



Schematic of a VARTM lay-up

MOTIVATION

➢ VARTM advantages:
- Low cost
- Large scale parts

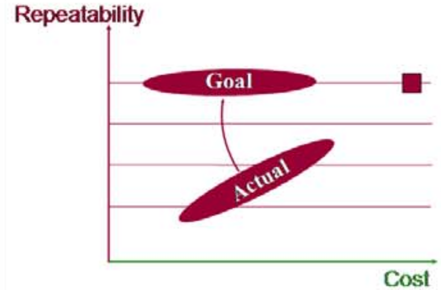
→ Very attractive process for the aerospace industry

➢ but still some limitations, especially:
- High variability
  - From part to part
  - In the same part

→ Aerospace grade composite parts hard to achieve

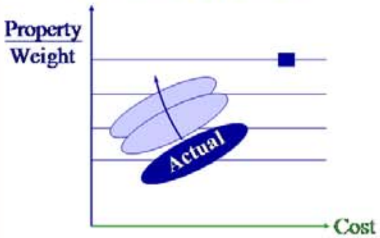
⇒The repeatability of the process has to be improved

VARTM vs. AUTOCLAVE Repeatability



Conditions to propose the VARTM process to the aerospace industry
- Process as repeatable as the autoclave (reference)
- Lower properties but much lower cost

VARTM vs. AUTOCLAVE Specific properties



A lower variation (higher repeatability) in properties improves the design allowable

PARAMETERS OF INTEREST

◆ Preform

df	Diameter of the fibers
ρ_f	Density of the fibers
R_{tows}	Radius of the tows
S_{tows}	Saturation of the tows
Vf_{tows}	Fiber volume fraction of the fiber tows
K_{tows}	Permeability of the fiber tows
ρ_A	Areal density of the fabric
ϕ	Porosity of the fabric
K	Permeability
Cp	Compressibility
C	Compaction
th_i	Thickness of the final preform
Vf_{wet}	Fiber volume fraction - Wet fibers
Vf_{dry}	Fiber volume fraction - Dry fibers
n_{debulk}	Number of debulking cycles
P_{debulk}	Pression of the debulking cycles
Binder	Presence of binder

◆ Resin

μ_R	Viscosity of the resin
Er	Young's modulus of the resin
θ	Contact angle
P_{deg}	Degassing pressure
t_{deg}	Degassing time
Tg	Glass transition temperature
	Cure kinetics

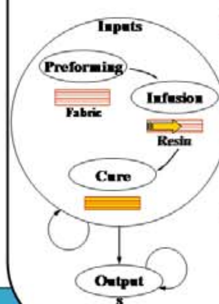
◆ Infusion

K_{DM}	Permeability of the DM
V	Vacuum pressure
Q	Flow rate
$t_{infusion}$	Infusion time
tgel	Gel time
Tgel	Gel temperature
ax,y,z	Vent location

◆ Final parameters

Vf_f	Final fiber volume fraction
Vv_f	Final void content
th_f	Final thickness
TS_f	Tensile strength
CS_f	Compression strength
$OHCS_f$	Open hole compression strength
σ_{flf}	Flexural strength
ILLS	Interlaminar shear strength
Kc	Toughness
E_f	Young's modulus

INFLUENCE OF PROCESSES AND MATERIALS ON REPEATABILITY



➢Inputs
- Incoming materials
- Infusion parameters
- Cure parameters

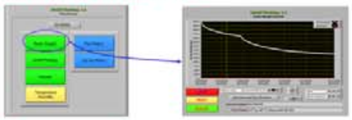
➢Outputs
- Quality of the part
- Mechanical properties

PROCESSES EXPERIMENTS

The SMARTMolding set-up is used to manufacture panels

ANALYSIS OF THE DATA

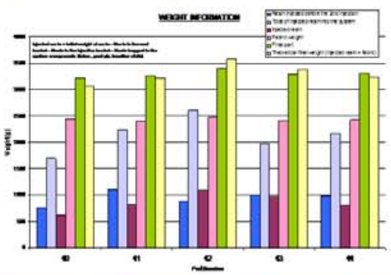
➤**LabVIEW Interface**



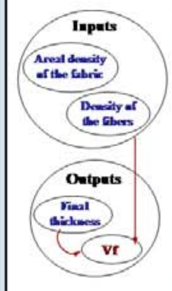
(Example with the resin weight data)

➤**Data reduction**

Example with all weights' data



METHODOLOGY TO SCREEN THE PARAMETERS ACCORDING TO THEIR INFLUENCE



For each critical parameter

Example: fiber volume fraction

- Identify specific influent parameter
  - →*Areal density of the fabric*
  - →*Density of the fibers*
  - →*Final thickness of the part*
- Evaluate their variations
- Find the most influent parameter(s)

INFLUENCES FROM THE DIFFERENT PARAMETERS

$$Vf = \frac{n \times \rho_A}{th_f \times \rho_f}$$

$$\begin{cases} \left.\frac{\Delta Vf}{Vf}\right|_{\Delta\rho_A} = \frac{\Delta\rho_A}{\rho_A} \\ \left.\frac{\Delta Vf}{Vf}\right|_{\Delta\rho_f} = -\left(\frac{n\rho_A}{\rho_f th_F Vf}\right)^2 \frac{\Delta\rho_f}{\rho_f} \approx -0.5 \times \frac{\Delta\rho_f}{\rho_f} \\ \left.\frac{\Delta Vf}{Vf}\right|_{\Delta th_F} = -\left(\frac{n\rho_A}{\rho_f th_F Vf}\right)^2 \frac{\Delta th_F}{th_F} \approx -0.5 \times \frac{\Delta th_F}{th_F} \end{cases}$$

The study focuses on parameters' gradients, not on parameters' absolute values.

MOST INFLUENT PARAMETER REGARDING TO Vf ?

$$\left.\frac{\Delta Vf}{Vf}\right|_{\Delta th_F} = -5\%$$

$$\left.\frac{\Delta Vf}{Vf}\right|_{\Delta\rho_A} = 3.34\%$$

$$\left.\frac{\Delta Vf}{Vf}\right|_{\Delta\rho_f} = -2.5\%$$

The most influent parameter on Vf is the final thickness gradient.

MATERIALS PARAMETERS MEASUREMENTS

Example: permeability

PERMSTAT is used to measure the 3D permeability of the preform

CONCLUSIONS

➤ **Identification of most of the parameters involved in VARTM**
⇒ **Overview of the process**

➤ **Manufacture of panels**
⇒**SMARTMolding set-up**

➤ **Identification of some relations between the parameters**
⇒**Screening of some of the most/less important/influent parameters**

FUTURE WORK

➤**Complete the theoretical step**

➤**Manufacture of VARTM panels:**
- To create a VARTM database
- To study the feasibility of the set-up and measurements
- To focus on the parameters identified as important

➤**Make the parts more realistic regarding to aeronautics standards**
- With stiffener
- With core material

ACKNOWLEDGEMENTS

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