LOCOMACHS:
Infusion for Thickness Adaption and Ultrasonic Laminate Thickness Control

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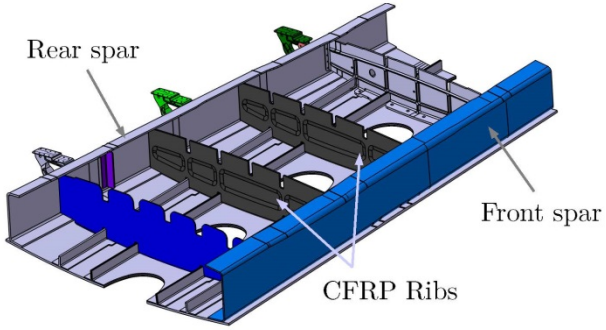
LOCOMACHS Public Forum, Coventry (UK)

16th June 2016

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement n°314003.

Objectives

- Production Ribs 2 and 3 of **L**ean **A**ssembly **W**ing **B**ox (LAWiB) by infusion of non-crimped fiber fabric
- High geometrical accuracy and laminate quality with low cost manufacturing supported by process monitoring

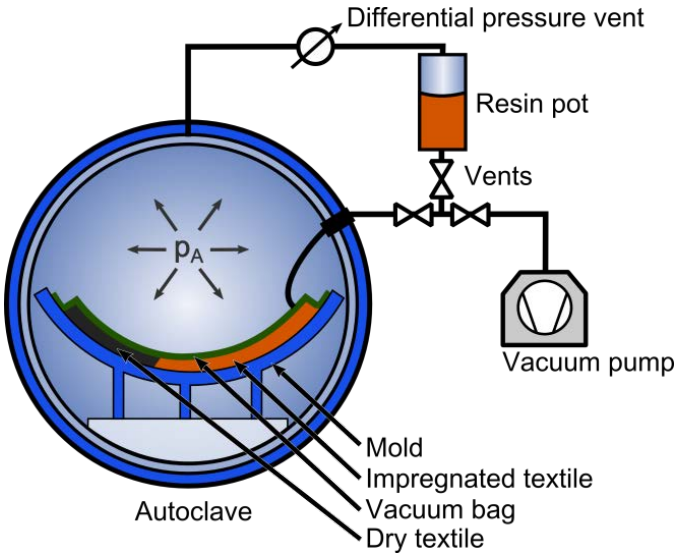


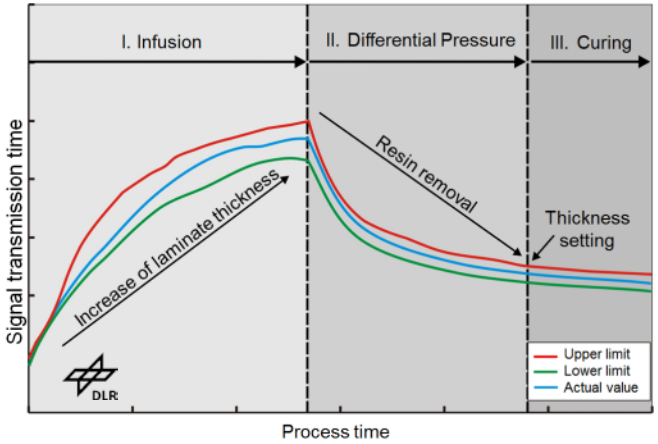
LAWiB demonstrator

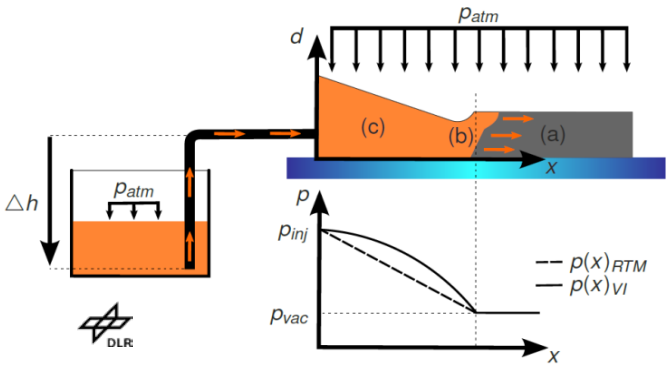
Tool concept (both ribs manufactured simultaneously on male mould)

Autoclave Infusion

- Higher pressure gradient accelerates infusion and enables high flow lengths and fibre volume content
- Infusion of NCF: cost effective, thickness variable due to flexible membrane
- Pressure adjustable for flow control → laminate thickness adaption
- Online thickness measurement by ultrasound



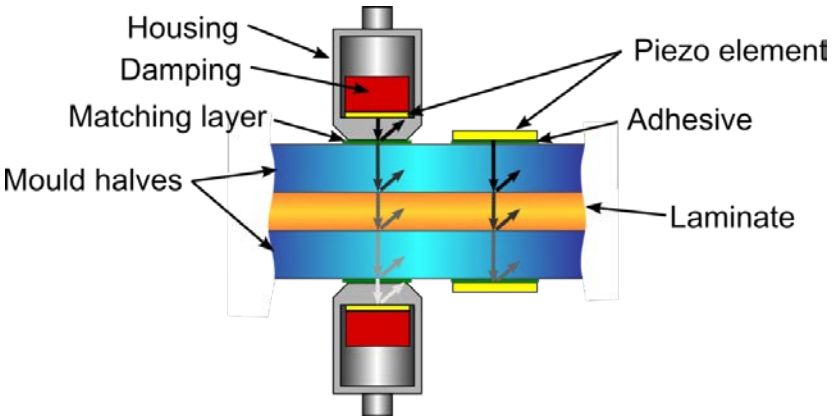




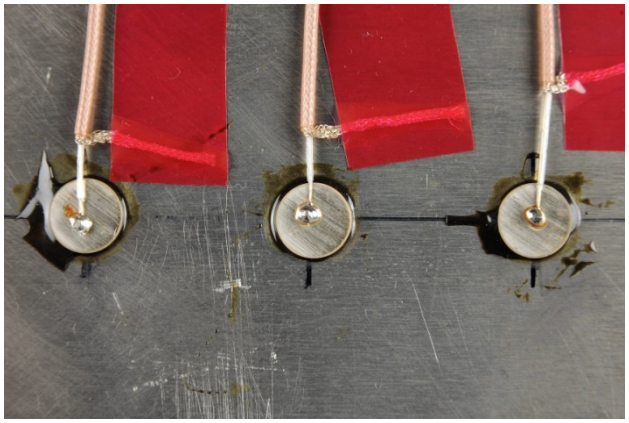
Ultrasonic Process Monitoring

- Sound impulses are sent through mould and laminate
- No direct contact to part, vacuum integrity and part surface unaffected
- Allows monitoring of resin arrival, cure, gelation, vitrification & thickness
- Conventional transducers difficult to integrate, limited temperature range
- Critical couple interface

  → Frequent fail of monitoring
- Resolved by direct application of piezo element on mould
- High reliability and measurement performance, low cost, easy integration



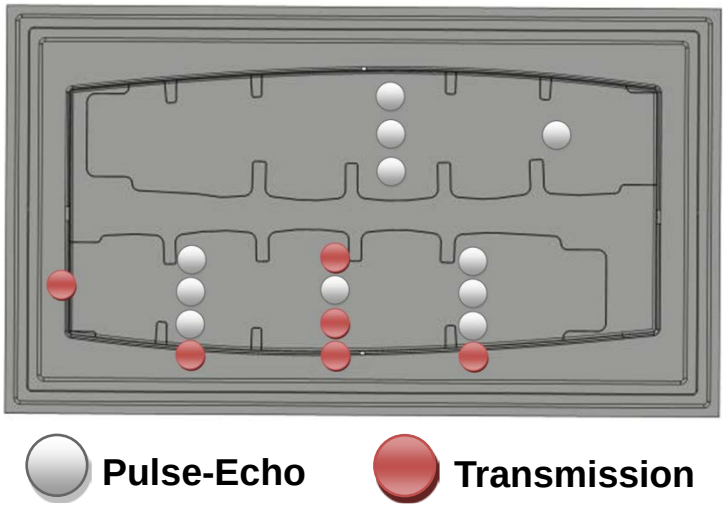
Conventional sensors versus tool mounted piezo elements

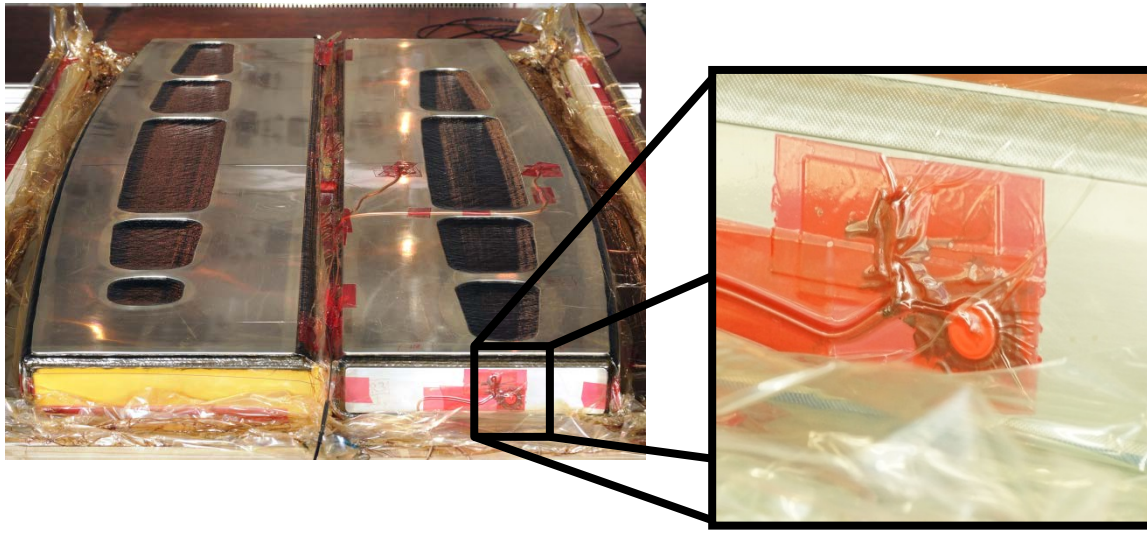


Low cost ultrasonic process monitoring sensors

Application to Rib Tool

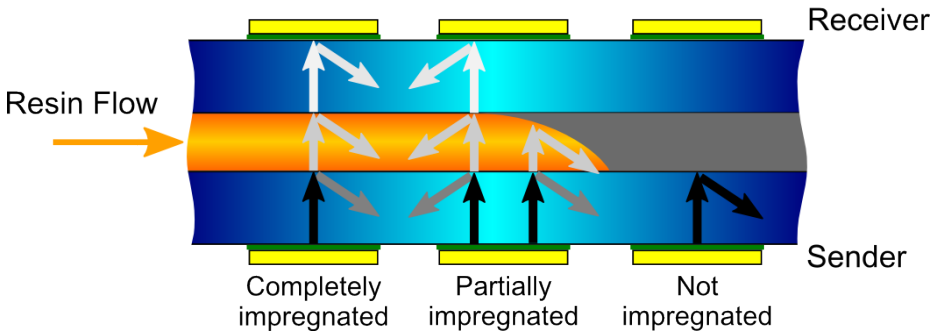
- Low cost aluminum tool
- Flange angles are Spring-In compensated
- 24 ultrasound sensors for process monitoring
- Transmission (separate transmitter and receiver) needed for thickness and cure monitoring, bag side sensors on top of caul plates
- Pulse-Echo (transmitter = receiver) sufficient for flow front monitoring

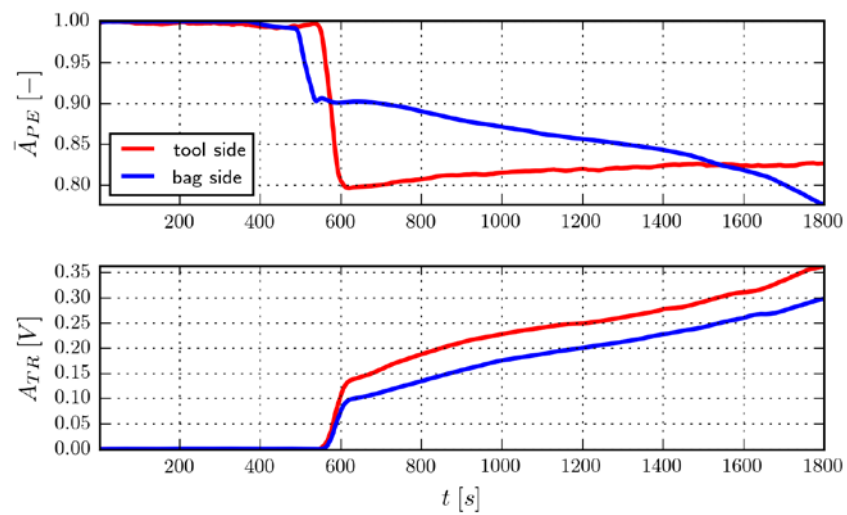




Resin Flow Front Monitoring

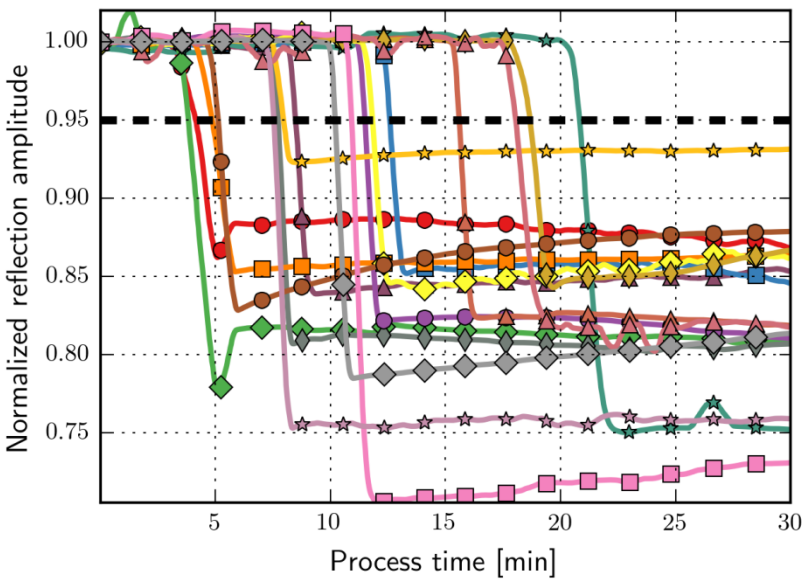
- *Pulse-Echo:* Total reflection before resin arrival → Then reflection amplitude drop
- *Transmission:* Signal reception upon resin arrival



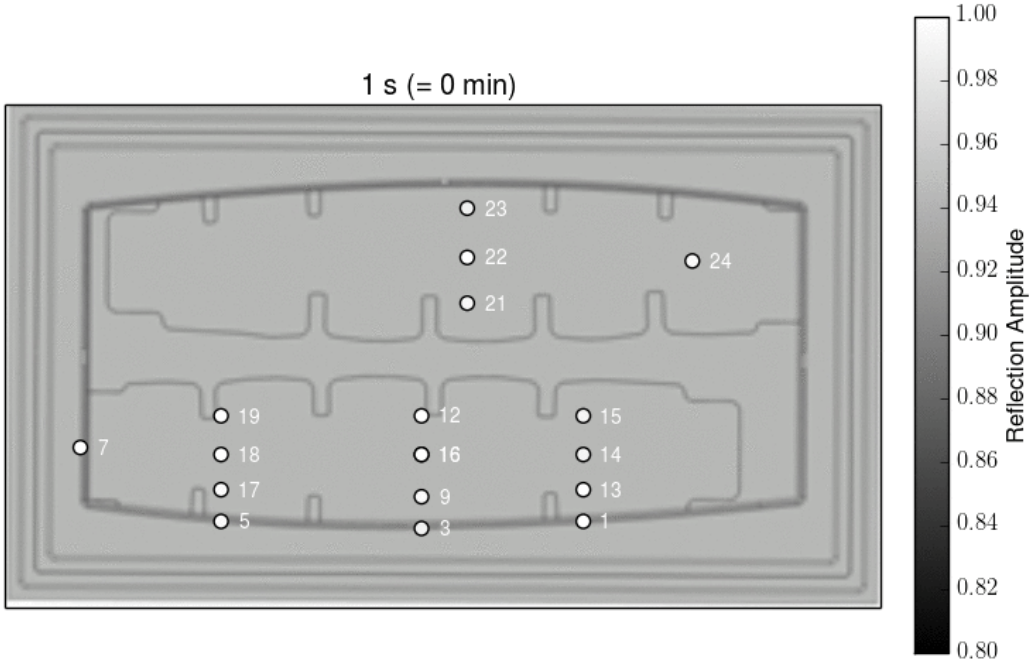


Resin Flow Front Monitoring

- Pulse-Echo results
- Determination of complete fill
- Control of symmetric impregnation of the two ribs



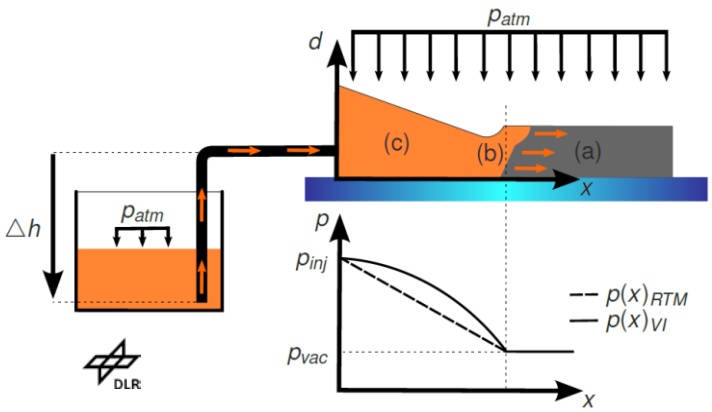
Reflection amplitude over time



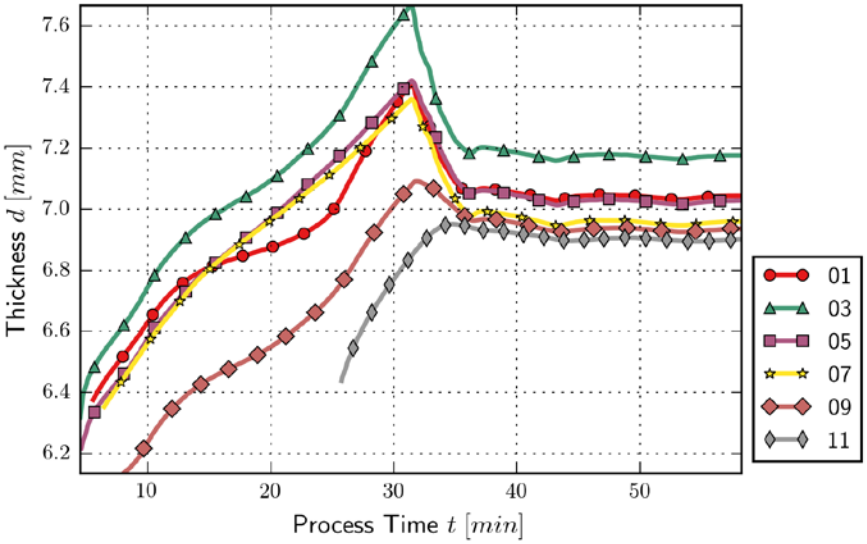
Reflection amplitude over time at sensor locations on mould

Laminate Thickness Monitoring

- After complete fill resin pressure was controlled to set laminate thickness
- Time of flight of transmission signal = Laminate thickness / Sound velocity
- In general low increase of sound velocity before gelation
- In this case very slow reacting resin at infusion temperature → Sound velocity increase negligible
- Compensation through calibration measurement or special sensor setting



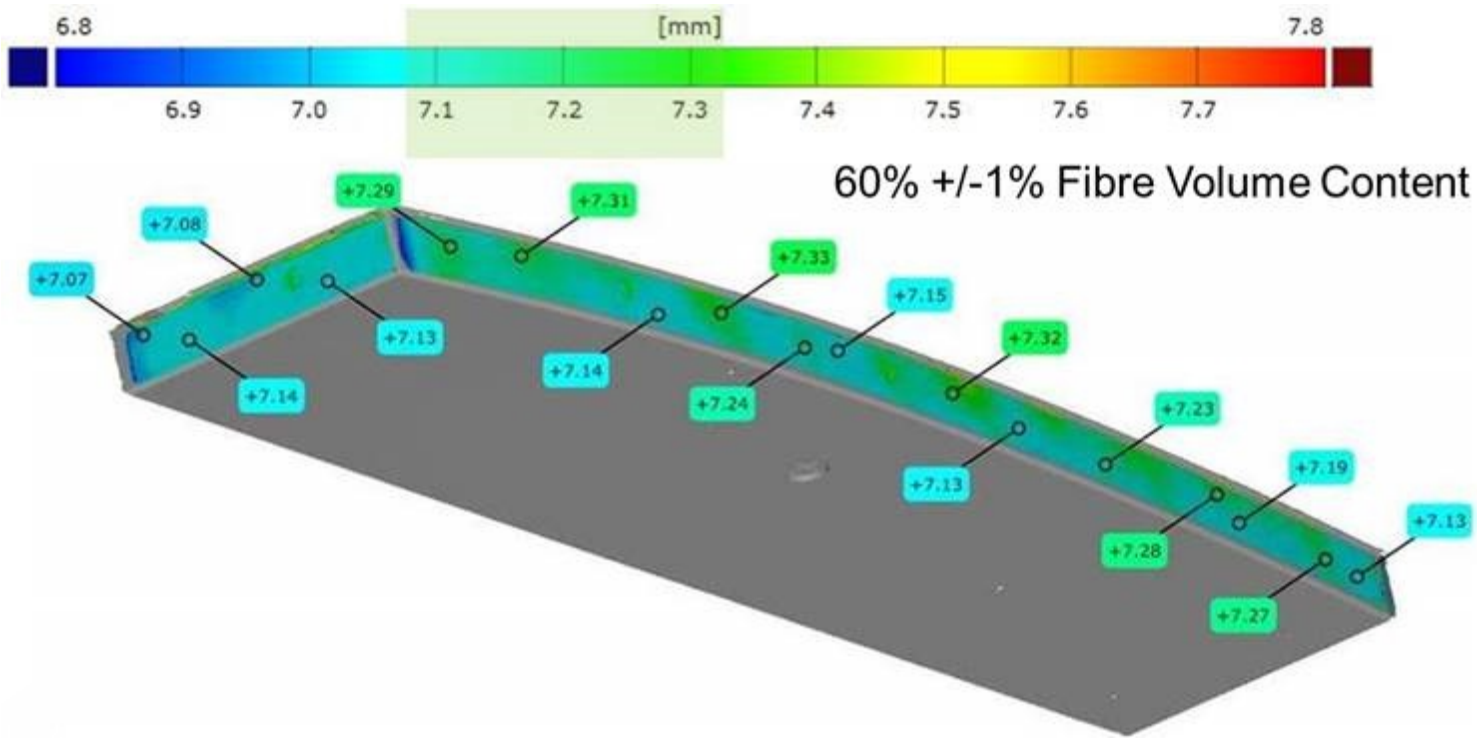
Physics of infusion process



Laminate thickness monitoring by ultrasound

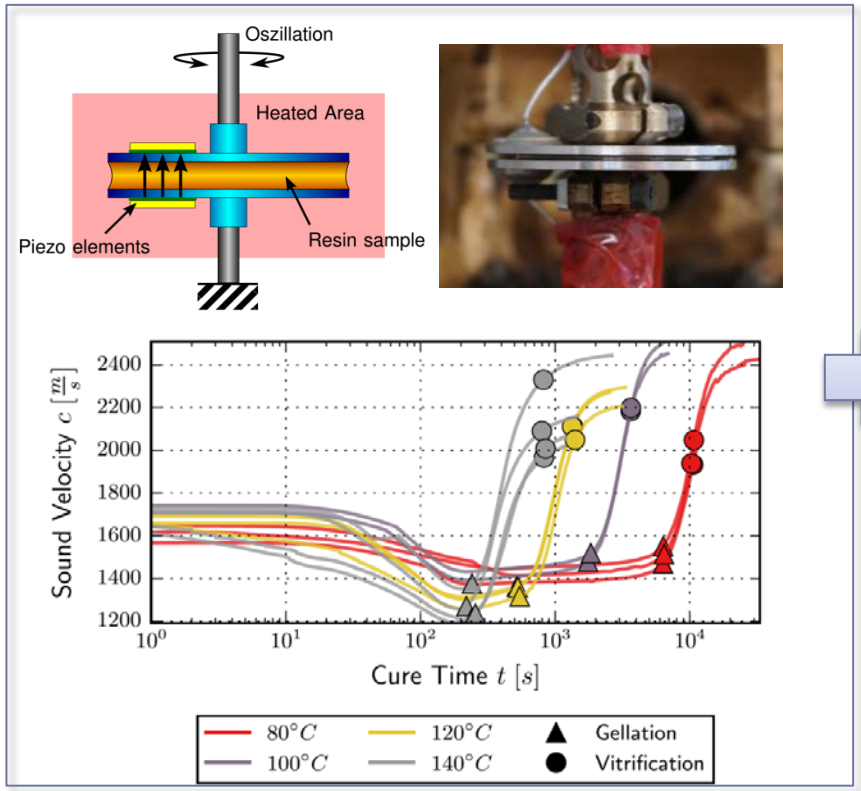
Laminate Thickness Monitoring

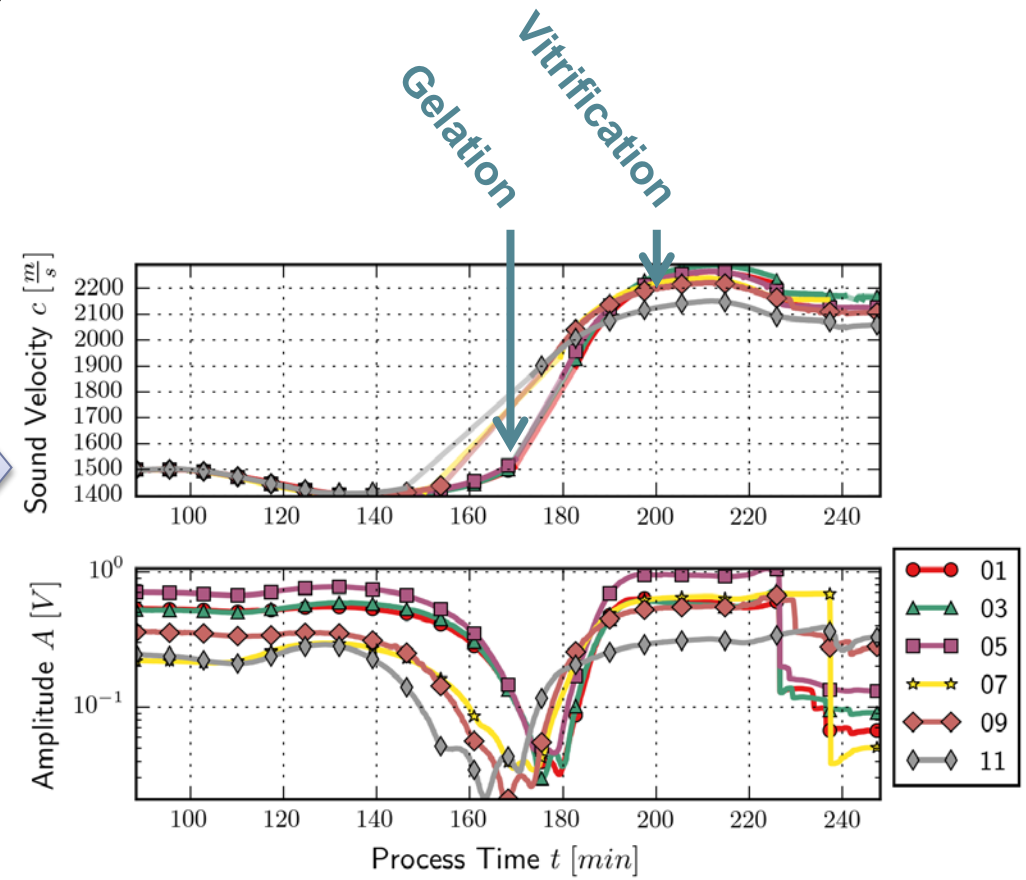
- Verification of reached thickness with GOM ATOS
- Thicknesses in tolerances, good agreement with sensor results



Cure Monitoring

- Sound velocity measurement for cure monitoring
- Gelation and vitrification: Calibration by simultaneous measurement of ultrasound velocity in rheometer





Conclusions

- Manufacturing of aeronautical wing ribs with toughened NCF
- Autoclave based infusion with low cost aluminium tool
- 24 low cost ultrasound sensors (tool mount piezo elements)
- All critical laminate parameters can be monitored and controlled:
  - Impregnation ← Resin pressure, valves
  - Laminate thickness ← Resin pressure, valves
  - Cure, gelation, vitrification ← Temperature
- Proven high technical reliability and maturity
- Innovation award with BAB, JEC show Houston 2015

Co-funded by the European Union