LOCOMACHS: Infusion for Thickness Adaption and Ultrasonic Laminate Thickness Control

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Objectives

- Production Ribs 2 and 3 of **Lean Assembly Wing Box (LAWiB)** by infusion of non-crimped fiber fabric
- High geometrical accuracy and laminate quality with low cost manufacturing supported by process monitoring

![LAWiB demonstrator](image1)

![Tool concept](image2)
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
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 \(\rightarrow\) 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 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