Process calibration – the missing link between an RTM-production line and its digital twin

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Dipl.-Ing. (FH) Sven Torstrick-von der Lieth
Automated RTM production in aerospace

...why is it that difficult compared to automotive?

- **Automated production must run 24/7**
  - High invest cost for both automation as well as RTM-tools
  - Cost only divided by number of parts

- **Robust process needed**
  - To avoid 100% inspection of each individual part
  - Rework is not an option

- **Shipset-wise production of multiple parts ("lotsize 1")**
  - Many different tools needed → more invest!
  - Flexibility makes process more complex → less robust!
Researchplatform „EVo“

**key features:**
- net shape preforming
- isothermal injection
- automated mould exchange
- inline-QA
- automated mould preparation (in progress)

**Automated Preforming & RTM production line**

**part portfolio:**
- fuselage frames
- ribs for empennage
- ribs for wing (in progress)
- Sandwich parts (in progress)

**Target:**
*predictable process for lotsize 1 production*
Researchplatform „EVo“

... a chain of subprocesses with a tail of data
Researchplatform „EVo“

… a chain of subprocesses with a web of linked data

1. Textile Supply
2. Cutting
3. Ply Handling
4. Pick & Drape
5. Hot Forming
6. Trim to Net Shape
8. Curing
8. Isothermal Injection

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Crosslinking

… the machine’s mindmap for process-information

„Four Layer Architecture“
Digital Twin

... visualize data together with context
Data acquisition

... of machine parameters and QA sensors
Individual Process regulation vs. Robust high volume production

**Individual production of large part:**
- Apply sensors on part
- Akquire Data
- (Simulate)
- **Regulate** parameters

**Serial production of high volume parts**
- Use machine’s sensors
- **Running-in**
- Acquire Data
- Determine process-window

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Running-in of a process with varying parts?
the missing link…

- **Properties**
  - geometry
  - compaction
  - cure

- **Context**
  - process step
  - dependency
  - interaction

- **Machine Data**
  - acceleration
  - pressure
  - temperature

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**Digital Twin**

**Semantics**

**Content**
the missing link...

- **calibration**: relate machine parameter to result on product
- **machine data**: context
- **properties**: source: Sartorius
  - 5,0001g = 5,0001g
- **Examples:**
  - Balance with calibration weight
  - DSC with Indium standard
  - Tensile Test machine with reference specimen
  - Melting point IN = 156.6°C
  - Reference specimen = Reference value

source: Mettler Toledo, Zwick

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Calibration

... why do we need it?

example process: **hotforming**

- estimation:
  - flat surface
  → homogenous temperature and pressure distribution

- reality:
  - stretches membrane over contoured surface
  → membrane thickness varies locally
  → membrane’s elasticity works against pressure

→ result:
inhomogeneous binder activation depending on geometry

Inhomogenous temperature distribution over time
Calibration

... how can we do it?

approach: sensorized calibration part

- separate part with integrated sensors
  - *not* the application of sensors to the product in production

- sensors will measure process parameters from the product’s point of view

- results lead to calibration factor as link between *machine parameter* and product related *process parameter*
Determination of Process Window

... and how to hit it

Pressure

Temperature

- process limit
- machine limit
- process window

- no effect
- damage

Calibration (product 1)
set values (machine)
real values (product 1)

Calibration (product 2)
real values (product 2)

→ expectation: good part
→ result: bad part

→ result: bad part
Variation of parts means variation of parameters

… but should not mean variation of quality
Variation of parts means variation of parameters

… but should not mean variation of quality
Vision Future Factory for RTM Parts:

... flexible production at constant quality

Automated Preforming & RTM production line

Target: predictable process for lotsize 1 production

- Digital Twin
- Semantics
- Calibration
- Content

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Thanks for your Attention!