Prozesskalibrierung als fehlendes Glied zwischen realer Produktion und digitalem Zwilling

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

Wissenschaftstag 2018
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 ("lot size 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

Target:
*predictable process for lotsize 1 production*

part portfolio:
- fuselage frames
- ribs for empennage
- ribs for wing (in progress)
- Sandwich parts (in progress)
Researchplatform „EVo“

… a chain of subprocesses with a tail of data
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
- Acquire Data
- (Simulate)
- **Regulate** parameters

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

---

**Digital Twin**

**Semantics**

**Content**

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
the missing link...

properties

context

calibration

machine data

relate machine parameter to result on product

Examples:
- Balance with calibration weight
- DSC with Indium standard
- Tensile Test machine with reference specimen

source: Sartorius
5,0001g = 5,0001g

source: Mettler Toledo
Melting point $IN = 156.6\,{}^{\circ}C$

source: Zwick
Reference specimen $= \text{Reference value}$
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:
inhomogenous binder activation depending on geometry
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*
Variation of parts means variation of parameters

... but should not mean variation of quality

- **Process window**: The area where both pressure and temperature are within acceptable limits.
- **Machine limit**: The boundary where the process may begin to degrade.
- **Process limit**: The extreme boundary where the process is considered undesirable.

### Graph Details
- **Real values (product 1)**: Machine performance failing, resulting in a bad part.
- **Calibration (product 1)**: Set values within expected range, resulting in a good part, with expectation: good part.
- **Real values (product 2)**: Machine performance failing, resulting in a bad part.
- **Calibration (product 2)**: Set values within expected range, resulting in a bad part.

### Key Points
- **No effect**: The area where both pressure and temperature are within the process window.
- **Damage**: The area where either pressure or temperature exceeds the machine limit, potentially leading to a bad part.

**Prozesskalibrierung als fehlendes Glied zwischen realer Produktion und digitalem Zwilling**

S. Torstrick-v.d. Lieth

18.10.2018
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
Thanks for your Attention!