

SMART MANUFACTURING LINES: LEARNING FROM SIMULATION MODELS AND REAL-TIME DATA

DR.IR. JOS HAVINGA



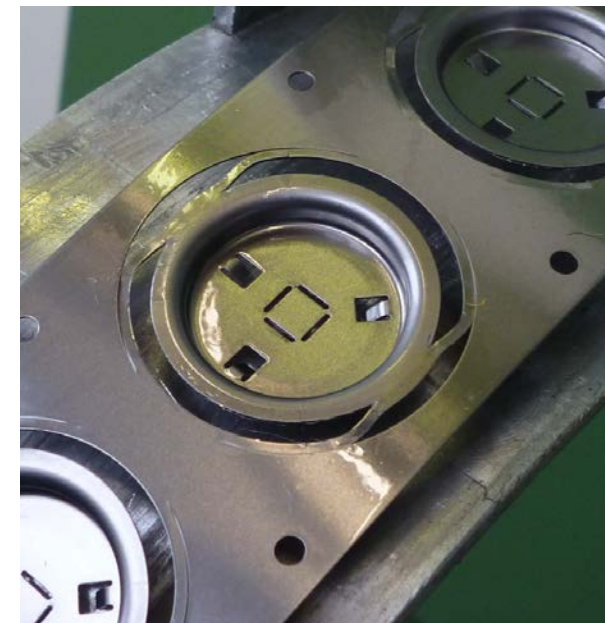
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CONTENT

Smart manufacturing lines:
learning from **simulation models**
and **real-time data**



CONTEXT



PROCESS VARIABILITY

- Tool wear
- Material properties
- Friction properties
- Product alignment

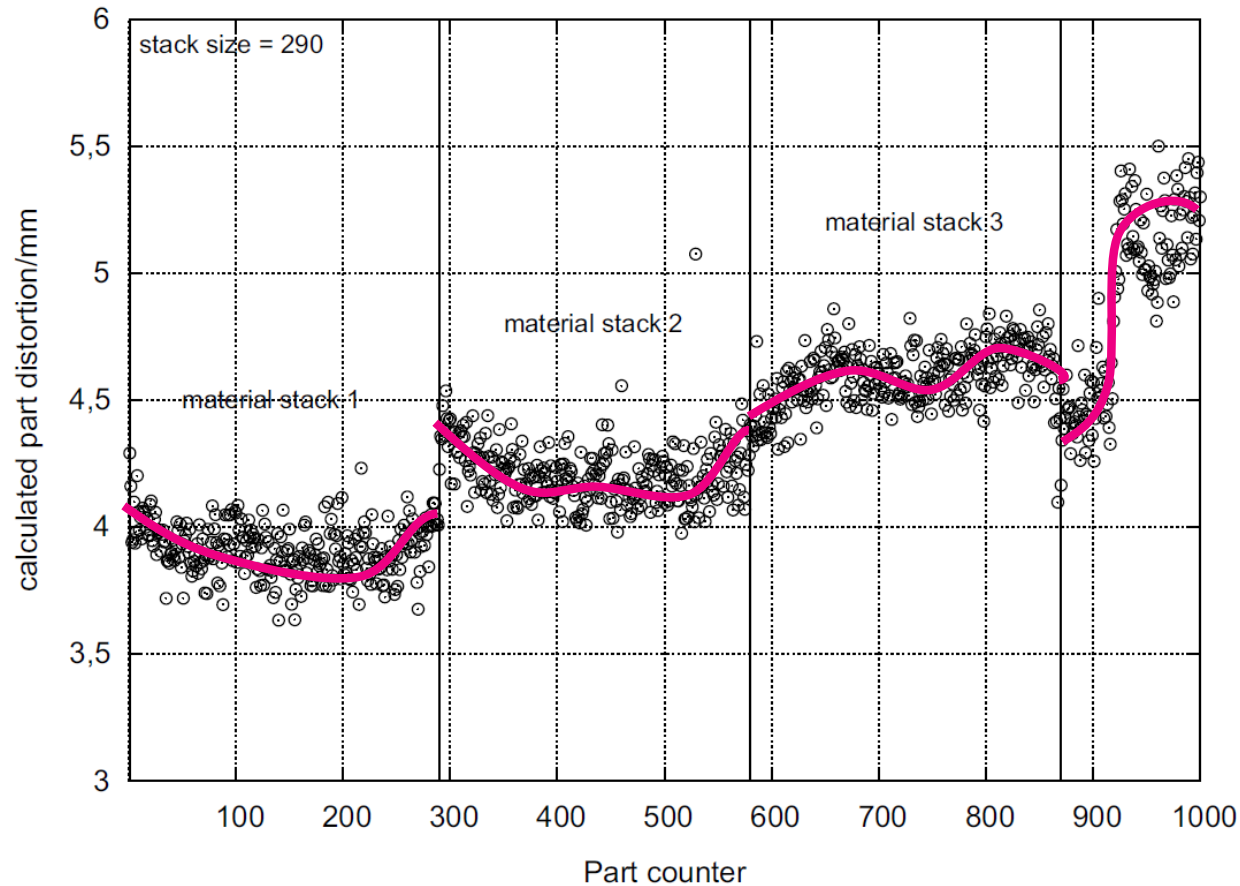
SLOW



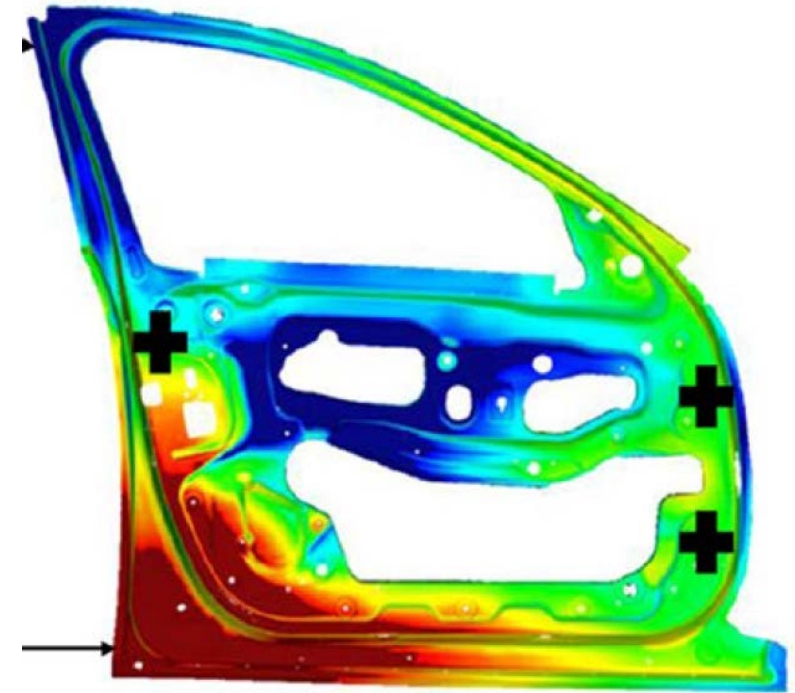
FAST



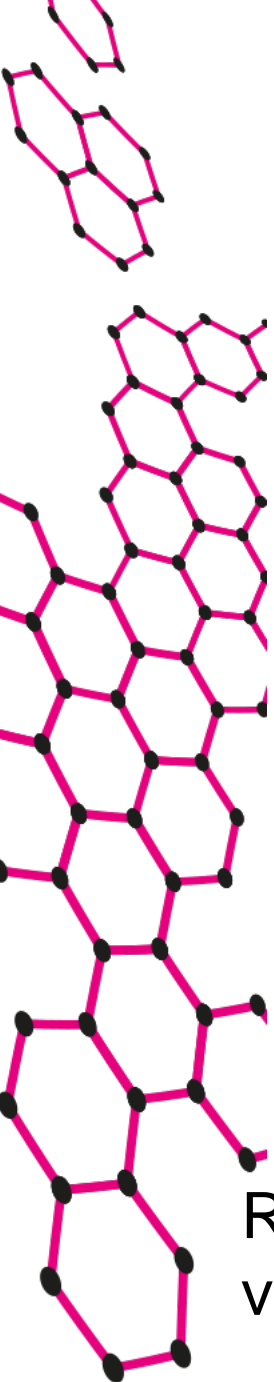
PRODUCT-TO-PRODUCT VARIABILITY



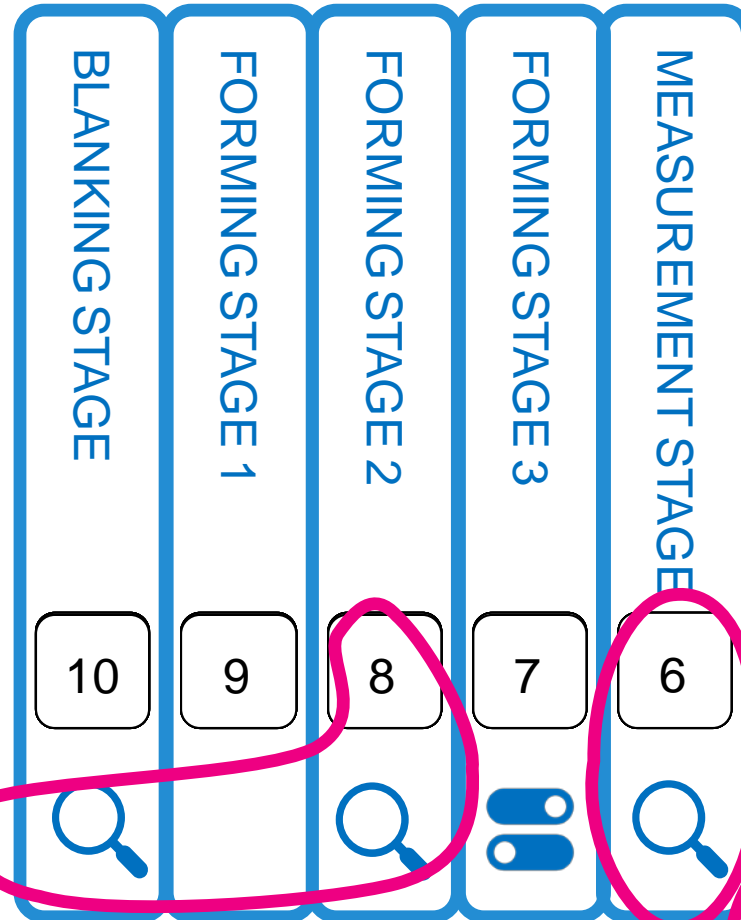
S. Maier, A. Liebig, T. Kautz, W. Volk / *Prod. Eng. Res. Devel.* 11 (2017): 307-313.



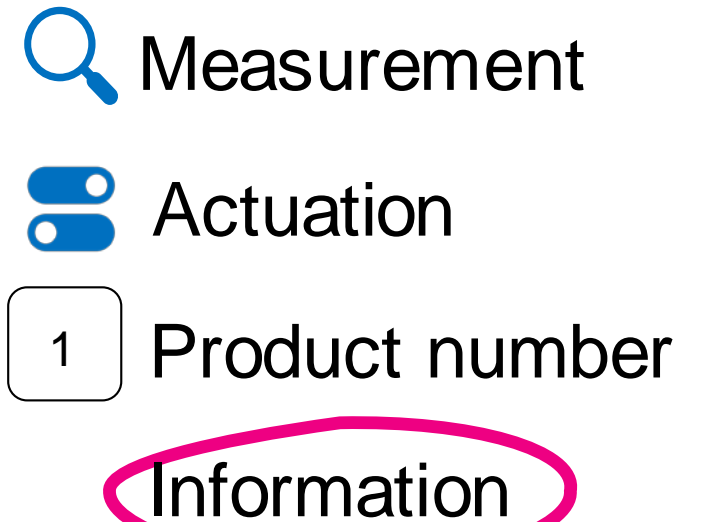
MULTISTAGE METAL FORMING



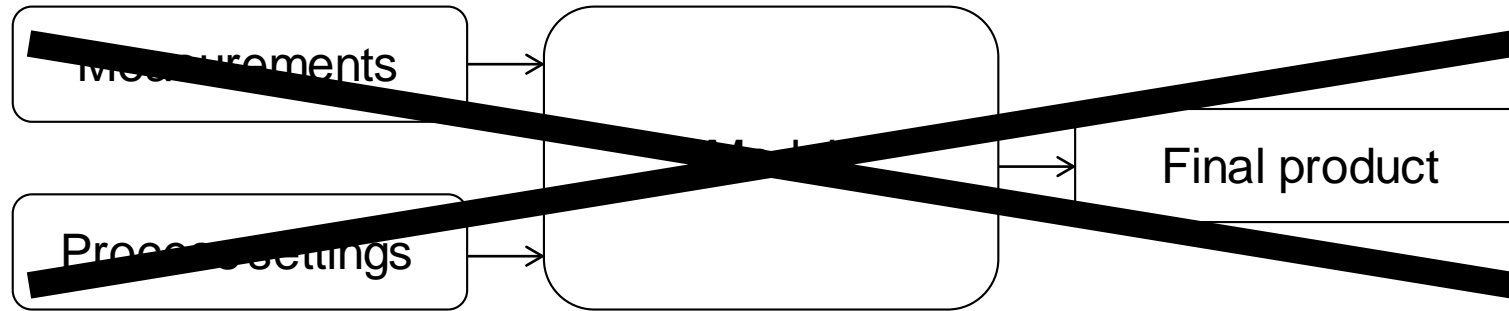
Relevant for fast variations



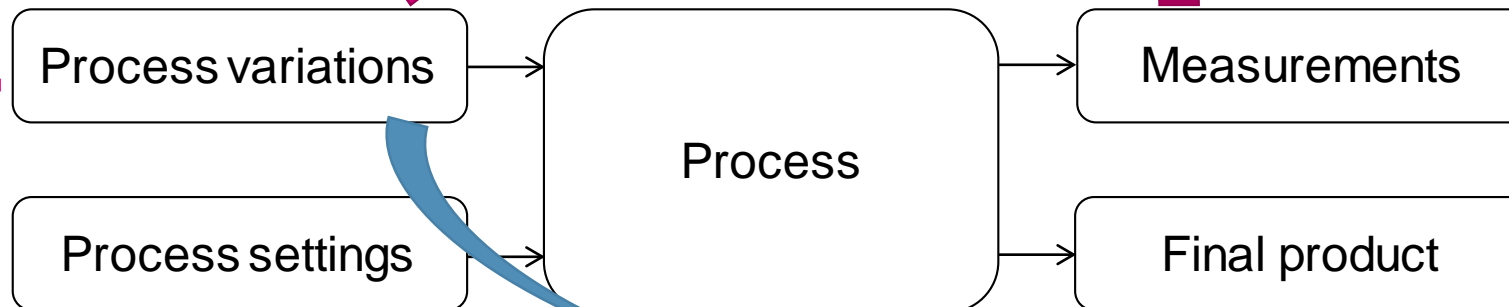
Relevant for slow variations



PROCESS MODELS



Process variation model



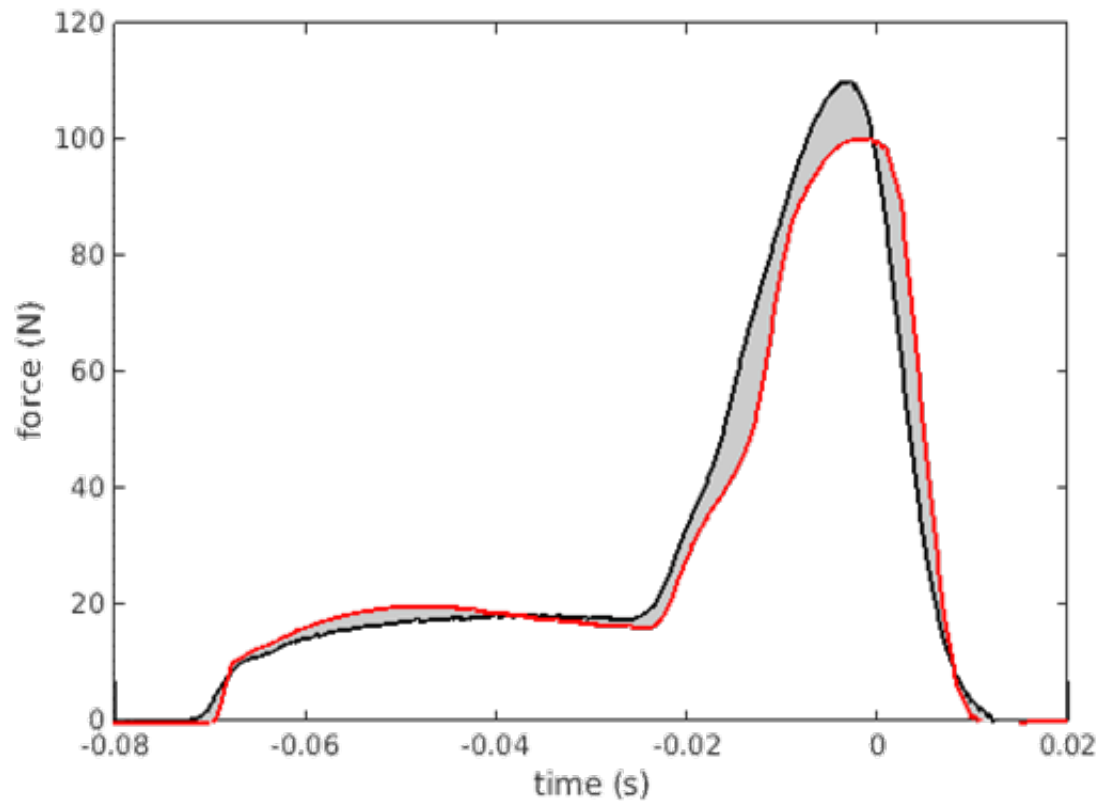
Process model

MODEL AND REALITY

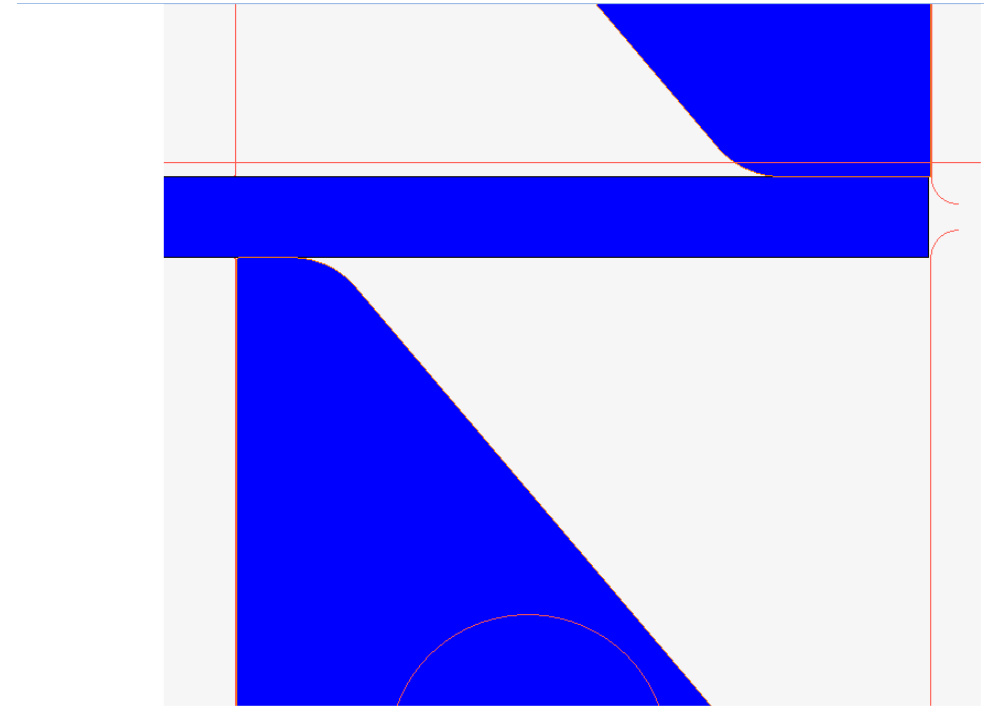
Distorting Mirror Post Cover painted by Norman Rockwell in 1921



MODEL AND REALITY



Black = process measurement, red = FE model



MODEL AND REALITY

Distorting Mirror Post Cover painted by Norman Rockwell in 1921



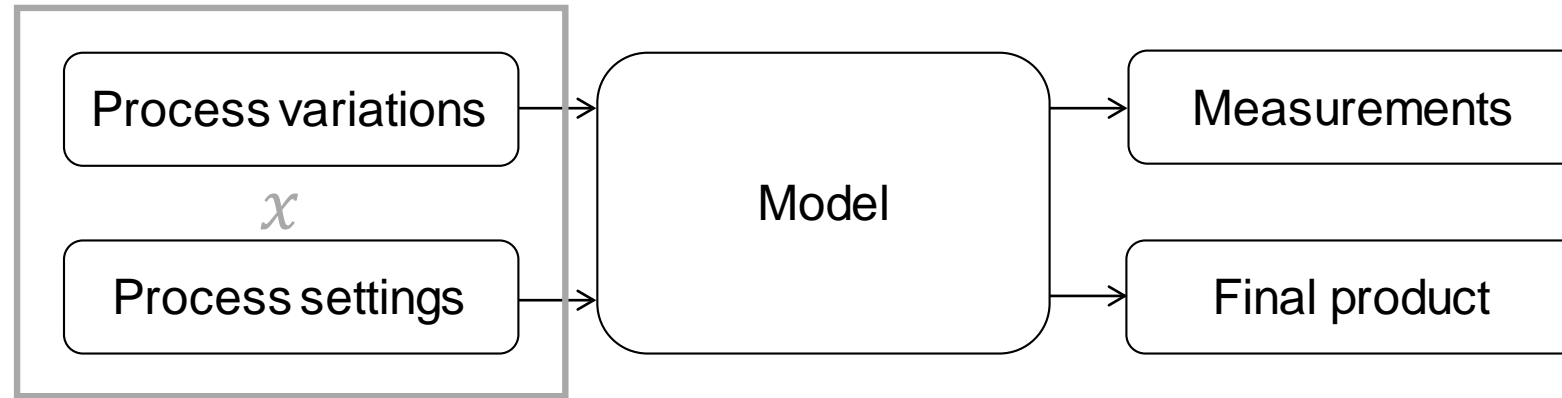
DISTORTING MIRROR
Post Cover • August 13, 1921
109

- How to create more accurate models?
- How much to trust these models?

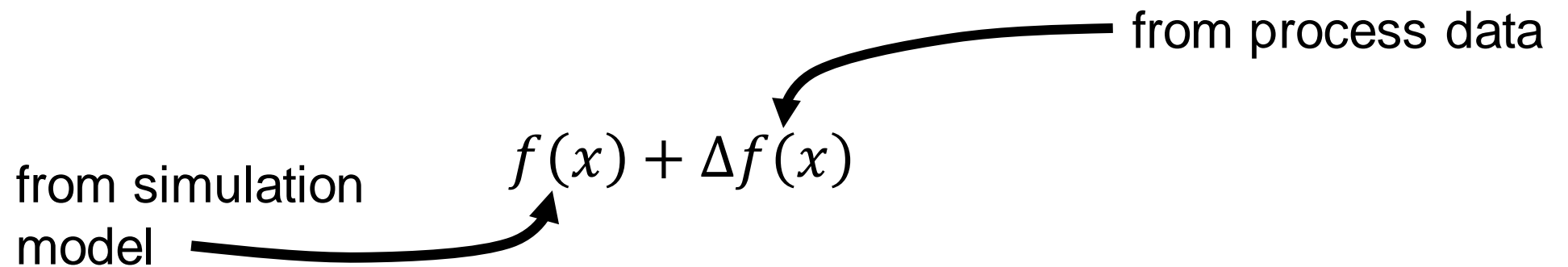
Hybrid modelling

Probabilistic (Bayesian) approach

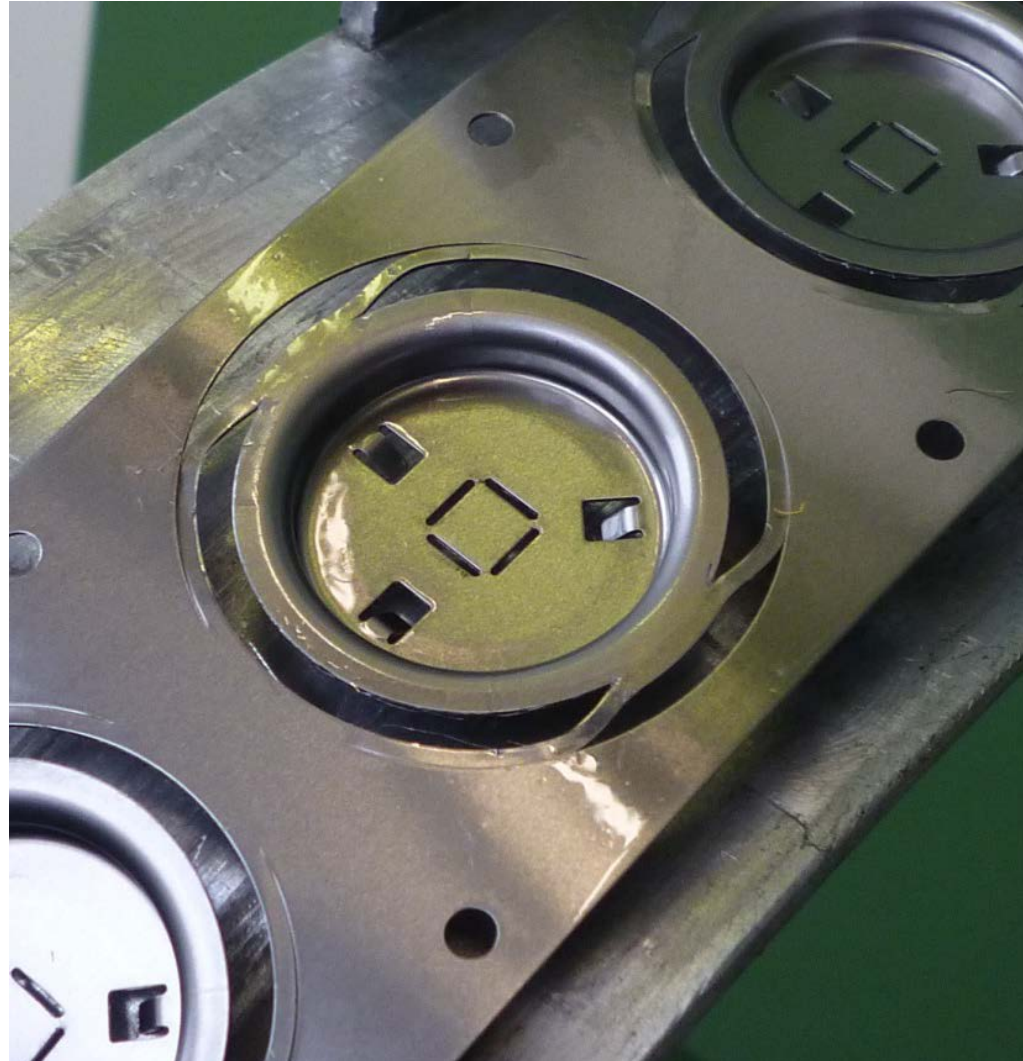
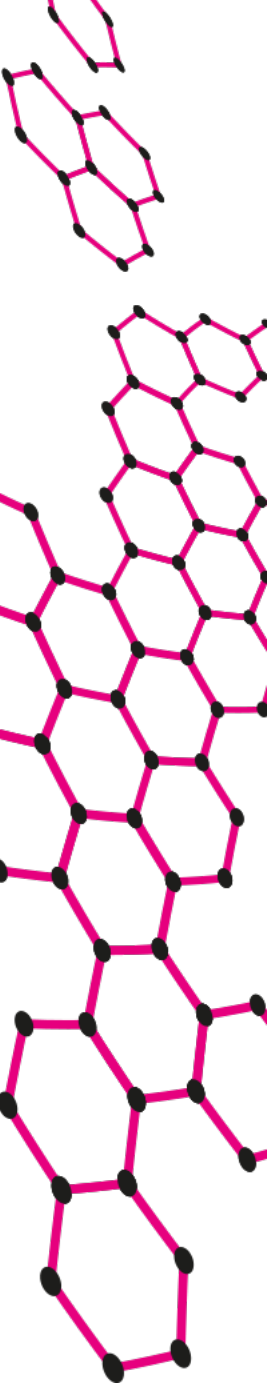
HYBRID MODELLING



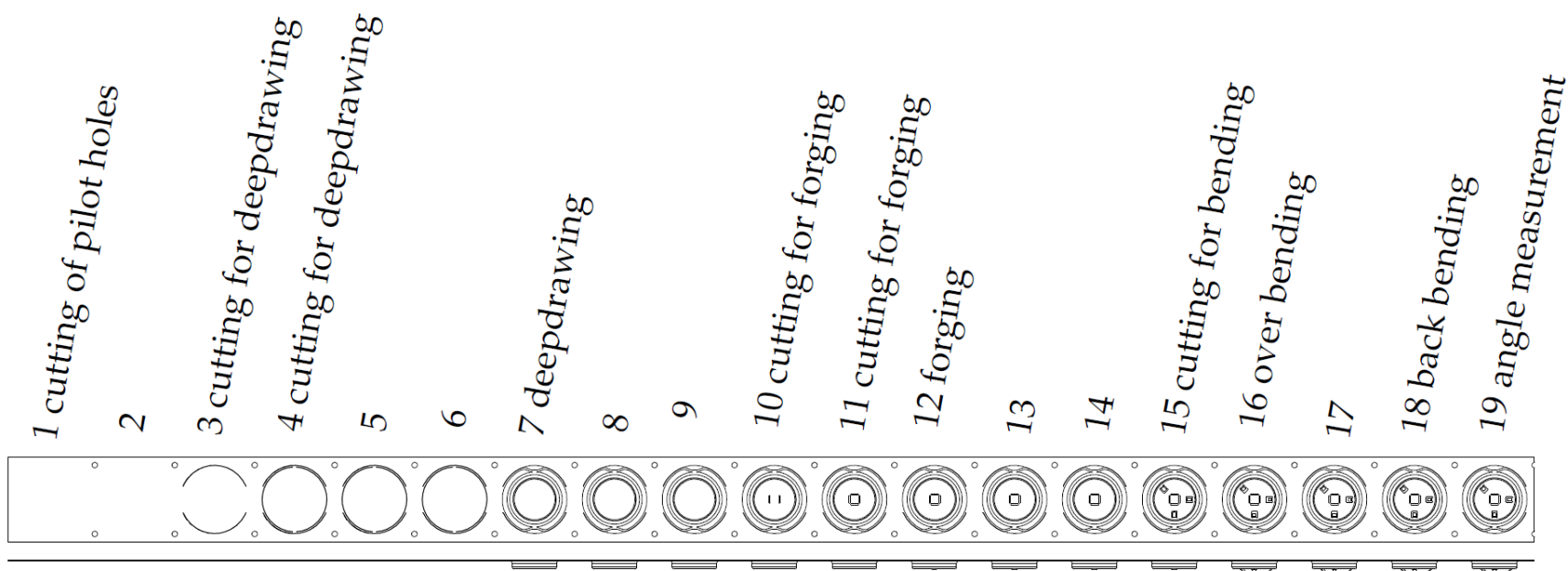
$$f(x)$$



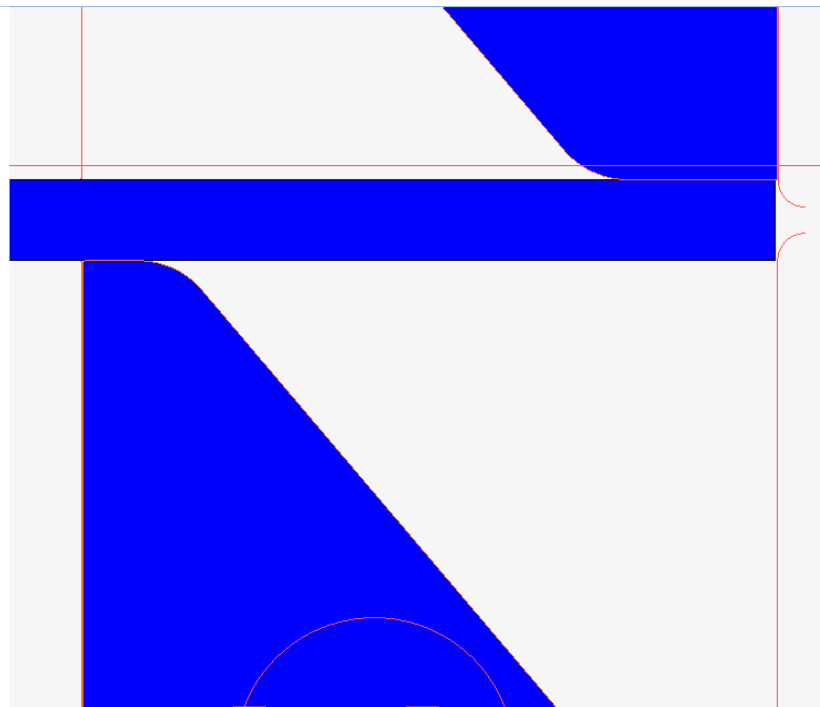
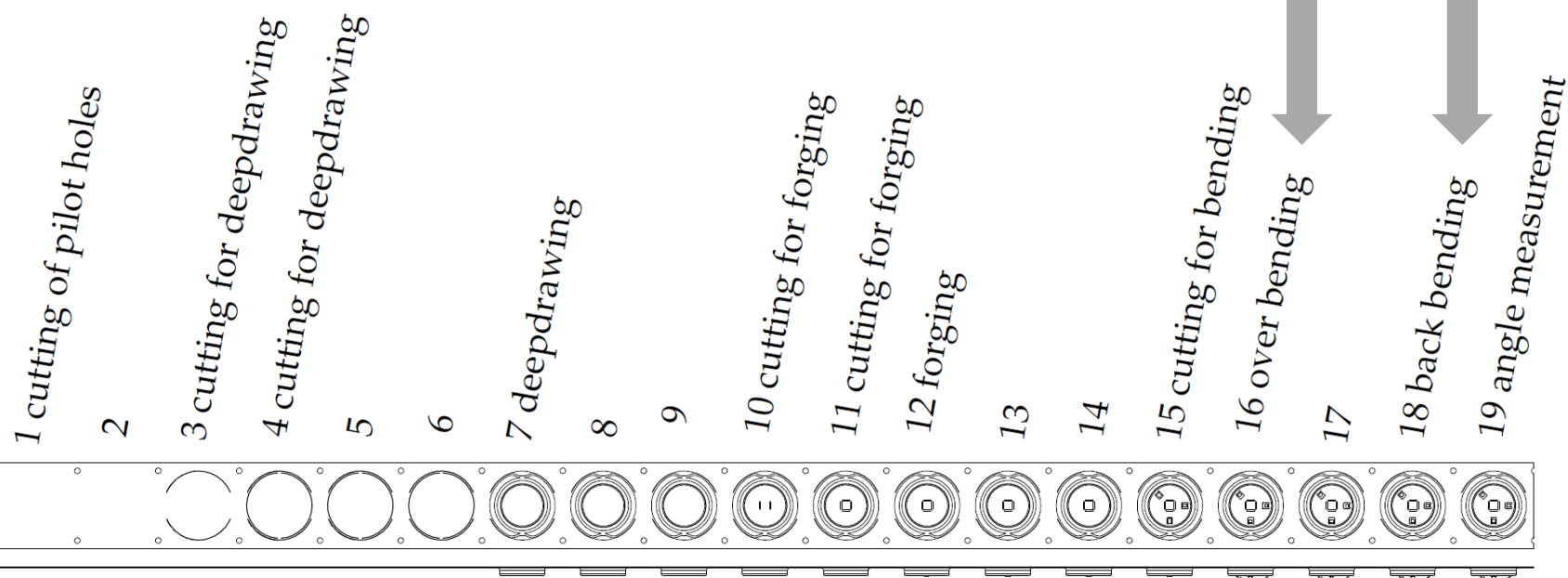
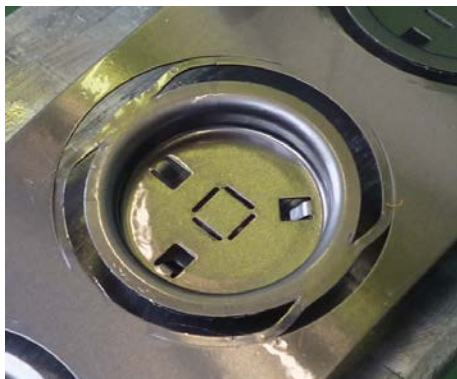
DEMONSTRATOR PROCESS



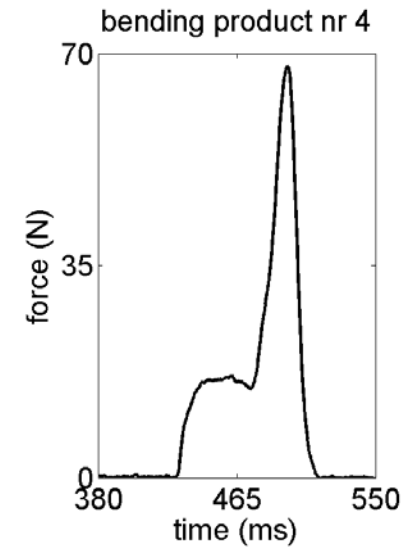
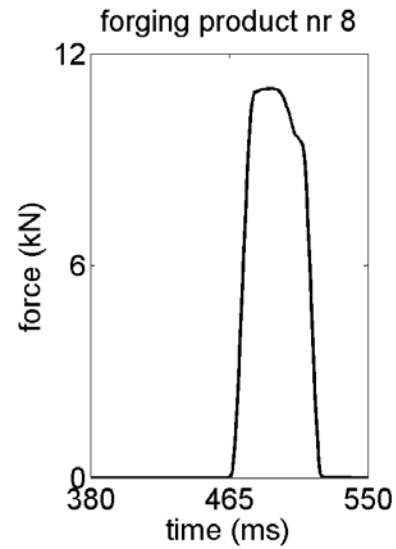
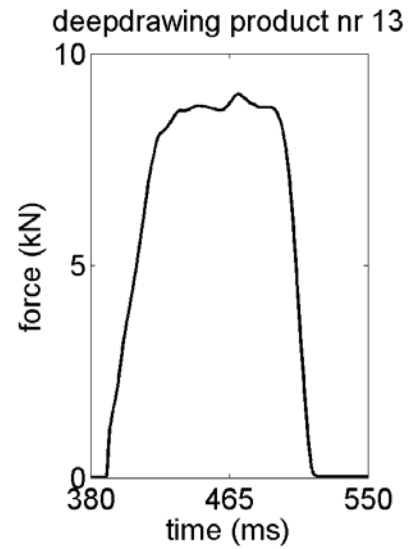
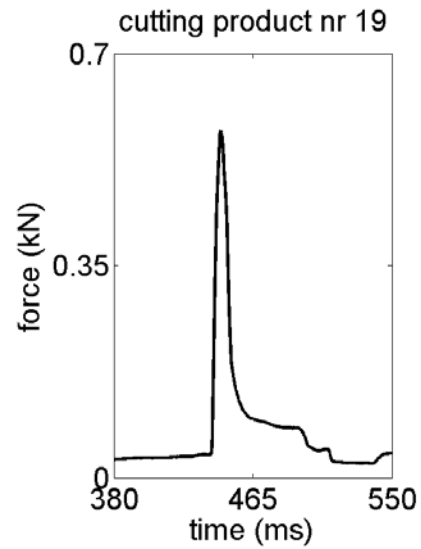
DEMONSTRATOR PROCESS



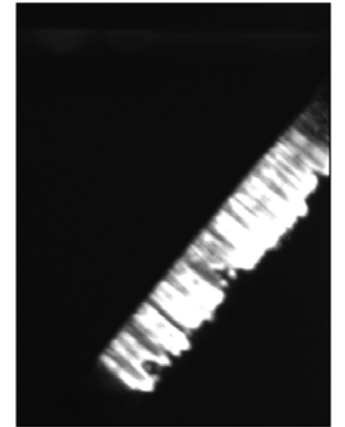
DEMONSTRATOR PF



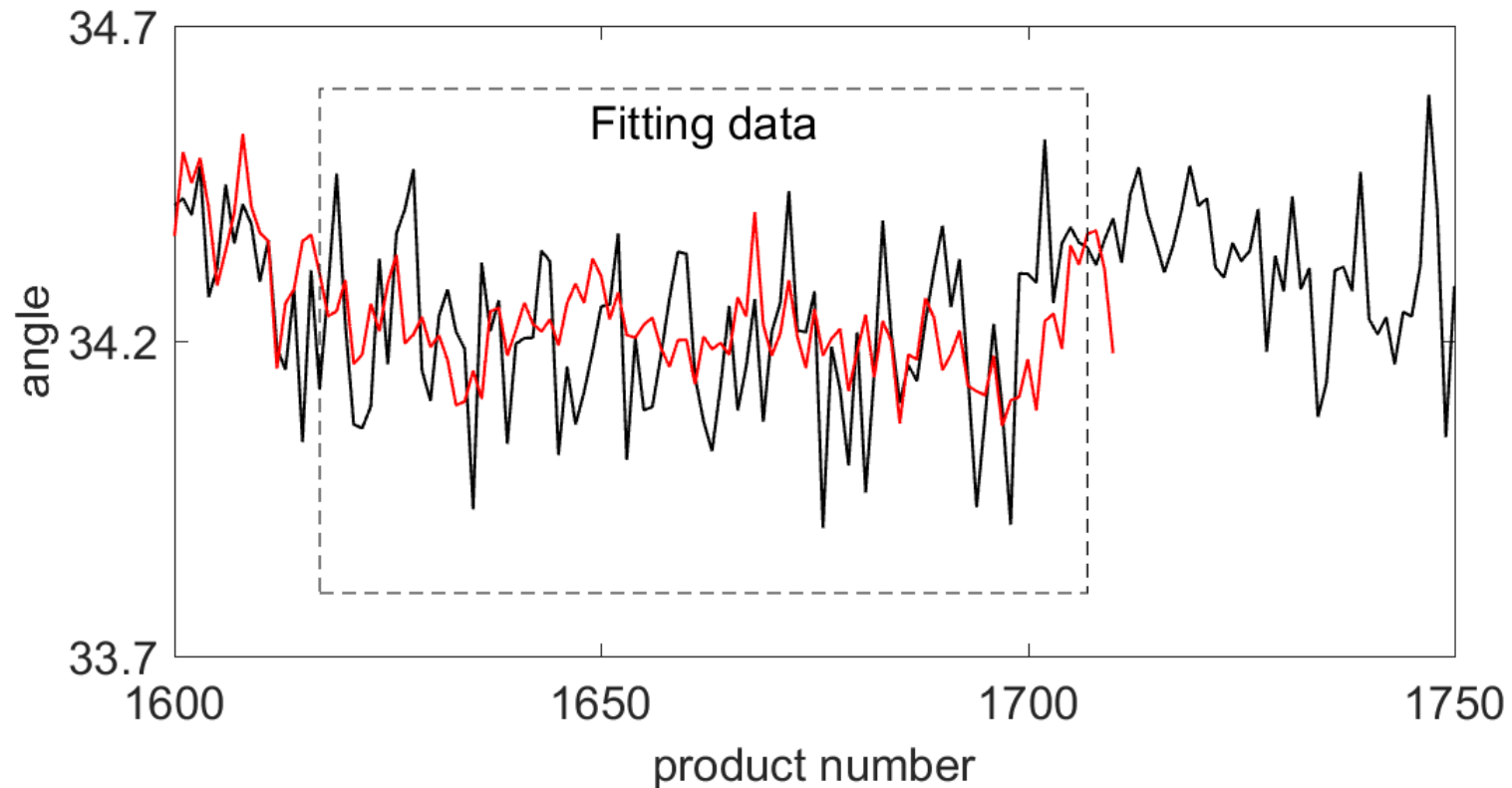
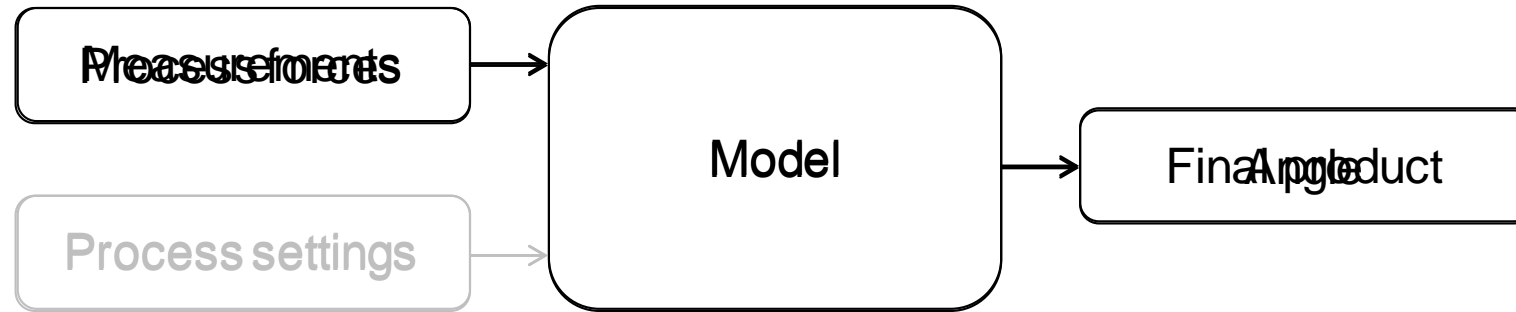
DEMONSTRATOR PROCESS



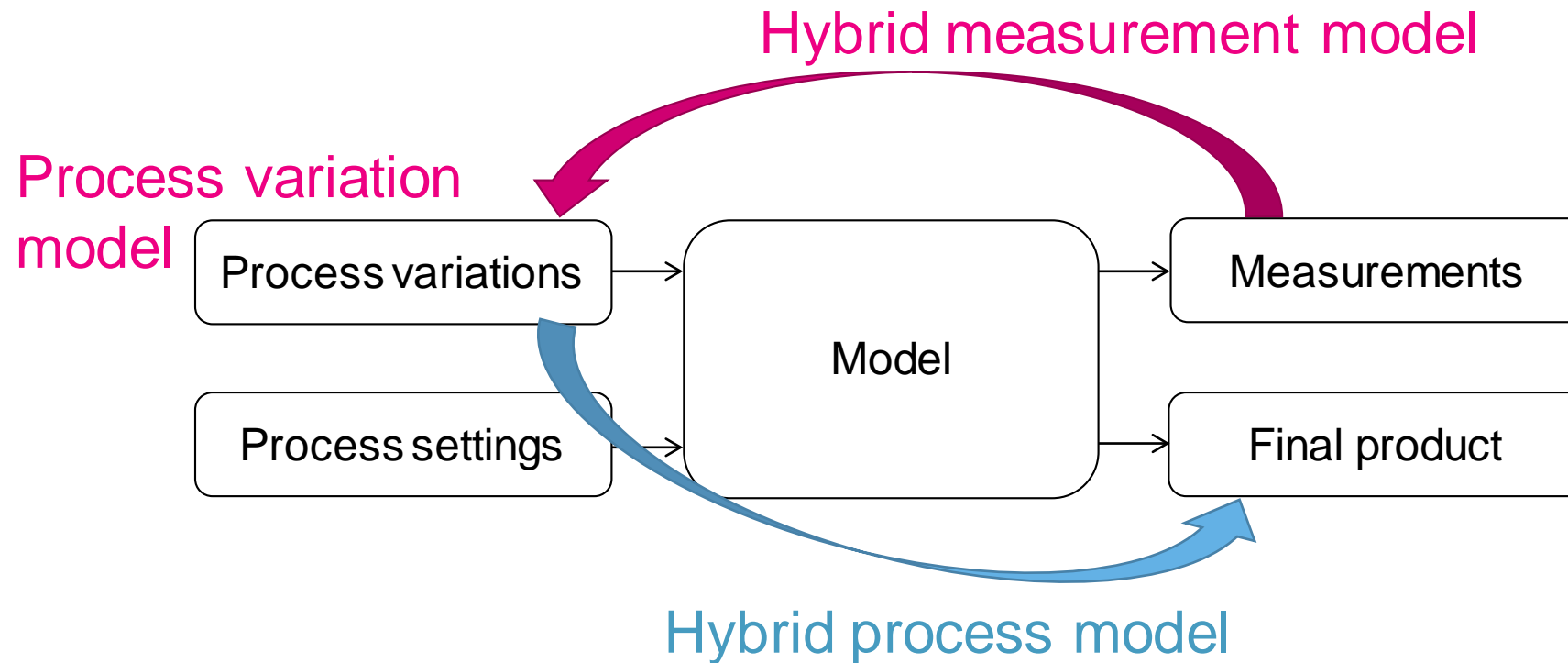
flap product nr 1



DATA-DRIVEN MODELLING

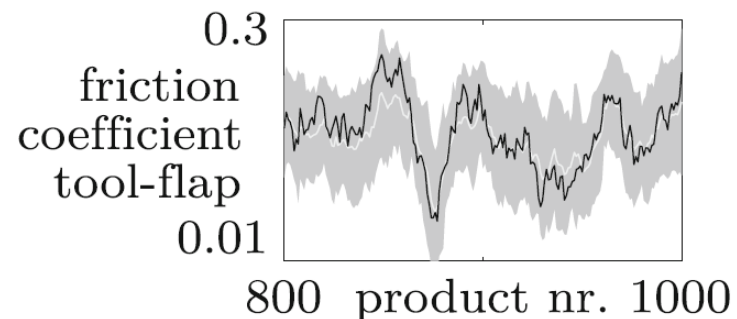
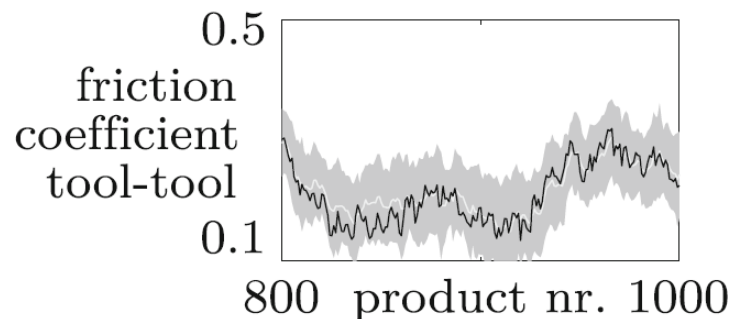
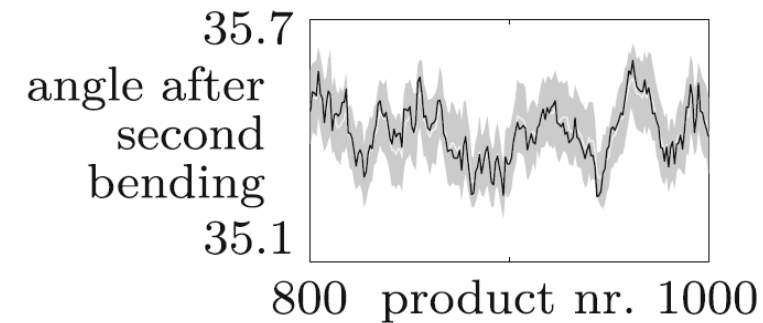
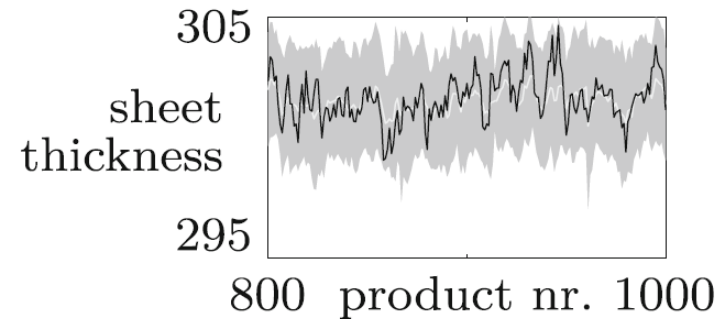
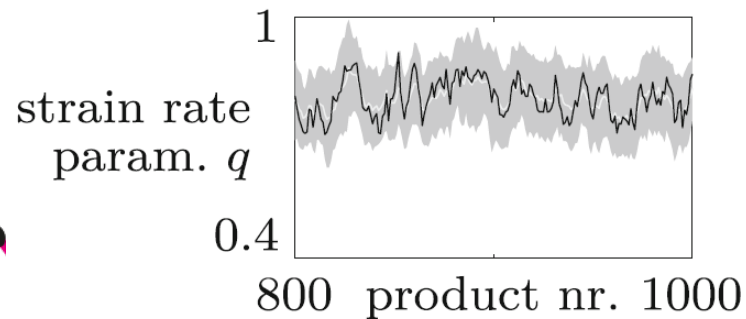
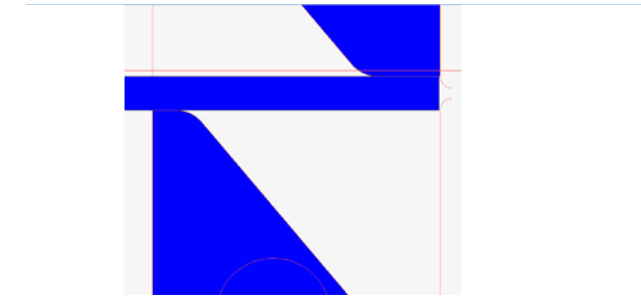
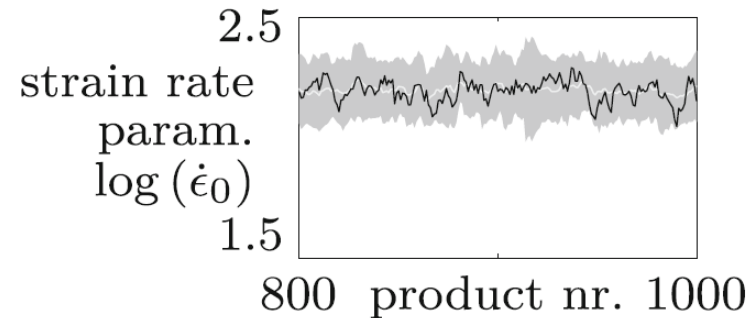
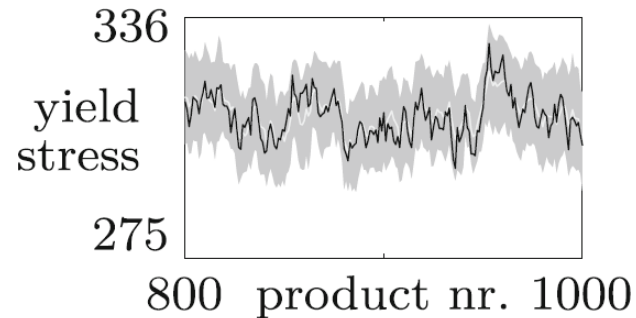
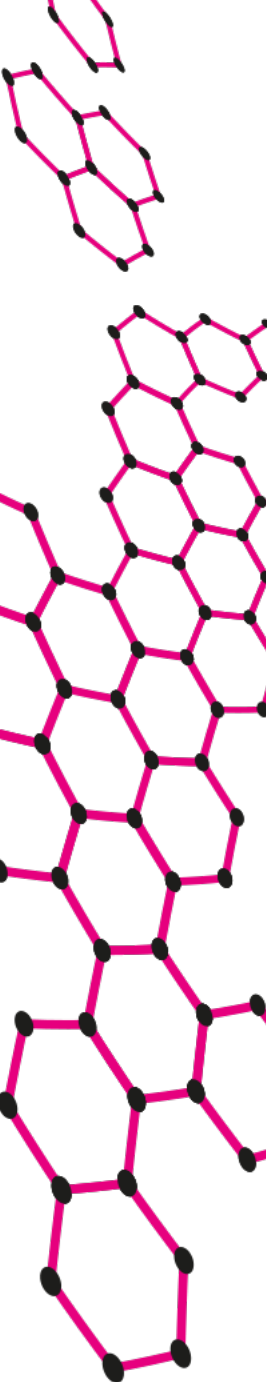


REAL-TIME STATE ESTIMATION



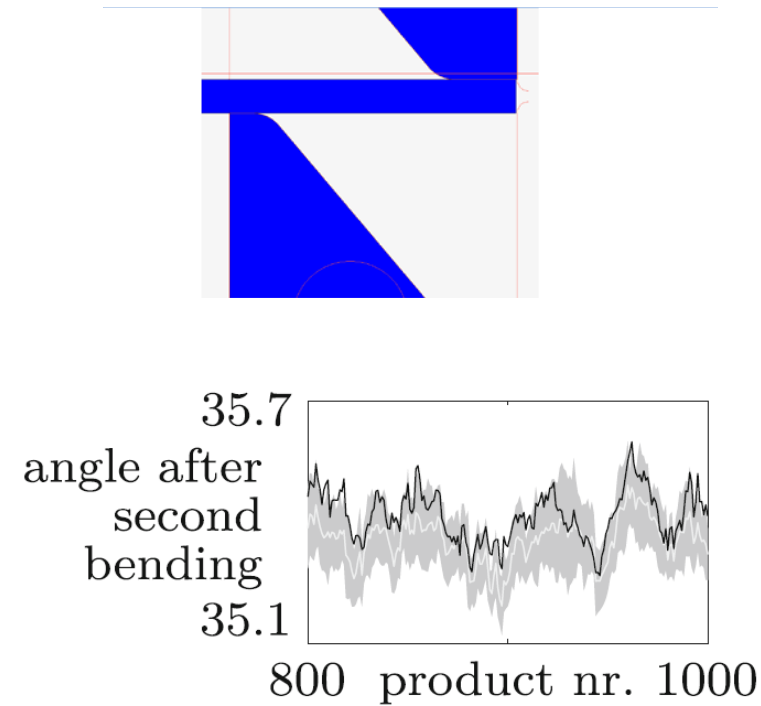
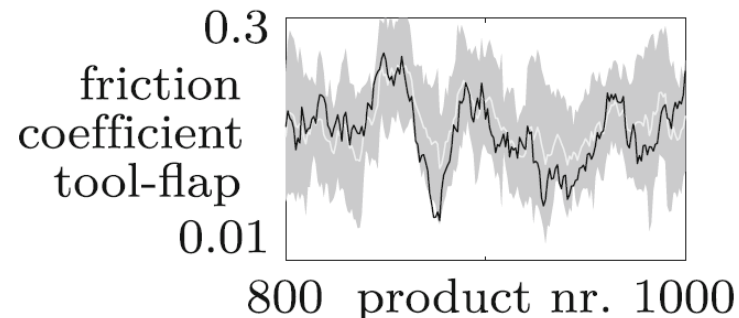
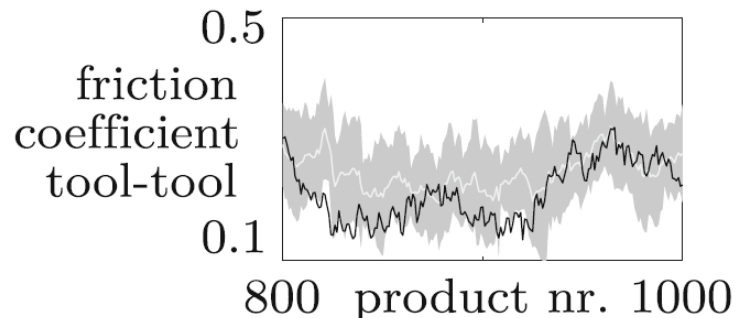
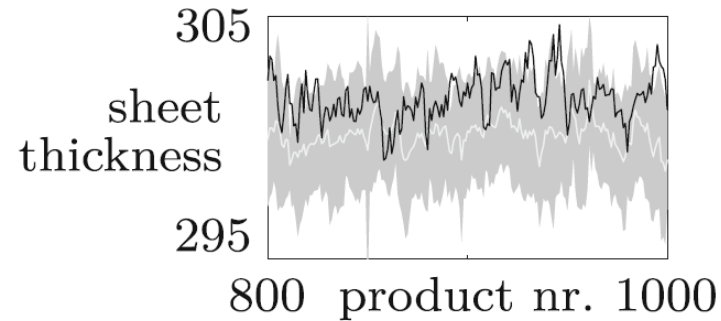
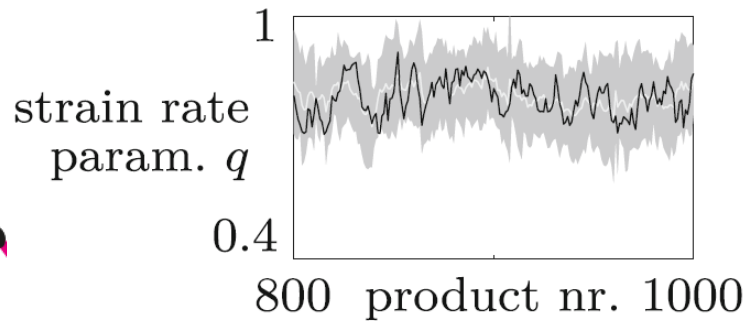
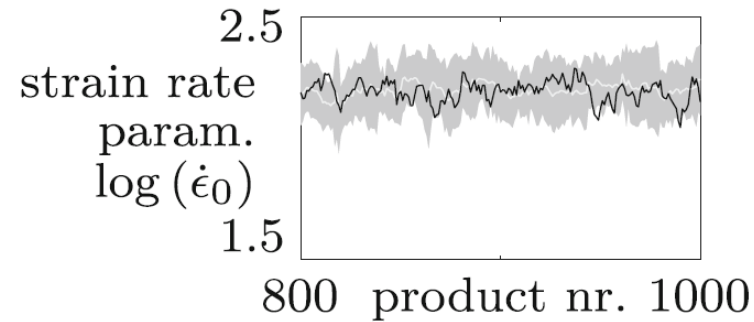
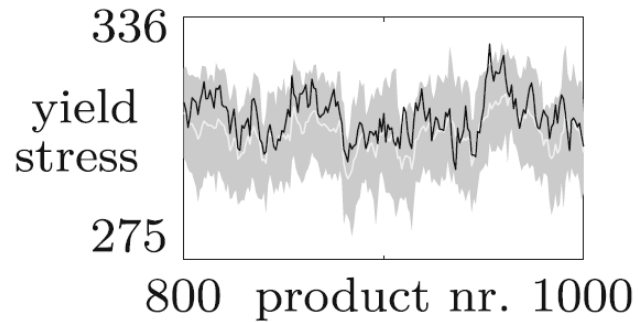
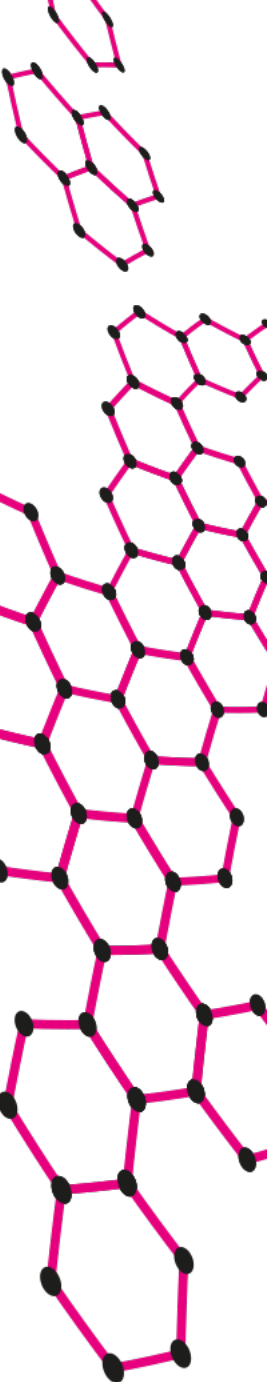
REAL-TIME STATE ESTIMATION

PSEUDO-DATA RESULTS WITH PERFECT MODEL



REAL-TIME STATE ESTIMATION

PSEUDO-DATA RESULTS WITH CORRECTION MODEL





REAL-TIME STATE ESTIMATION

CHALLENGES FOR FUTURE DEVELOPMENTS

Hybrid modelling

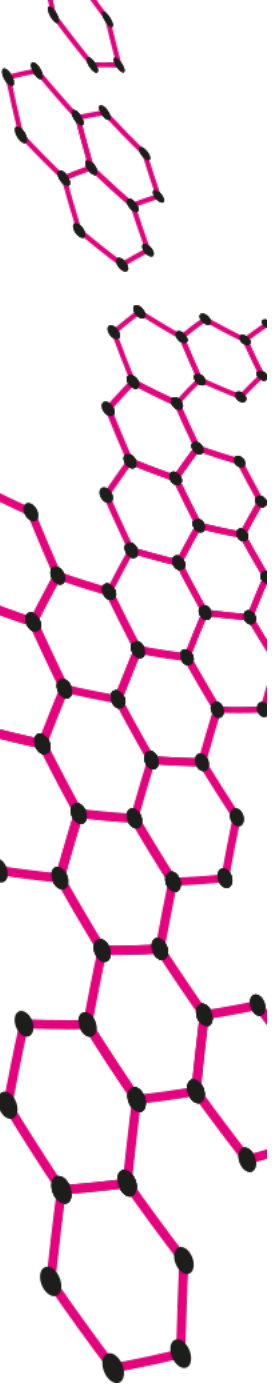
Robust statistical
algorithms

Fast in-line
models

Understanding
process
variations

LABORATORY OF THE FUTURE





THANK YOU FOR YOUR ATTENTION!

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