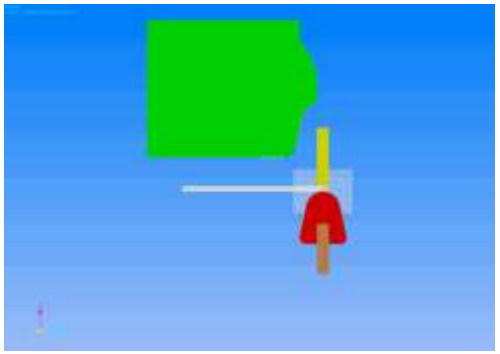
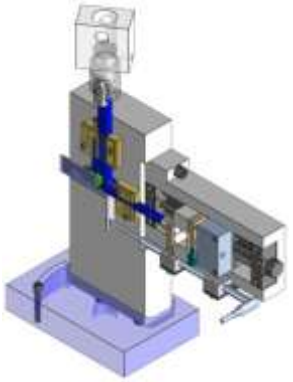
MODEL-BASED DESIGN OF SELF-CORRECTING FORMING PROCESSES

M. Krüger, M. Borzykh, W. Schaermann





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The Technology-Network:
Intelligent Technical Systems
OstWestfalenLippe . Germany
it's owl

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Project Group Mechatronic Systems Design

Fraunhofer Project Group
Mechatronic Systems Design

- Project Group of Fraunhofer Institute for Production Technology
- Start in March 2011
- 51 employees

Competences

- Product engineering
- Control engineering
- Software engineering

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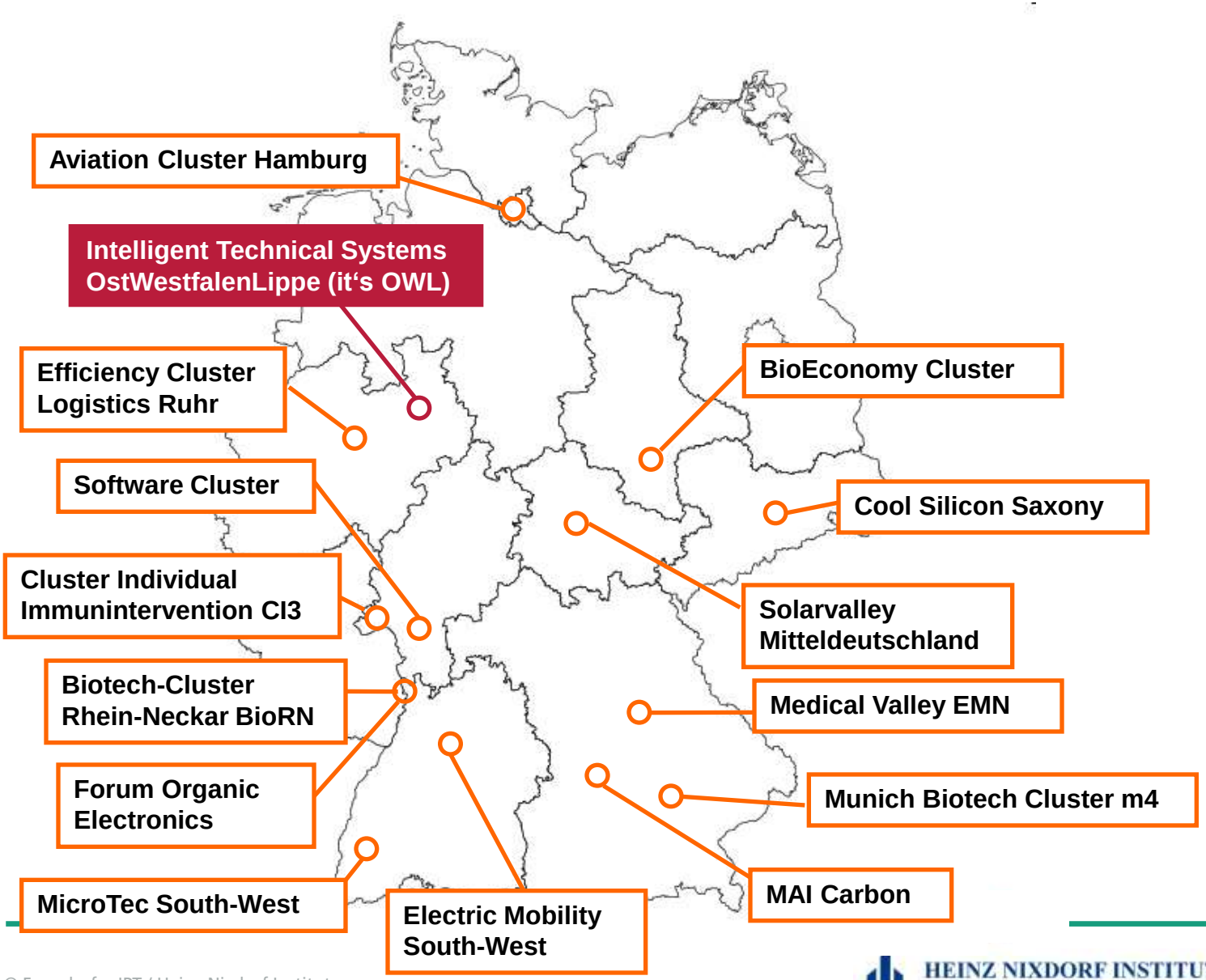
IPT

it´s owl – one of 15 Leading-Edge Clusters in Germany



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Leading-Edge Cluster it´s owl

Innovation Leap Towards Technical Systems with Inherent Partial Intelligence

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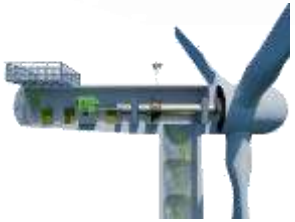
Mechanics




Mechatronics

Intelligent Systems




Intelligent Networks

Industry 4.0

Self-Optimization

Cyber-Physical Systems

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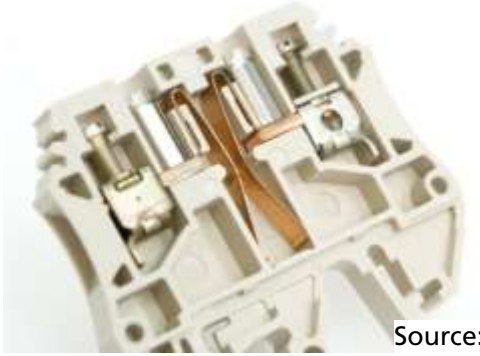
Introduction

Manufacturing of metal parts for the electrical connection technology

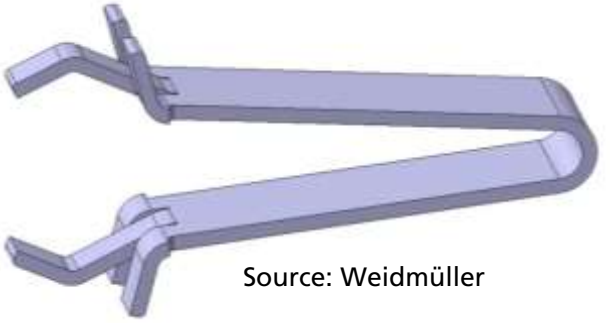
Punch-bending machine with NC servo drives

Source: Bihler



Source: Bihler

Reference dimension: opening



Source: Weidmüller

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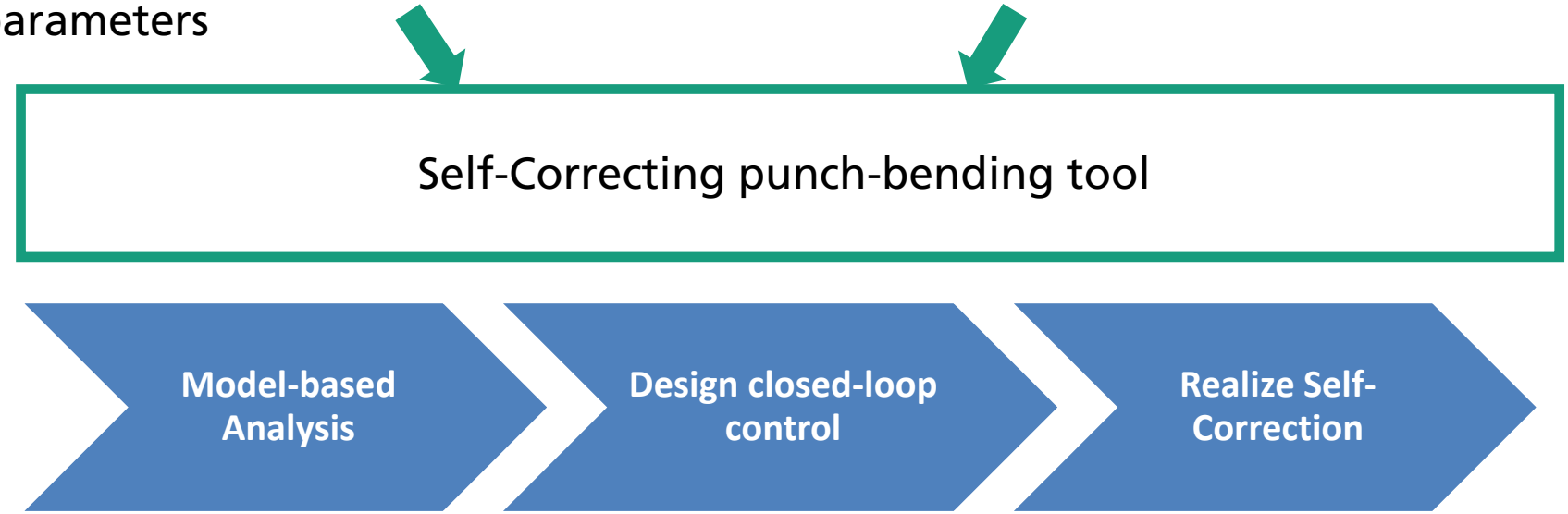
Introduction
Challenges of punch-bending

Geometrical deviations appear during manufacturing leading to

- high scrap rate
- long setup time
- time consuming interruptions of the process for setting new process parameters

Trend in the electrical-connection technology moves towards

- decreasing part size
- tighter tolerances
- use of high-strength materials



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MODEL-BASED DESIGN OF SELF-CORRECTING FORMING PROCESSES

1. Introduction
2. Modeling of Forming Processes
3. Feedback Control and Implementation
4. Conclusion

Machine- and Technology Models

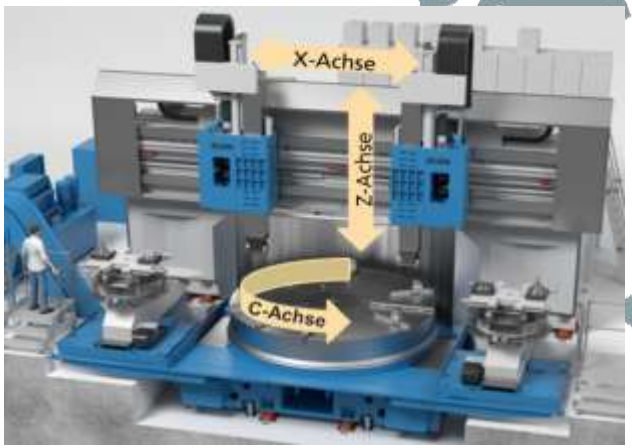
- Architecture
- Control strategy
- Interfaces

Control / Automatio

- Dynamical behavior
- Thermal effects
- driving motors

Machine

Technology models



- Interaction tool / workpiece
- Measurement technology

Process

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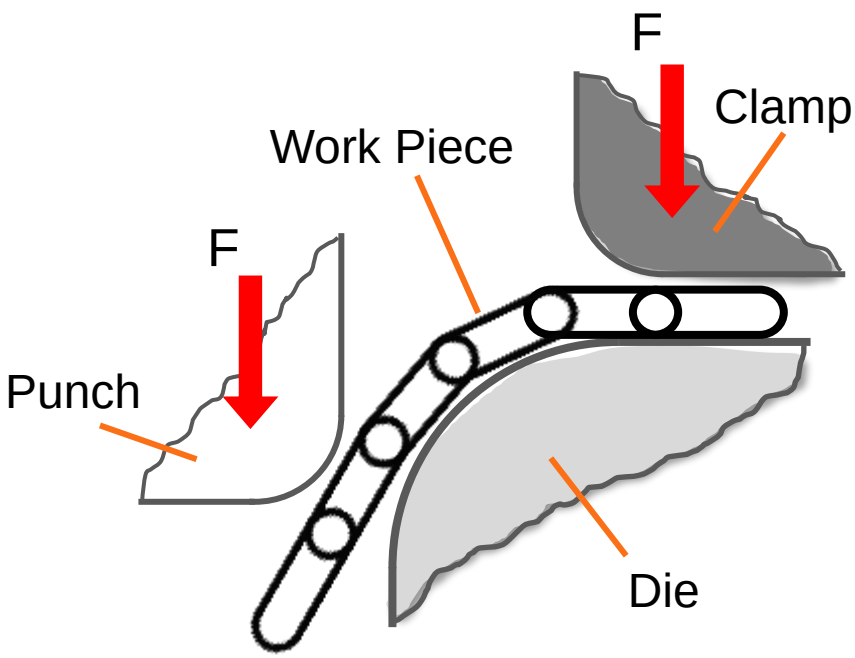
Modeling of bending process



- Requirements for the model
  - System dynamics
  - Elastic-plastic deformation
  - Implementation of control architecture
- FEM-simulation possible but has long computational period and is expensive to create and/or change

➔ Reduction of model complexity

➔ Build up in RecurDyn Media Transport Toolkit 2D (MTT2D)

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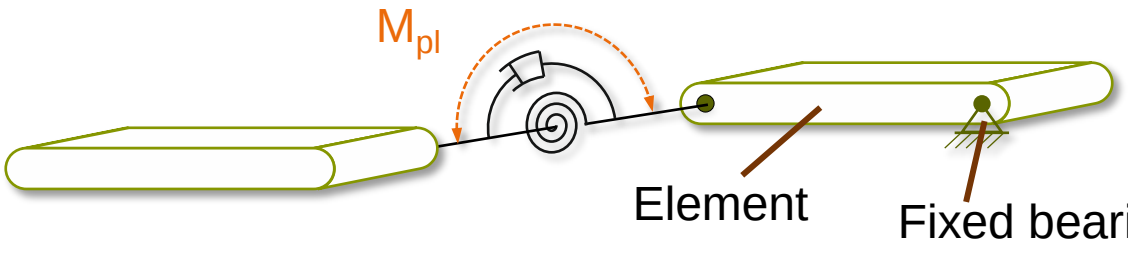
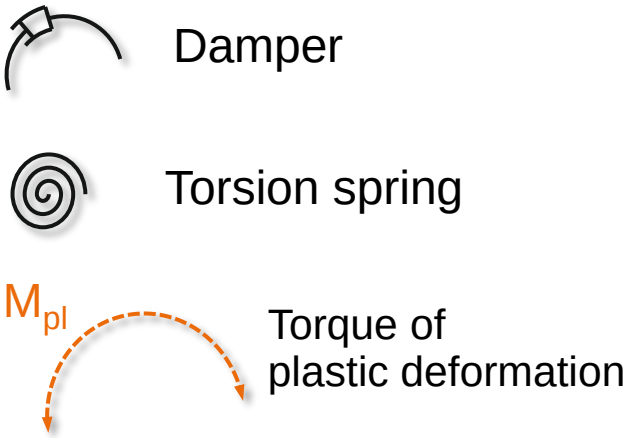
Modeling of bending process

Multi-Body-System

Model of the work piece





- Work piece is built up as a chain of (n) sheet-bodies
- Sheet-bodies are connected by a spring-damper system
  - Representation of elastic material behavior
  - Stiffness corresponds to material constants
- Implement the plastic deformation as external axial torque

$$M_{pl} = d \cdot \alpha_{pl}$$

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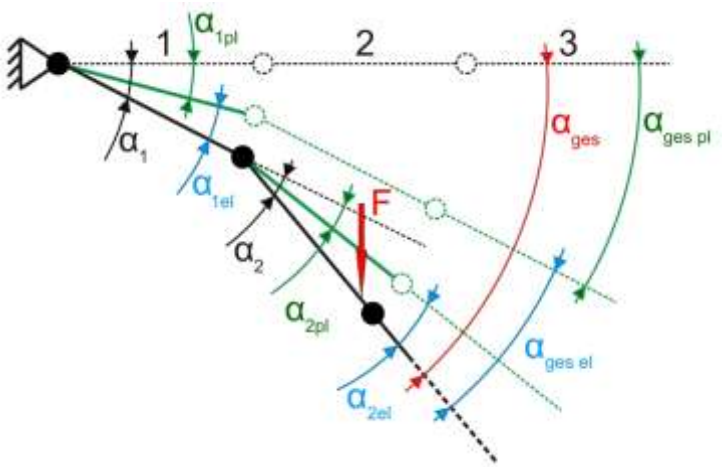
Modeling of plastic deformation

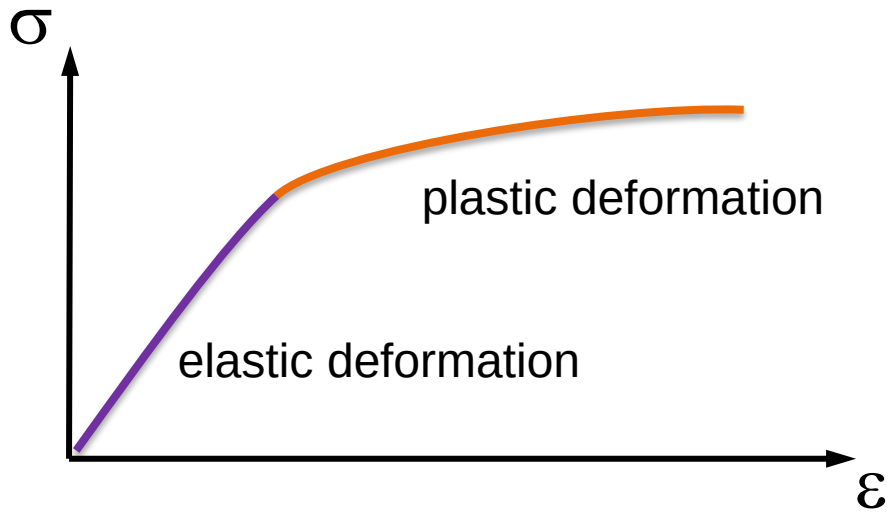
- Bending theory after Ludwig which depends on:
  - Angle between two sheet-bodies
  - Stress-strain curve
  - Profile geometry

$$\alpha = \alpha_{el} + \alpha_{pl}$$

$$\alpha_{pl} = K\alpha$$

$$K = 1 - \frac{r_m \cdot M_B}{E \cdot I}$$





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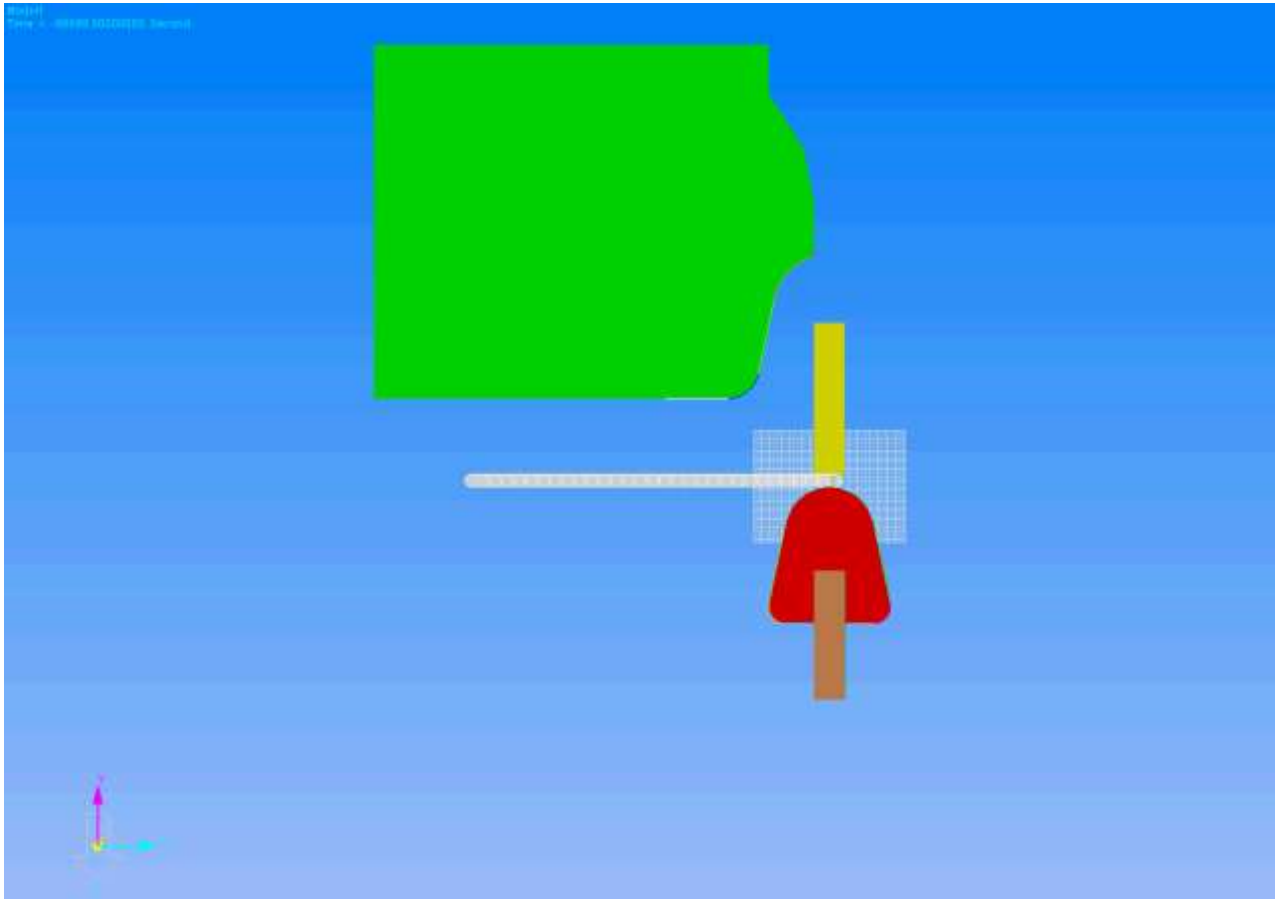
Modeling of bending process

Result



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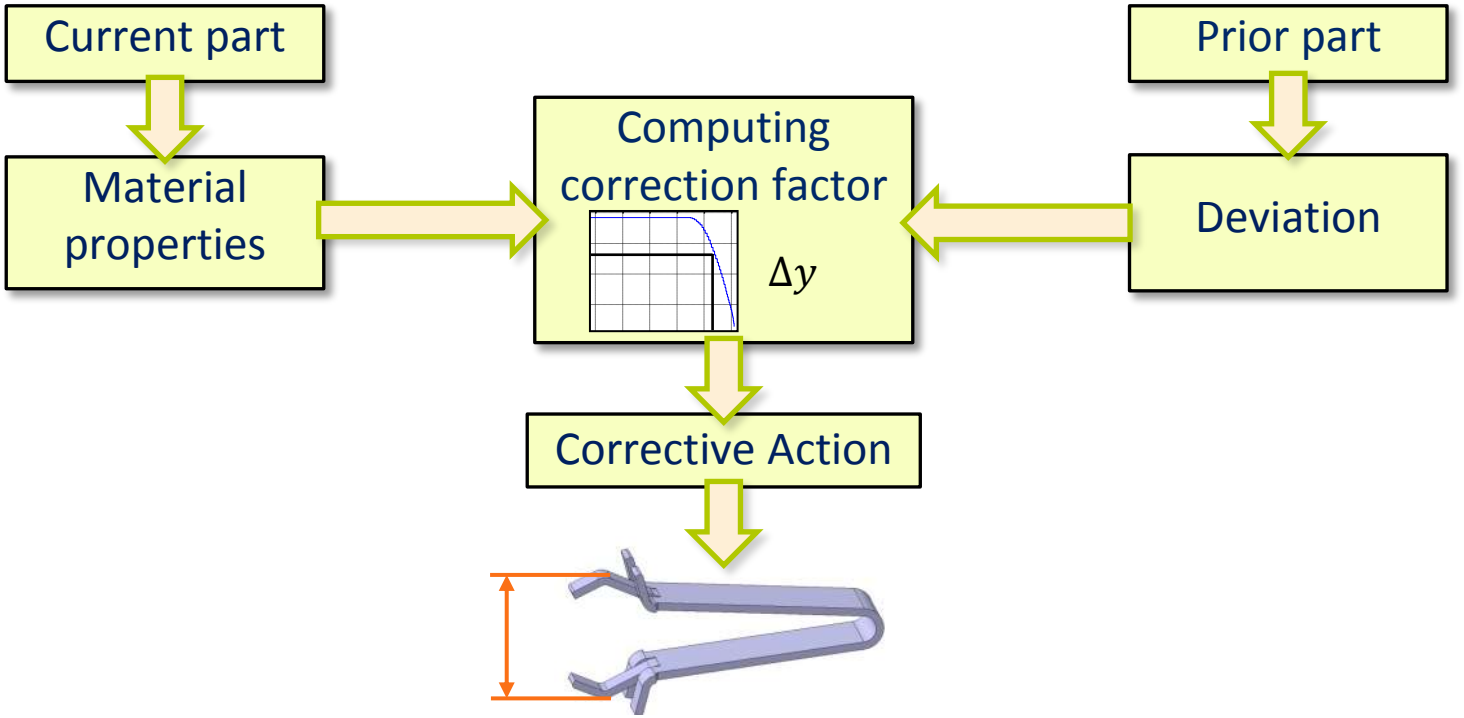
Self-correcting Strategy

General idea

Due to the manufacturing process and results of model-based analysis, the following information will be used:

- changes in material from the current work piece
- geometrical deviation of the prior work piece



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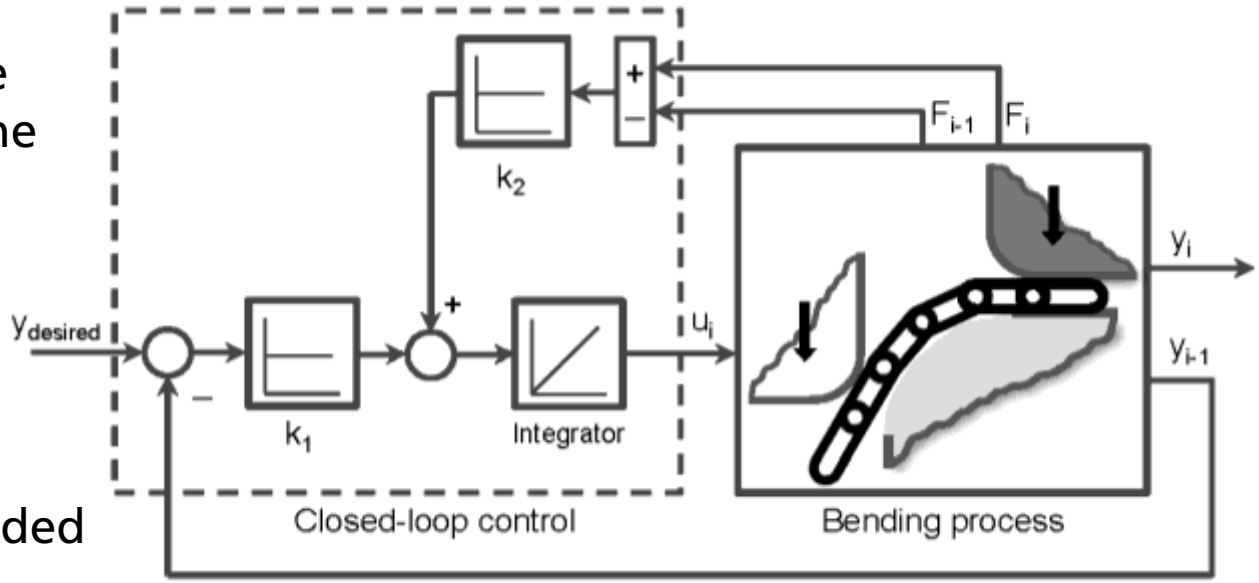
Self-correcting strategy

Implementation

Closed-loop control for corrective action in runtime is realized by:

- discrete I-controller for opening dimension measured by prior part
- Consideration of the change of thickness by measuring the force on the punch



Simulation results:

- Leaving of tolerances is avoided
- Zero defects tendency
- Quality is increased

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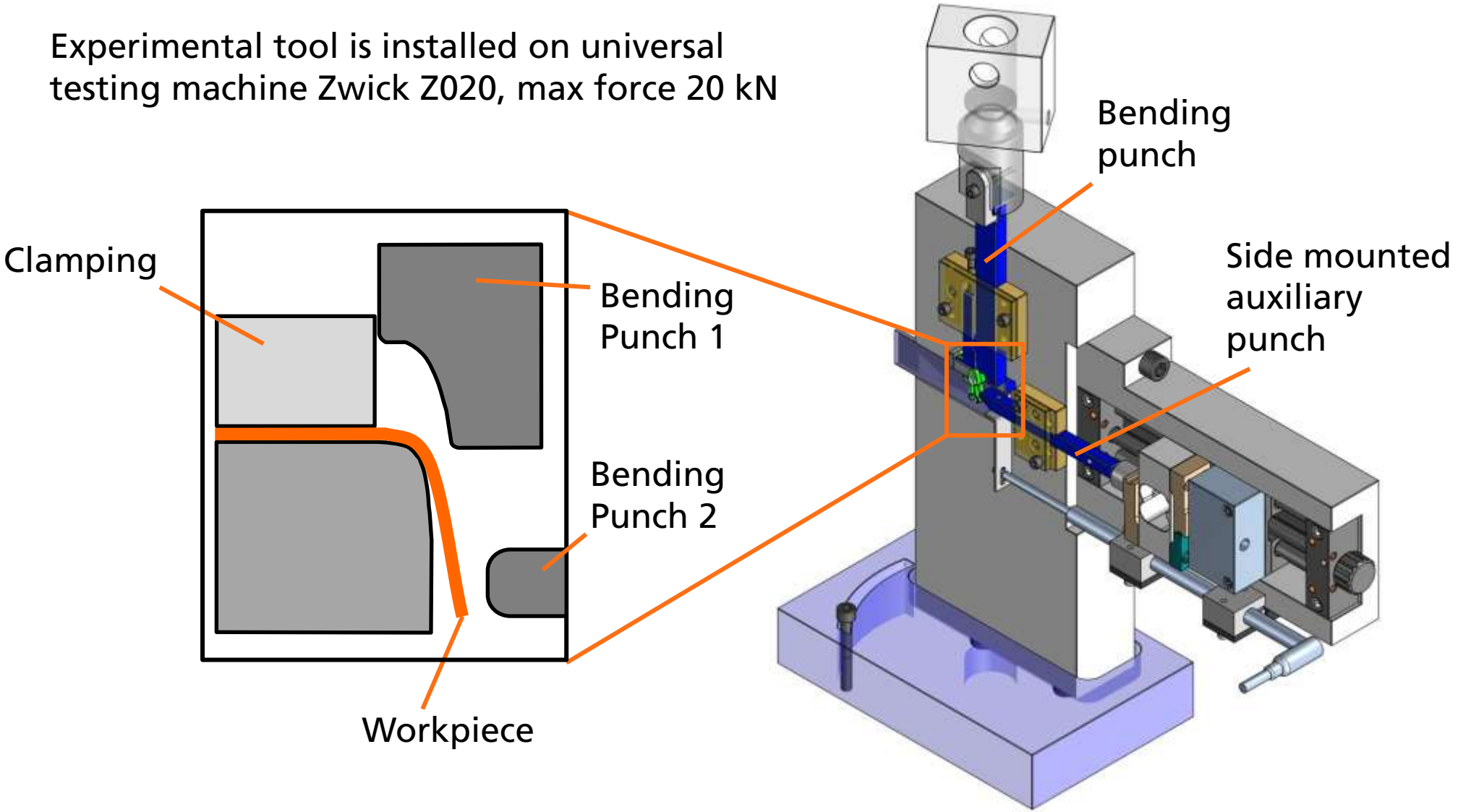
Experimental Tool & Measurement Devices

Experimental tool is installed on universal testing machine Zwick Z020, max force 20 kN



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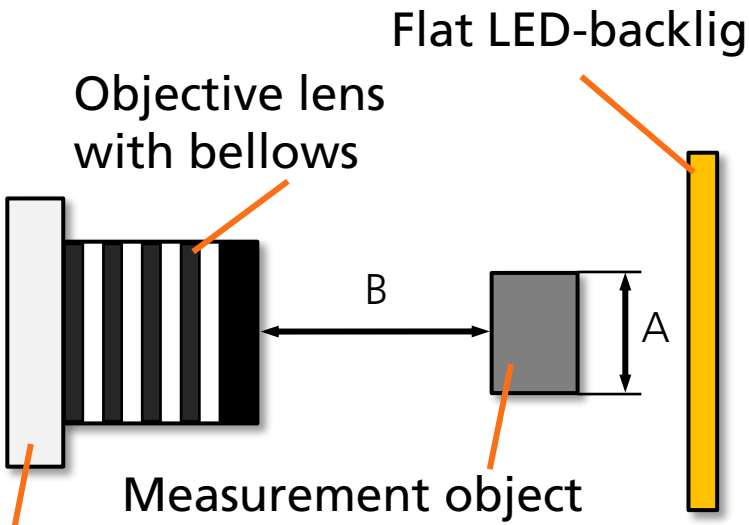
Experimental Tool & Measurement Devices

Setup of optical measurement method

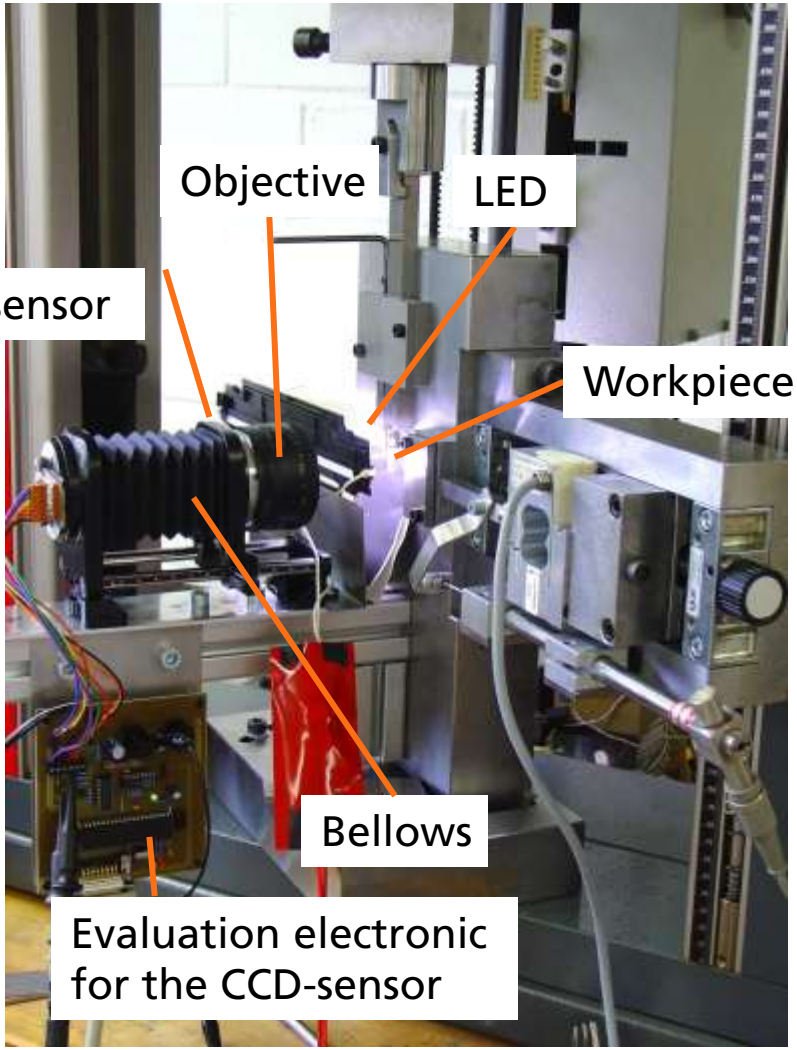


CCD-sensor:

Length: 29 mm with 2088 pixels

Pixel size: 0.014 mm

Measurement accuracy: 0.02 mm



Measurement device installed on the experimental tool

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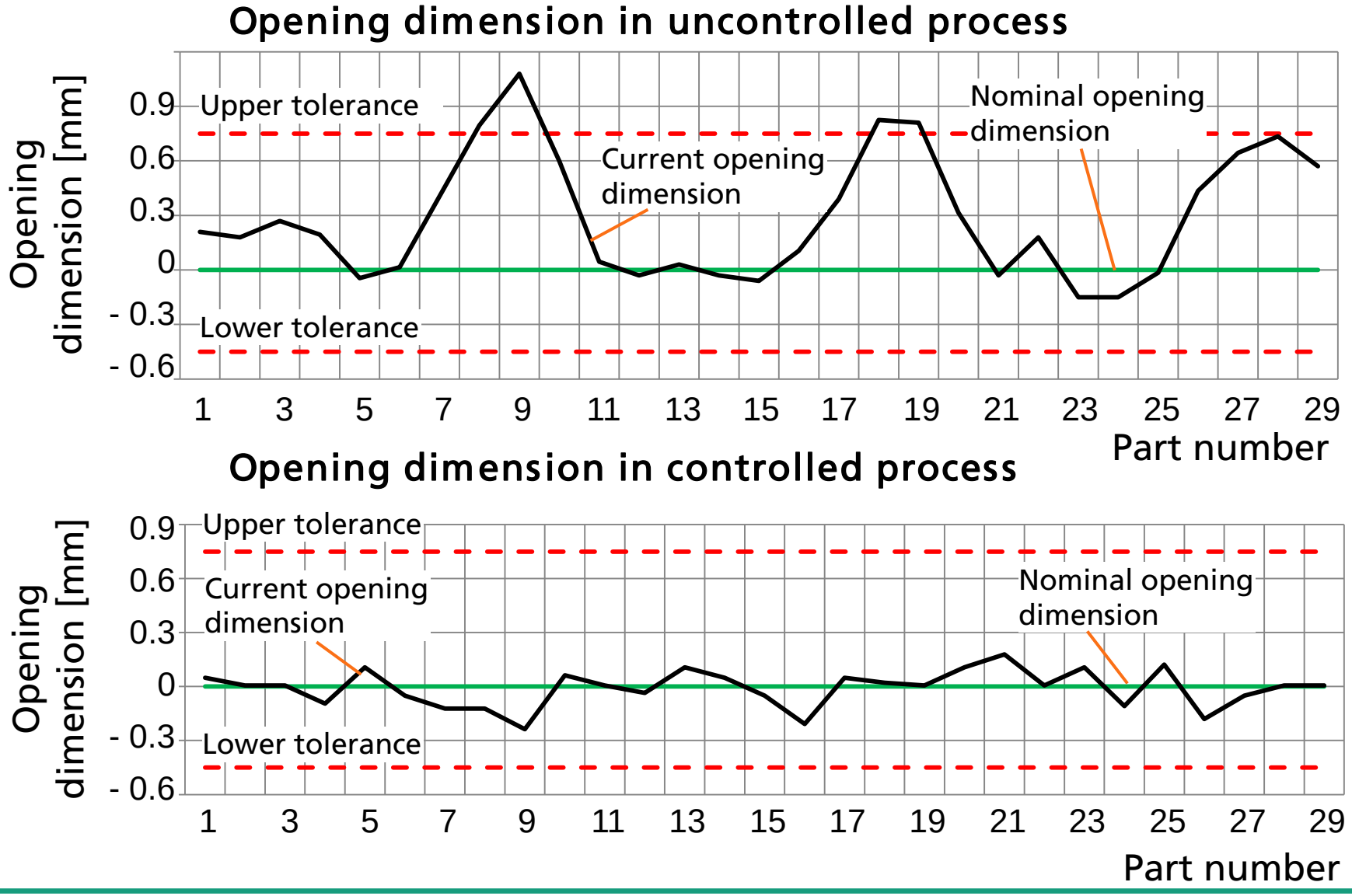
Results



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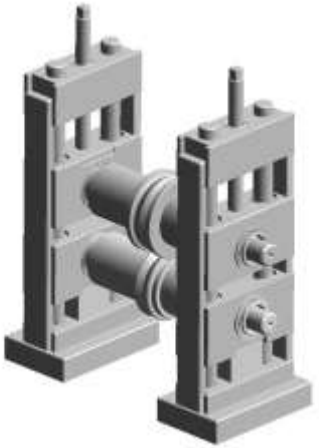
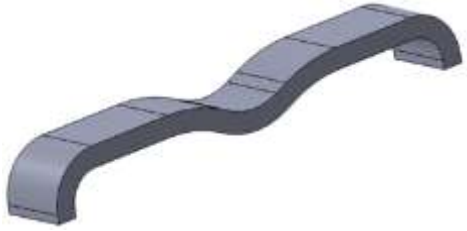
Conclusion

- MBS-model for bending process
  - Elastic & plastic deformation
- Feedback control to realize self correction
  - decreasing geometrically deviations

Outlook

- Transfer self-correction approach to other processes (e.g. roll forming)
  - different modeling approach?
- increase robustness / usability
- Self-correction for high production rates





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