Remote Tube Bending Lab

Excellent Teaching and Learning in Engineering Science

ELLI2

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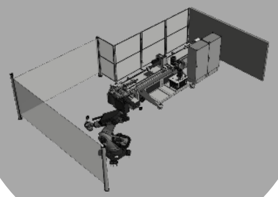
Remote Tube Bending Cell



Tube Bending Lab

Conclusion

MOTIVATION FOR A LAB

Combining theory with praxis– Improved learning experience

Literature	Feedback from Students
"Laboratory teaching assumes that first hand experience in observation and manipulation of the materials of science is superior to other methods of developing understanding and appreciation. It is frequently used to develop skills necessary for more advanced study or research" *Gage, N. L., et al. (1963)*	*"I would like more interaction with physical objects to better understand some concepts"*
"Sustained investments in hands-on experiences help inspire students to further their education and prepare them for high-technology careers by fostering skills sought by potential employers." *American Chemical Society*	*"Somethings are still behind foggy clouds since there are too much theory. I am a better understander when I see something with my eyes… "*

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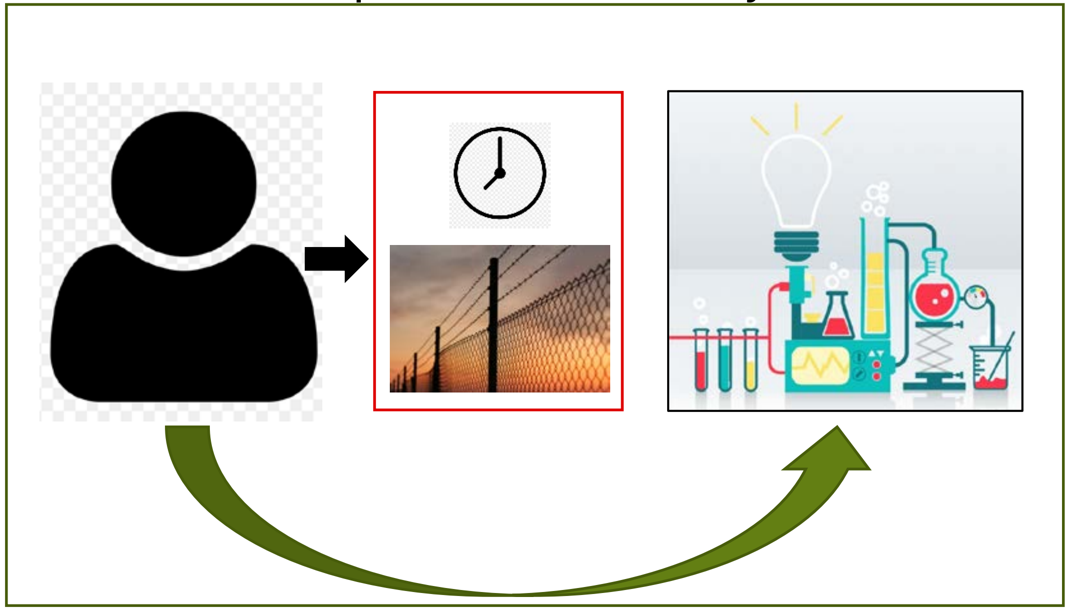
MOTIVATION FOR A REMOTE LAB

Improved accessibility



Globalised education

Resource efficiency

(Source: Vectorstock; steemit; lightremaine)

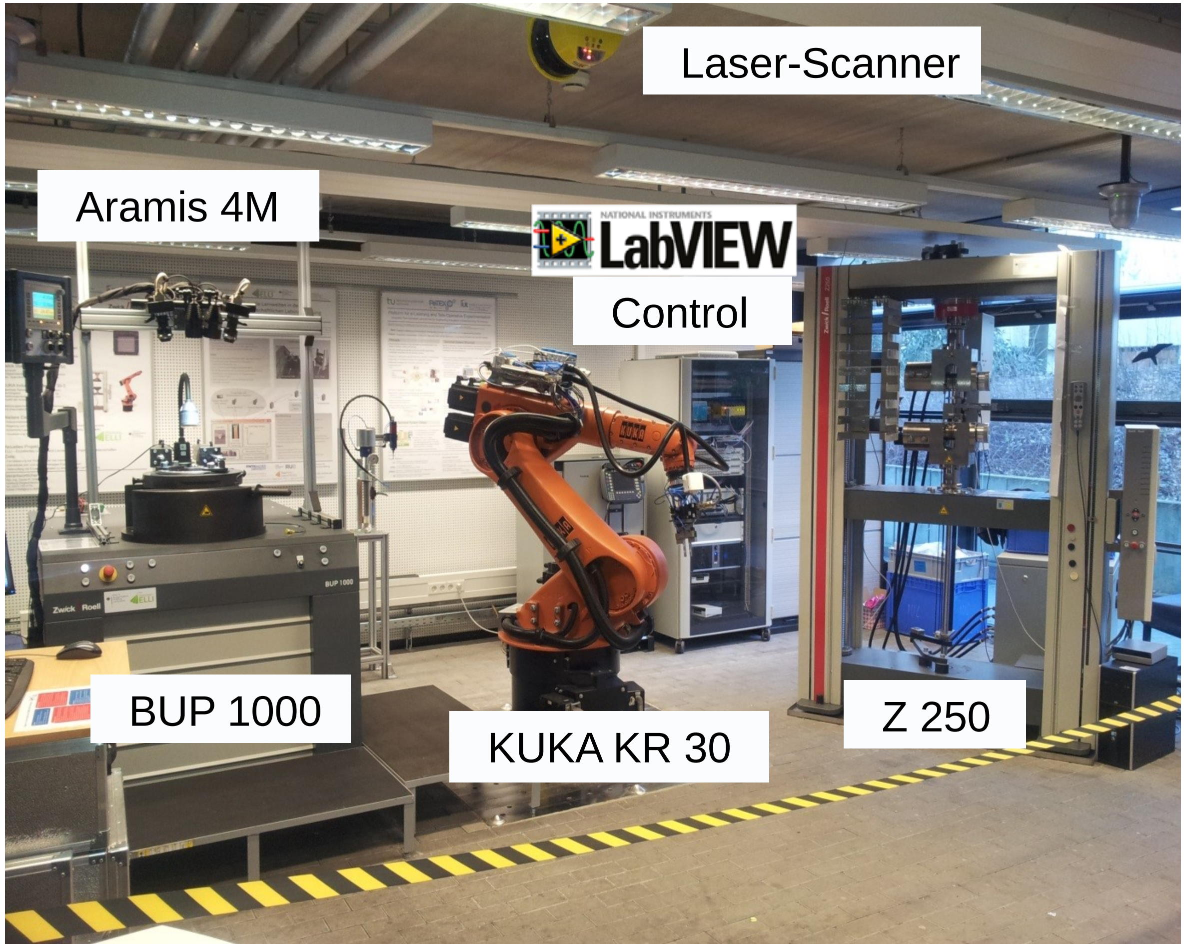
MOTIVATION FOR A REMOTE LAB

(Source: Com-magazin)

MOTIVATION FOR A REMOTE TUBE BENDING LAB

ELLI1

Remote Material Testing Cell



ELLI2

Labs with standard forming process /industrial machines

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Exzellentes Lehren und Lernen in den Ingenieurwissenschaften
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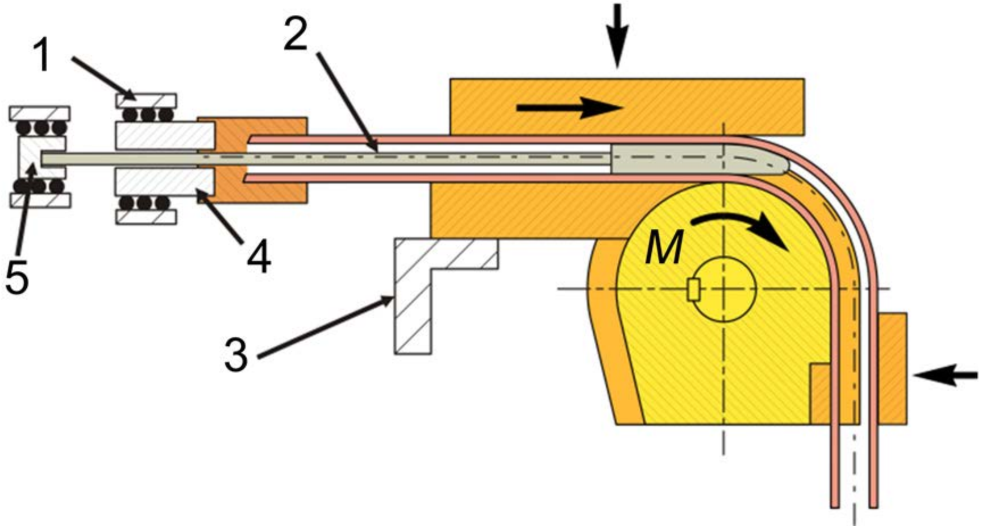
Rotary Draw Bending

Rotary Draw Bending Process

Sectional view



1	Tube Feed mechanism
2	Mandrel rod
3	Wiper die holder
4	Tube rotation mechanism
5	Mandrel feed mechanism

(Source: VDI 3430)

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ROTARY DRAW BENDING MACHINE

Transfluid DB 2060 CNC –
Rotary Draw Bending Machine

Manufacturer	Transfluid
Tube diameters	20 - 60 mm
Max. length of tube	3000 mm
Max. bend radius	200 mm
Max. bend angle	190°
Max. bending moment	14.4 kNm
Max. bending speed	30 °/s

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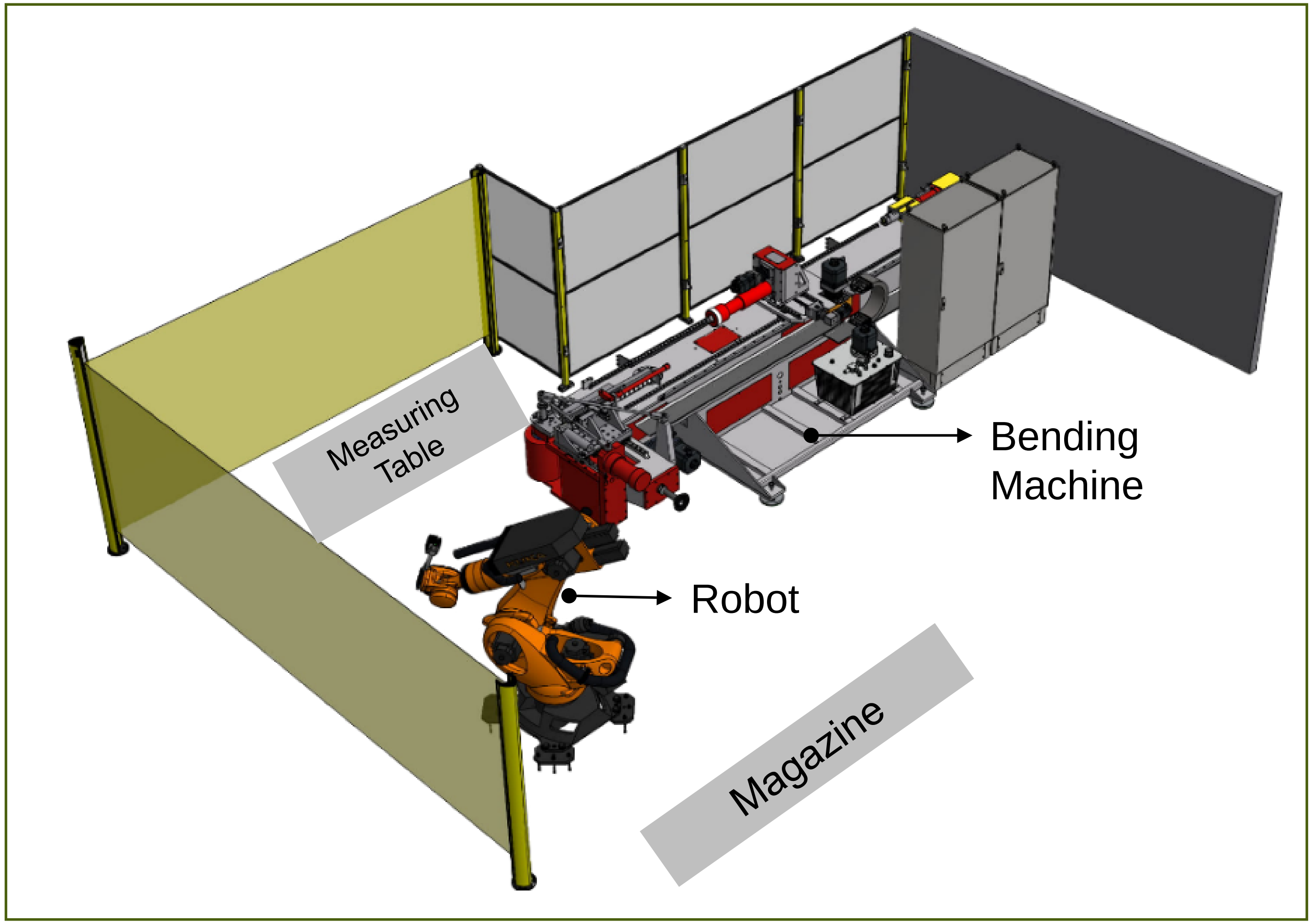
KUKA KR90 R3700 K

Technical Data	
Maximum reach	3701 mm
Rated payload	90 kg
Rated supplementary load	50 kg
Rated total load	140 kg
Position repeatabilty	± 0.06 mm
Number of axes	6
Mounting position	Floor
Footprint	830 mm x 830 mm
Weight	1204 kg
Protection rating	IP 65
Controller	KR C4

(Source: Kuka)

STRUCTURE OF THE REMOTE TUBE BENDING CELL

Mechanical Layout of the Cell



Safety System

Collision sensor

Laser Scanner

Light curtain

(Source: SICK; Schunk)

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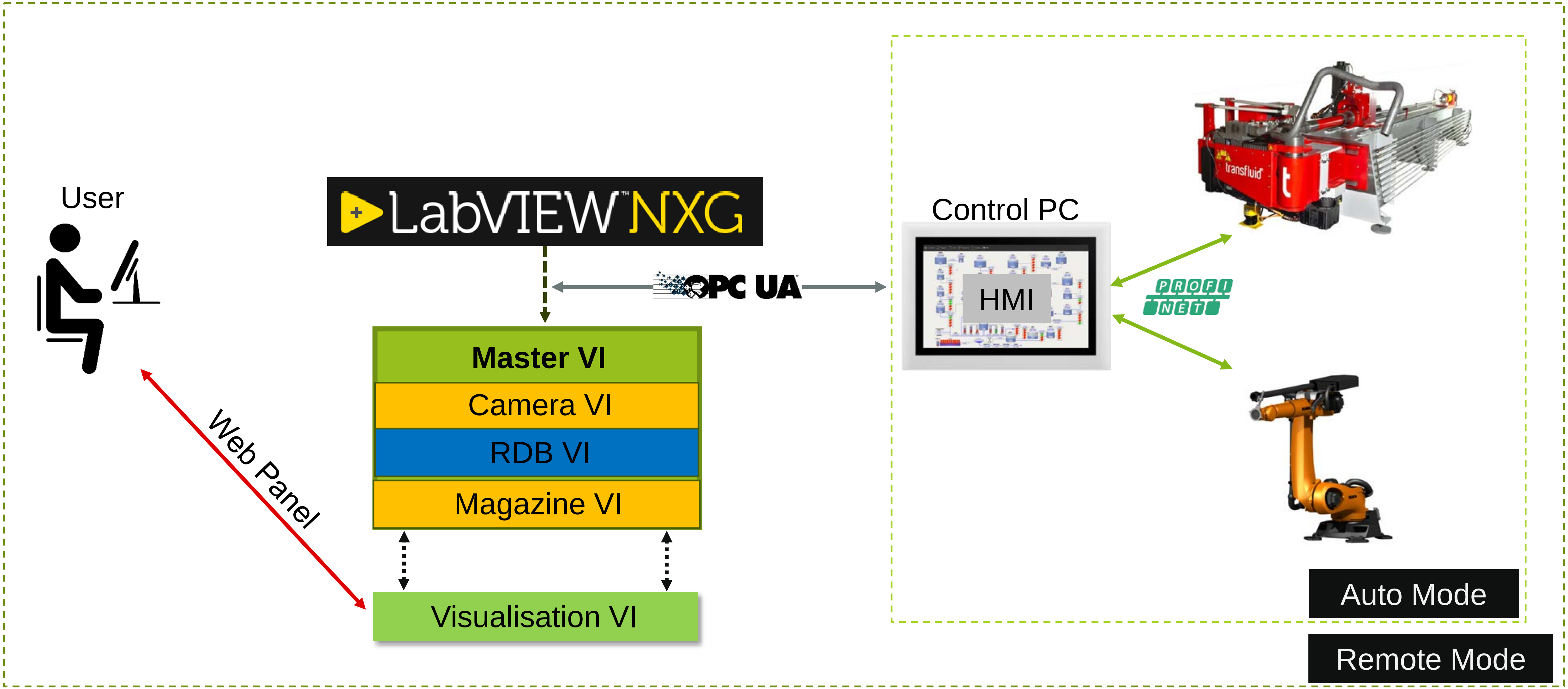
COMMUNICATION



(Image: Vectorstock)

Specimen Handling System

Requirements:

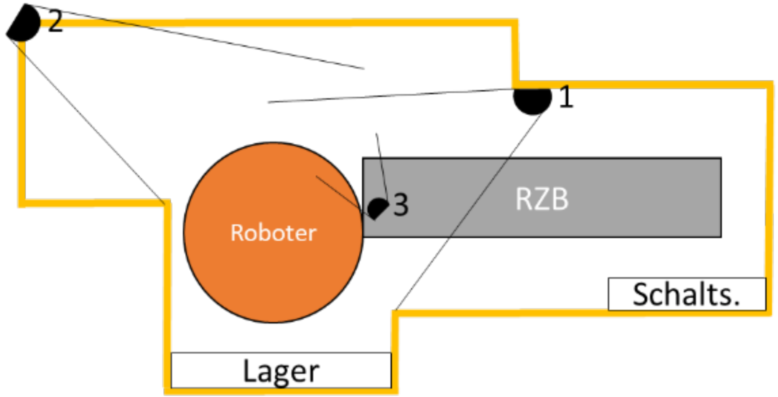
- Length and diameter independent storage
- Gap between individual tubes
- Accurate positioning to ensure repeatability

Cantilever racks

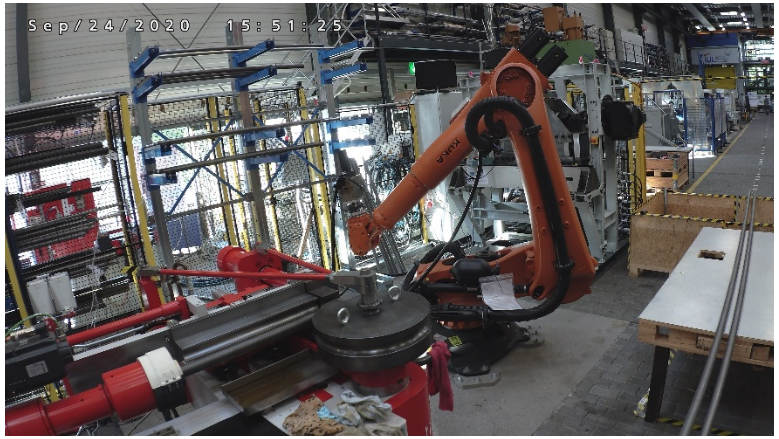
Mount with end stop

Gripper

Observation System

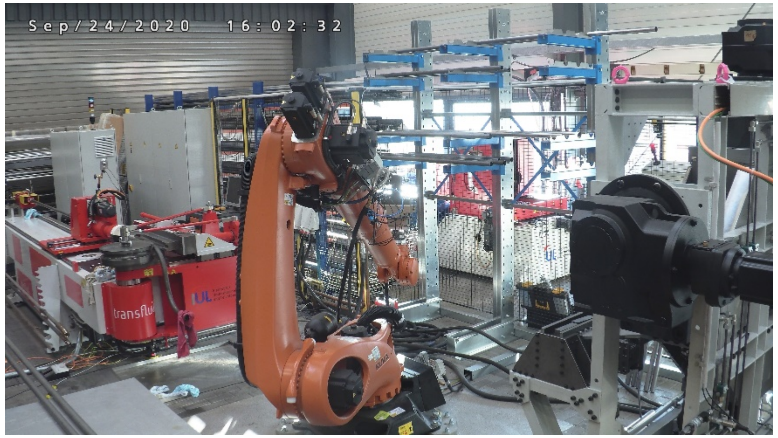


Camera 1



Specimen loading and unloading

Camera 2



Complete view

Camera 3

Forming zone

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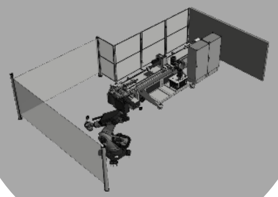


Tube Bending Lab

Conclusion

Absence of a Reference Lab

(Source: Self-avenue)

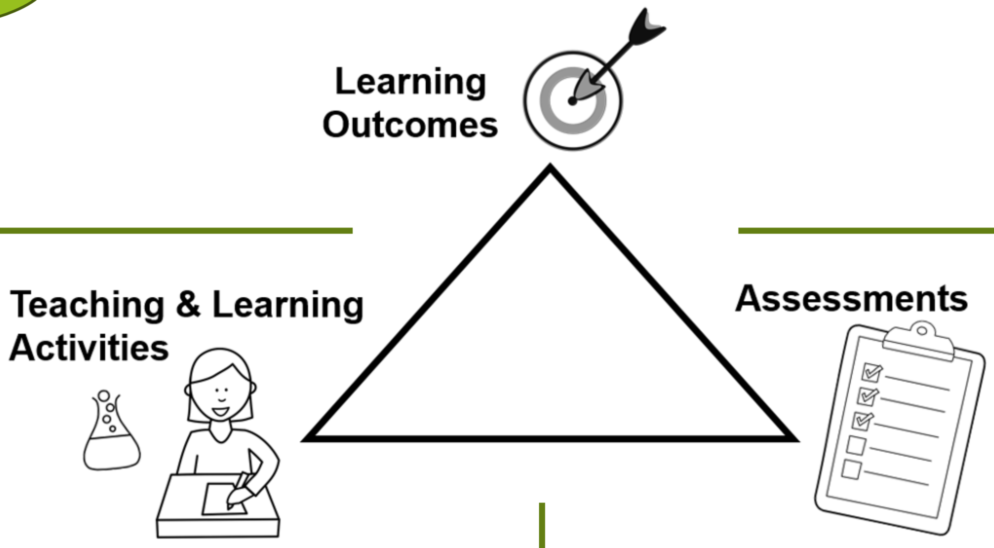
The Boring Tube Bending Lab

Hi → Do This, Do That! → Learn this, Learn that! → Bye

(Source: Odyssey)

Constructive Alignment

- Problem Solving
- Data Recording
- Data Analysis
- (Digital) Team skills
- Subject competency & In-depth understanding
- Resource management
- Independency
- Decisiveness
- Familiarity & Confidence around Industrial Machines



- Student motivation
- Interest stimulation
- Opportunity to work together

Have we arrived yet?

(Source: Higher Education Academy Engineering Education Centre ; Teaching and Learning centre, UoIT; Vectorstock)

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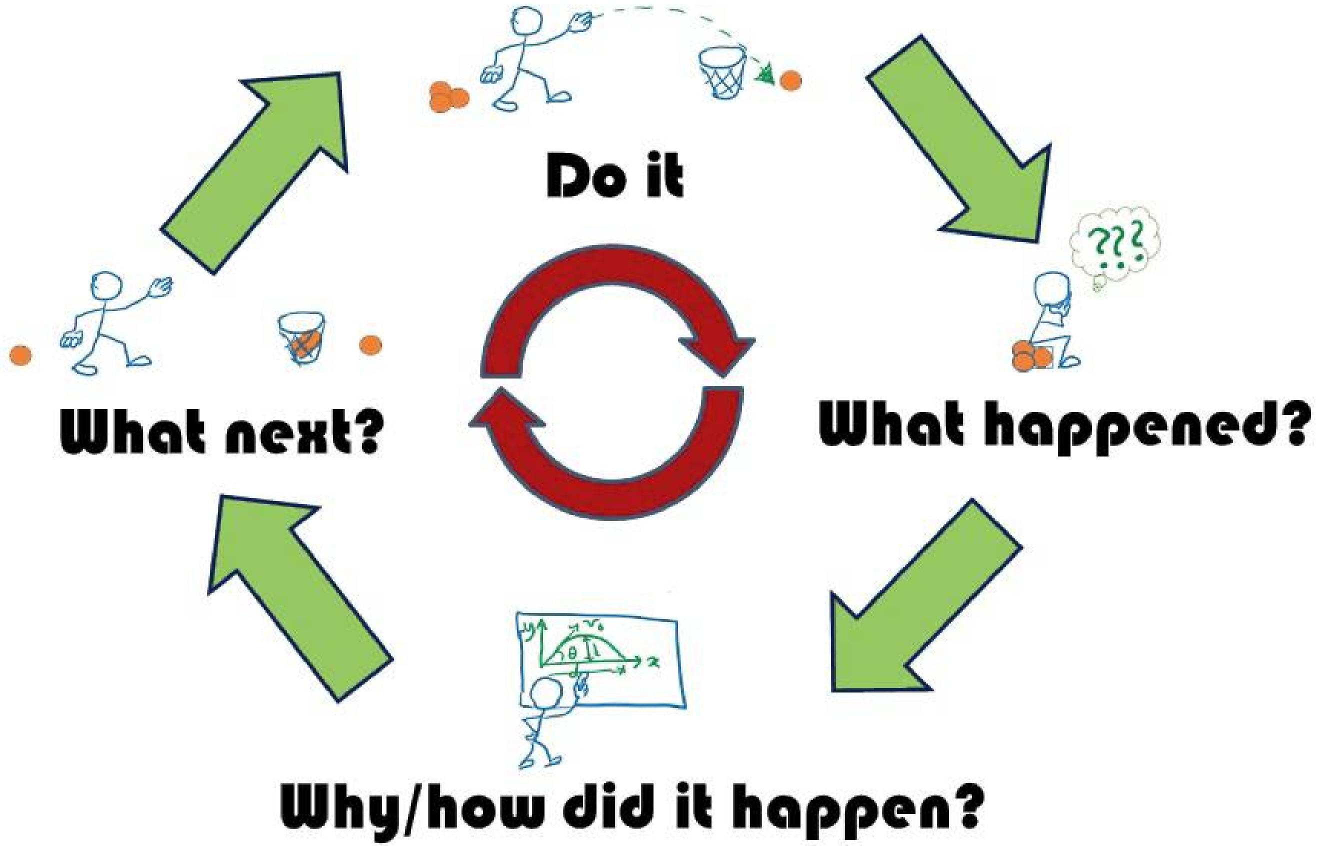
Kolb's Experiential Learning Cycle



(Source: Rowshan Rahmanian)

Traditional Learning

Told what we need to know → Memorize it → Problem assigned to illustrate how to use it

Problem Based Learning

Real world problem → Identify what we need to know → Learn and apply it to solve the problem

(Source: Centre for Faculty Development and Innovation, Southern Illinois University)

Product Manufacture Cycle

Design of the lab using the product manufacture cycle as a reference

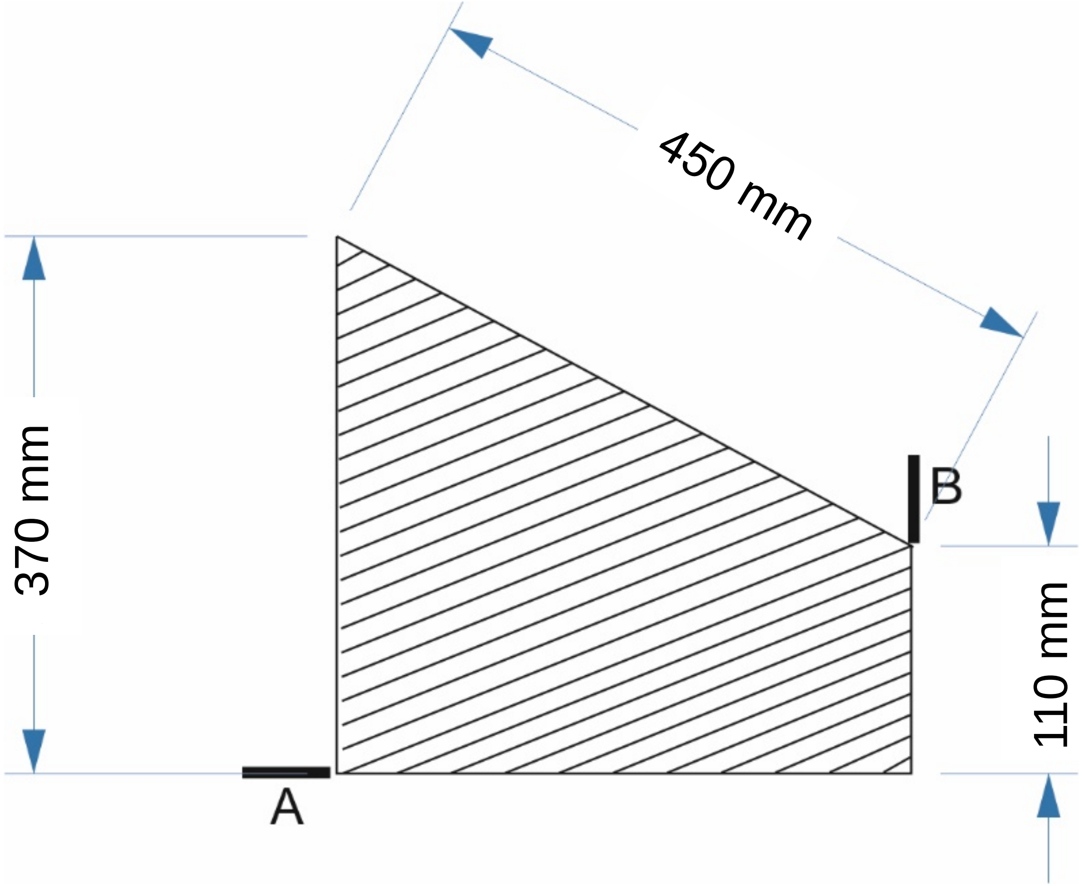
Problem → Product Design → Process Planning → Testing and Validation → Production

(Source: Classroom-clipart)

PROBLEM

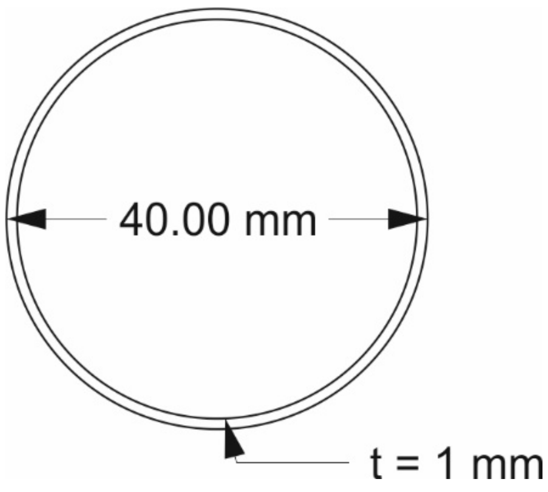
„Every Problem is an Opportunity in Disguise“

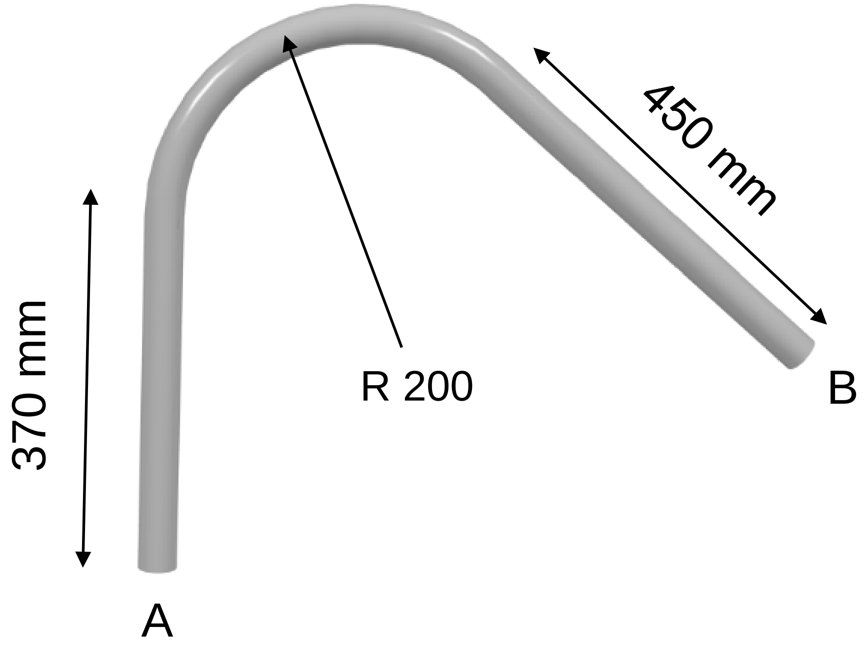
- Steel pipeline to connect A and B
- Flow rate required: 40 m^3/hr
- Flow velocity required: 10 m/s
- Regular pigging of the pipeline
- Mass production



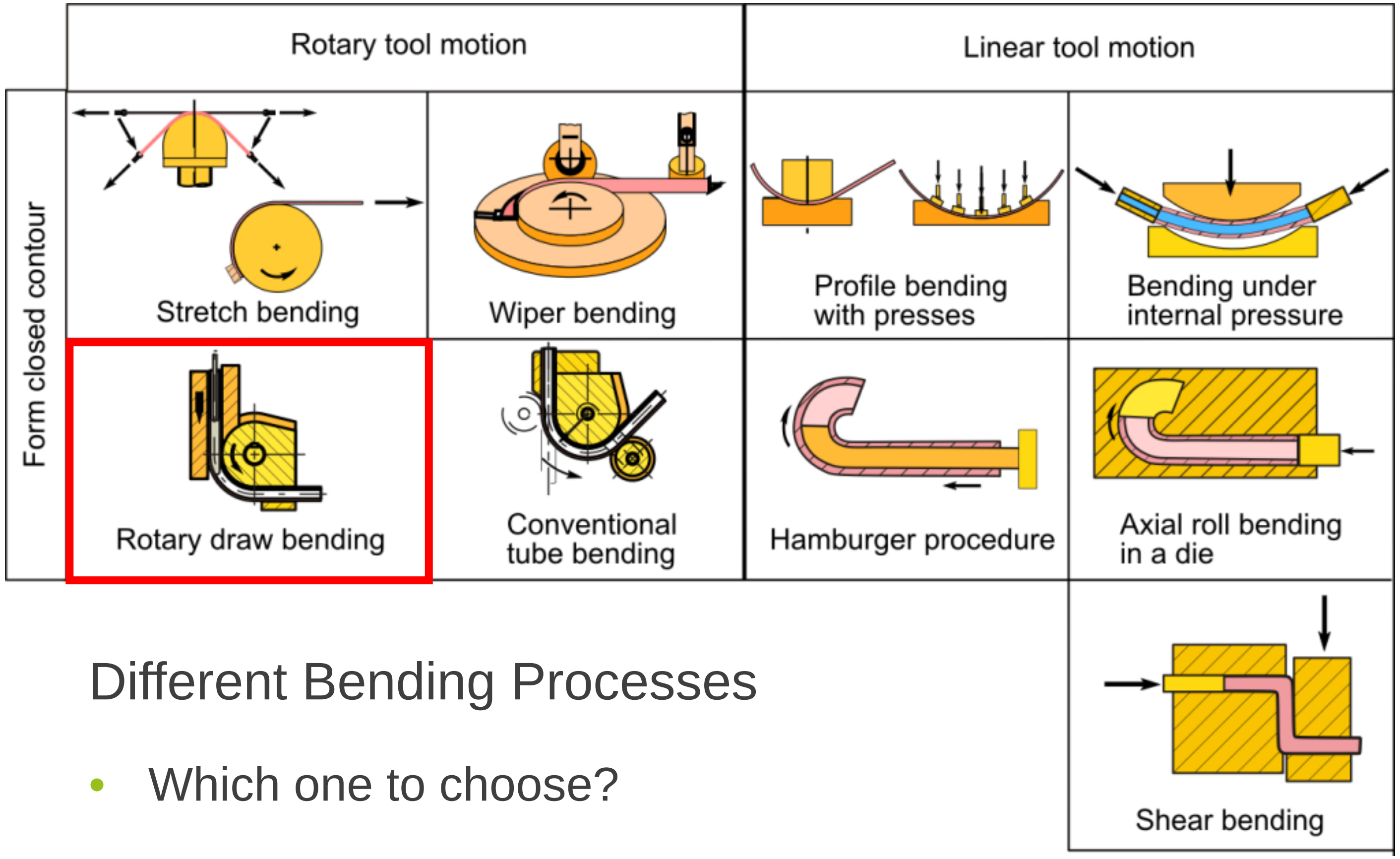
SOLUTION (PRODUCT DESIGN)

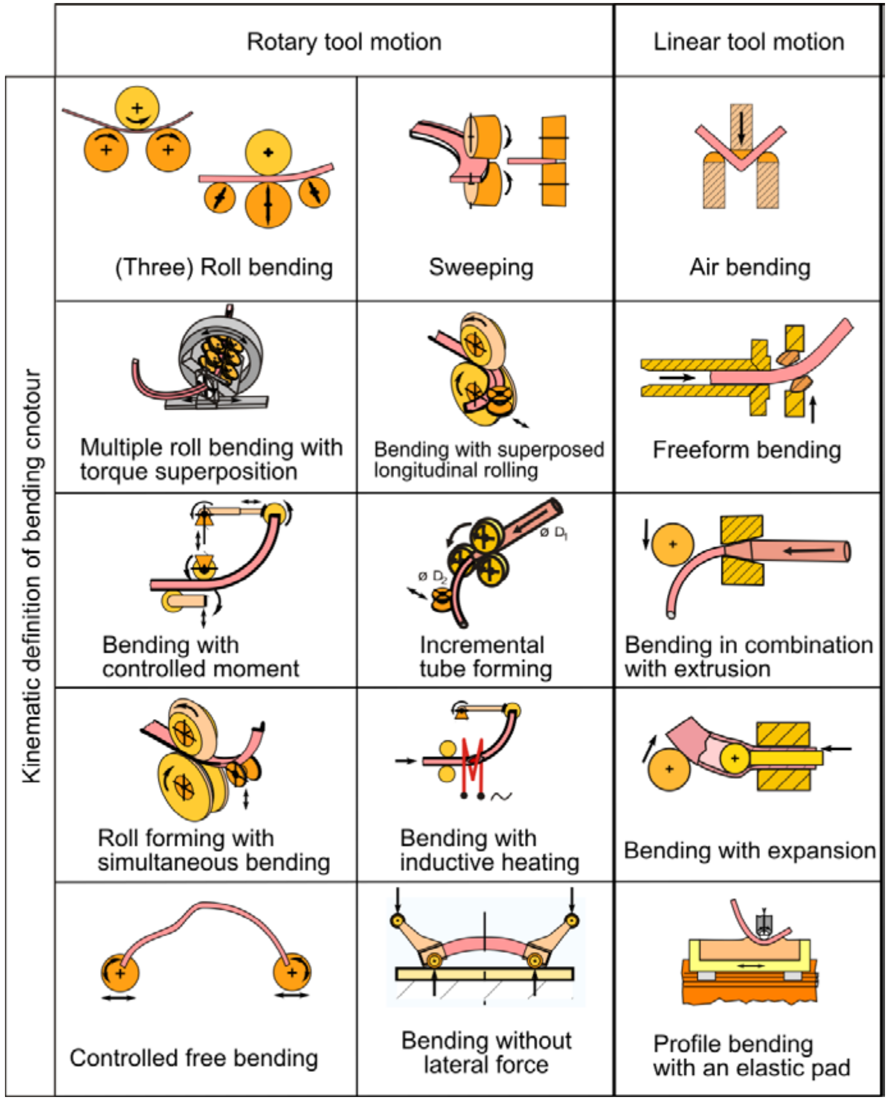
- Flow rate Q = Area * Velocity
- Pipe thickness $t = \frac{p \cdot D}{2(S \cdot E + p \cdot Y)}$
- Pigging – Bend radii : 3-5 D
- Bend angle θ = 130°





PROCESS PLANNING





Different Bending Processes

- Which one to choose?
- What tools to choose?
- Recap of theory

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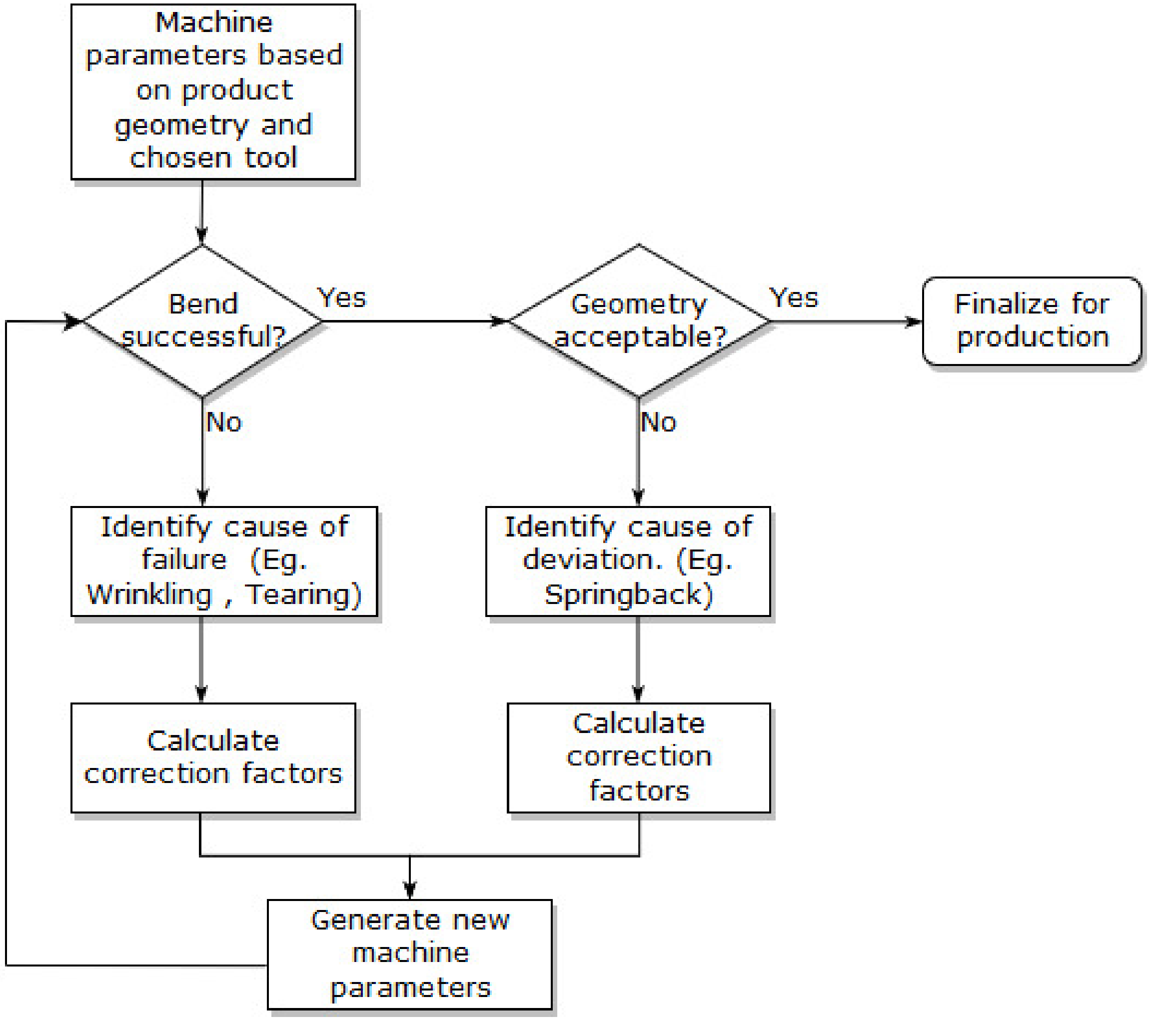

Springback not considered

Springback calculated according to theory

Actual Geometry ≠ Target Geometry

(Source: pngtree)

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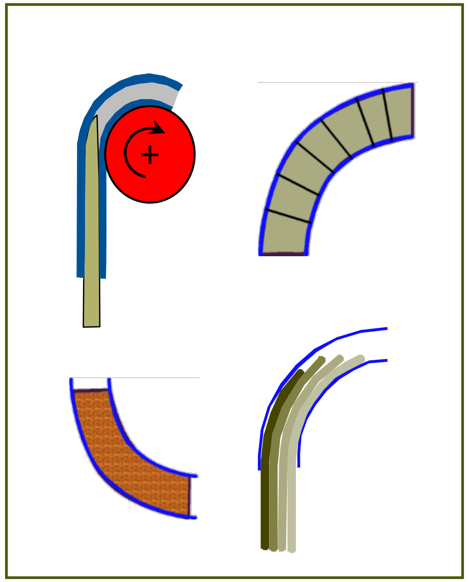
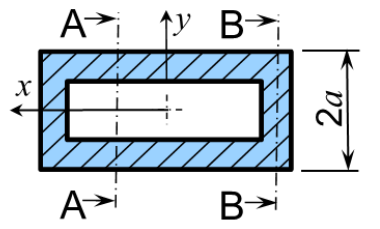
LEARNING OBJECTIVES

Lecture content→ Reinforcement through lab

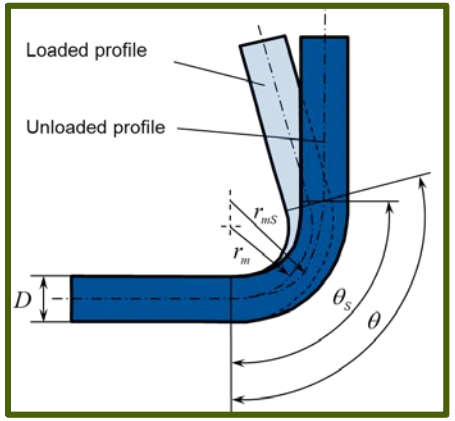


Profile Bending

- Process limits
- Bending moment
- Mandrel
- Springback



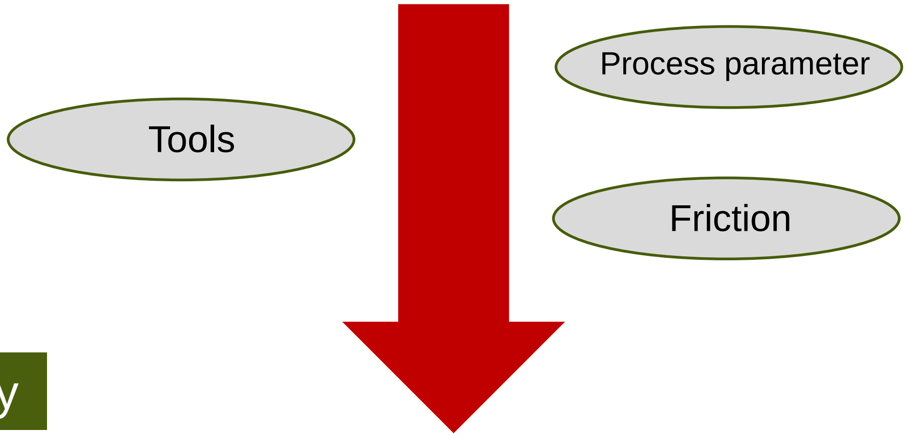
$$M_b = 2 \cdot \int_0^a \sigma_{zz} \cdot y \cdot dA$$



Bending moment: Theory vs. Reality

Theory

$$M_{B,ideal} = M_{B,el} + M_{B,pl} = \int_{A_{el}} \sigma(y) \cdot y \cdot dA + \int_{A_{pl}} \sigma(y) \cdot y \cdot dA$$

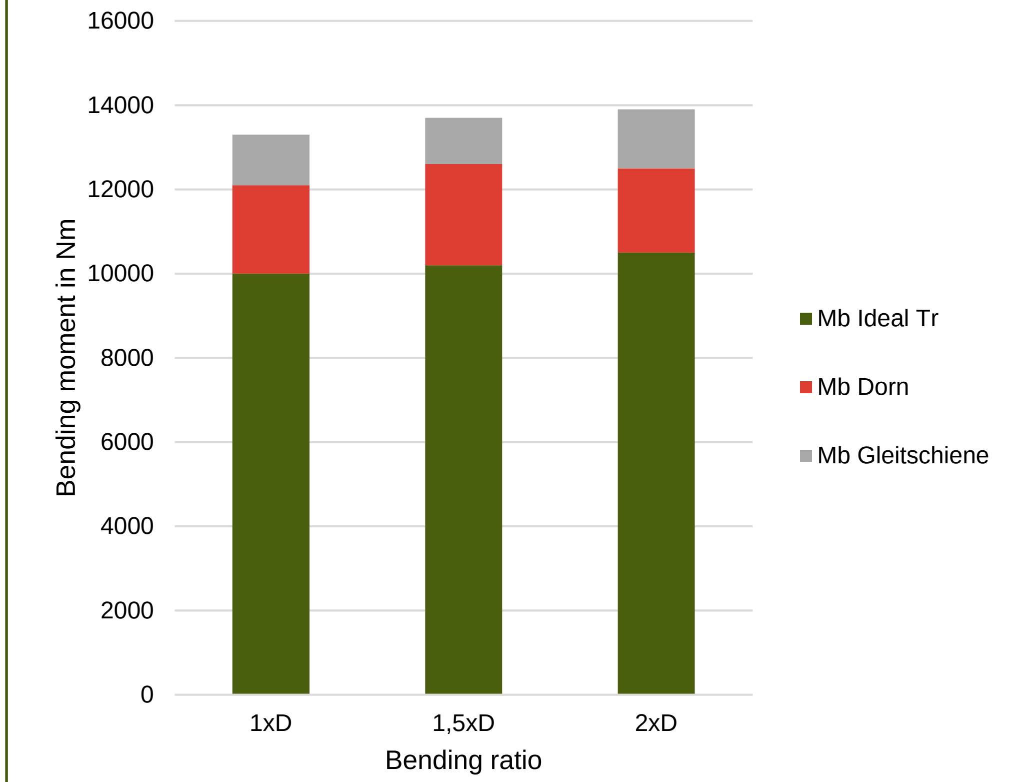


Reality

$$M_{B,real} = M_{B,ideal\ Tr} + M_{B,Dorn} \pm M_{B,pressure\ die}$$

Force sensor

Bending moment – Influence of bending ratio



(Source: Engel, 2008)

Biegefaktor = Biegeradius/Rohrdurchmesser

SPRINGBACK: THEORY VS. REALITY

Exzellentes Lehren und Lernen in den Ingenieurwissenschaften ELLI2

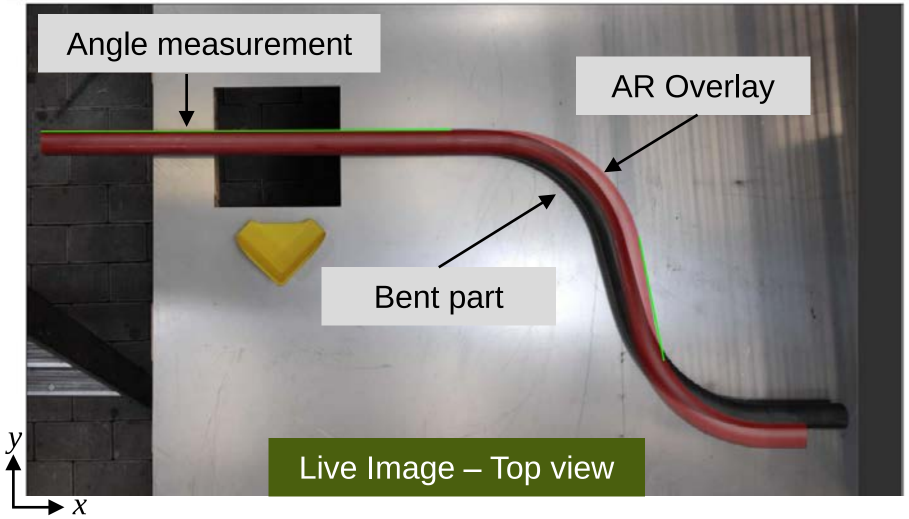
$$\frac{1}{r_{mS}} = \frac{1}{r_m} - \frac{M_b}{E \cdot I}$$

Theory

Material and geometry | Stiffness | Control

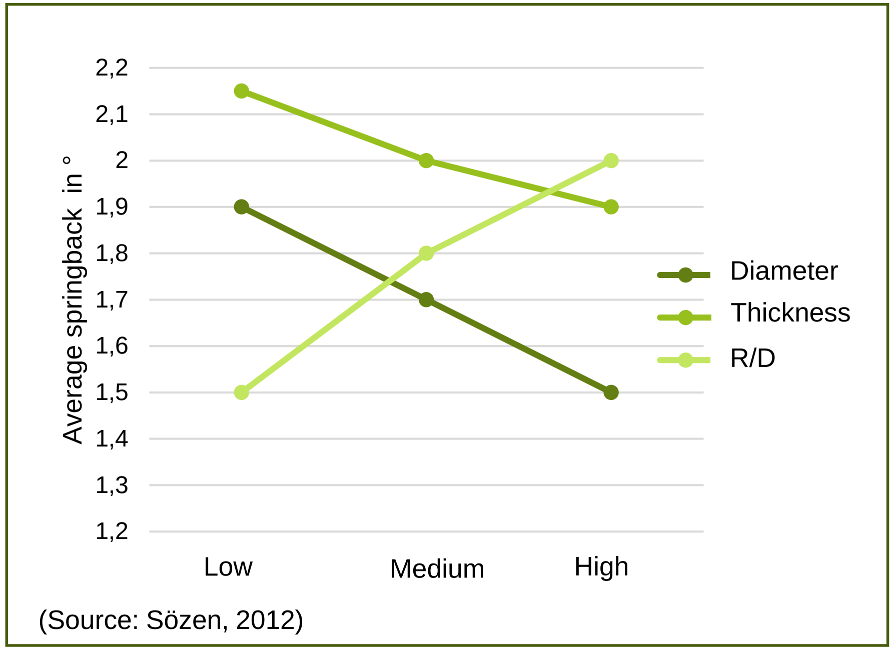
Springback

Reality



Biegewinkel
$\theta_{soll} = 80°$
$\theta_{ist} = 82°$

Influencing parameters on springback



(Source: Sözen, 2012)

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