UNIVERSITÄT PADERBORN
Die Universität der Informationsgesellschaft

I²FG International Impulse Forming Group

Influences of different process parameters on the deformation of tubes and sheet metals using pneumo-mechanic and electrohydraulic forming

Werner Homberg, Eugen Djakow, Olga Akst

May 2013

Motivation – High speed forming

Chair of Forming and
Machining Technology
University of Paderborn

Save resources and environmental protection

⇨ New materials: high strength steels, hybrid materials …

⇨ Multifunctional parts

⇨ Innovative and efficient processes like high speed forming

- Prepare high speed forming processes for a wide field of industrial use
- Analyse and control the process' phenomena
- Influence of different process parameters on the forming result

Content

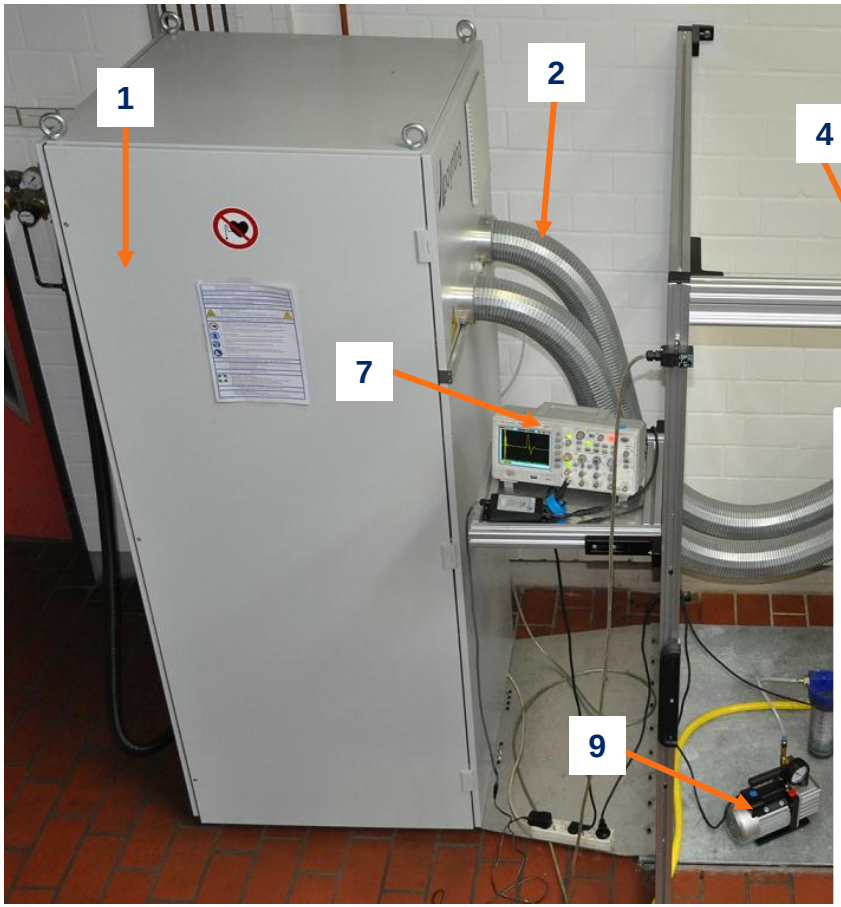
Chair of Forming and
Machining Technology
University of Paderborn

- Electrohydraulic Forming
  - Influence of the load energy on the repeatability of the forming hight and the pressure distribution on the blank
  - Influence of the working medium on the forming result

- Pneumo-mechanic Forming
  - Forming of tubes by pneumo-mechanic Forming compared to conventional forming processes
  - influence of different process parameters on tube forming

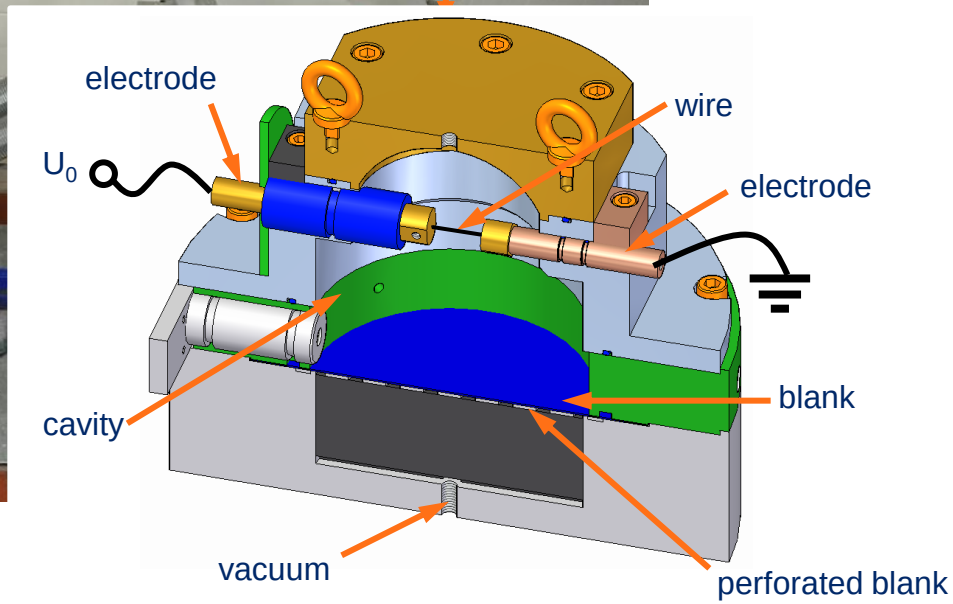
Set-up for Electrohydraulic Forming

Chair of Forming and
Machining Technology
University of Paderborn



SSG 0620 (two capacitor banks):

- Max. Load energy: 6 kJ (3 kJ/capacitor); overload: 9 kJ
- Capacity: 30 µF (15 µF/capacitor)
- Max. Load voltage: 20 kV; overload: 25 kV
- Max. current: 160 kA (80 kA/bank)



1: Pulse power generator
2: HV-Cable
3: Table
4: Partition/ Fence
5: EHF-Tool
6: Protective case
7: Oscilloscope
8: Rogowski-coil
9: Vacuum pump

Overview on the process parameters used

Chair of Forming and
Machining Technology
University of Paderborn

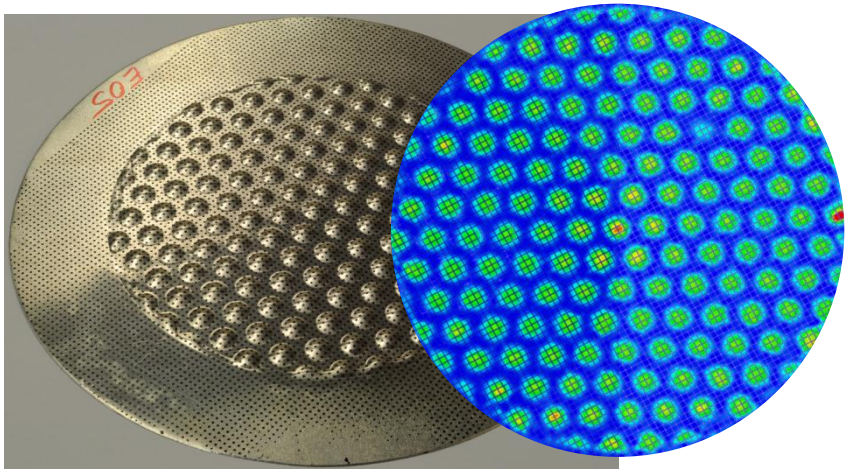
- Reproducibility of the forming hight
- Reproducibility of the discharge process
- Pressure distribution on the blank

Load energies

2 kJ…4 kJ

Electrodes

Material: CuCrZr
Geometry: plane



Working medium

- Water
- Starch + Water
- Slime
- Ethylen glycol

Wire

Material: CrNi44 (Constantan)
Thickness: 0.3 mm

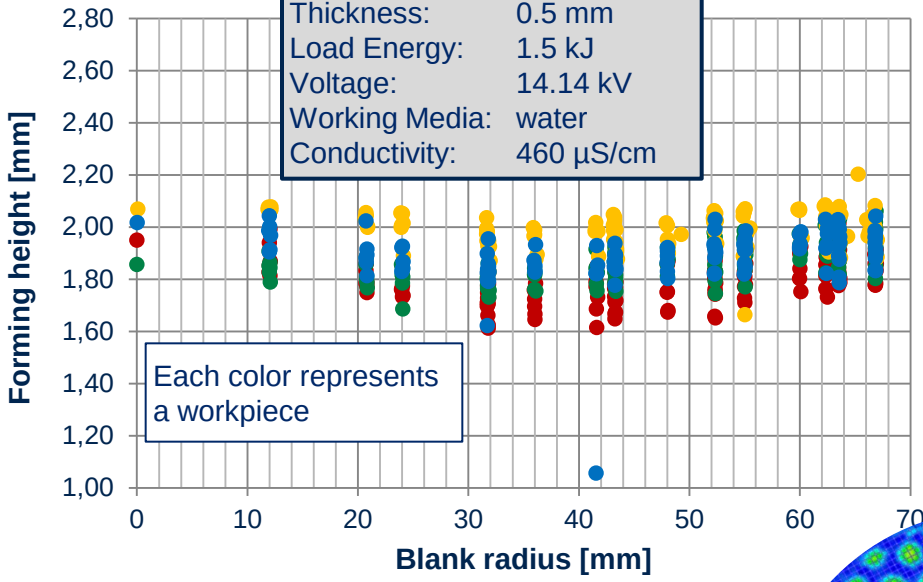
Sheet metal

Material: AA1050, 1.0338
Thickness: 0.5 mm

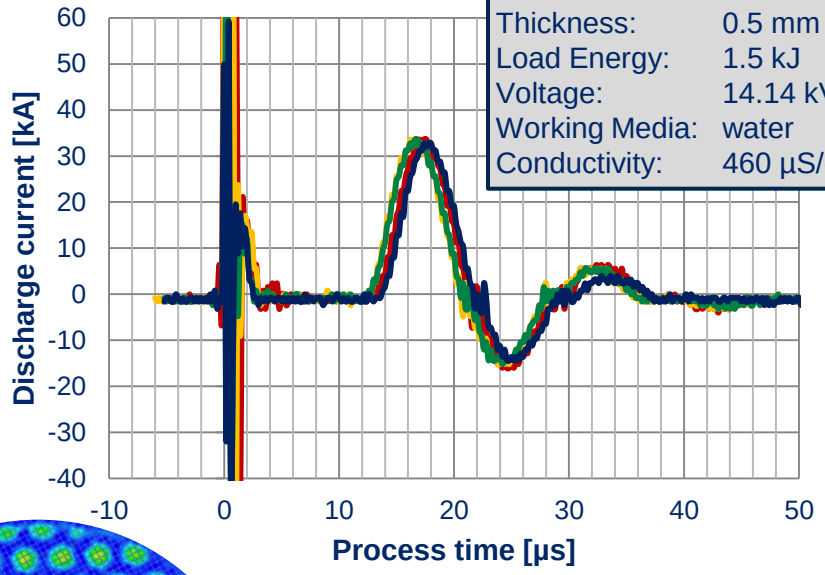
Pressure distribution and reproducibility using water

Chair of Forming and Machining Technology
University of Paderborn

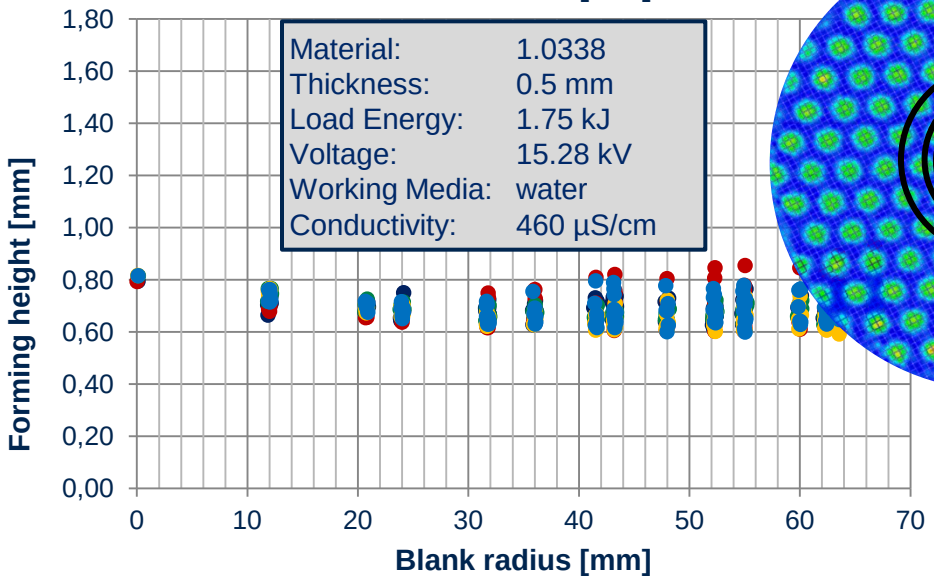
Material:	AA1050
Thickness:	0.5 mm
Load Energy:	1.5 kJ
Voltage:	14.14 kV
Working Media:	water
Conductivity:	460 µS/cm

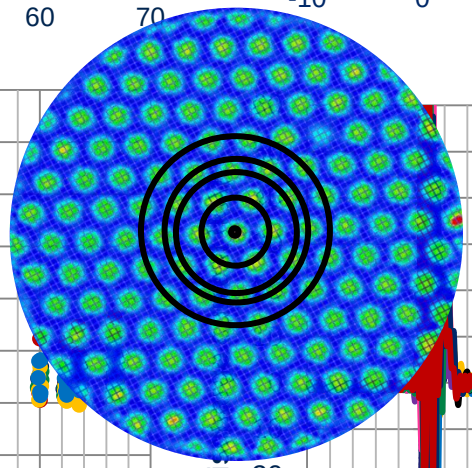


Material:	AA1050
Thickness:	0.5 mm
Load Energy:	1.5 kJ
Voltage:	14.14 kV
Working Media:	water
Conductivity:	460 µS/cm

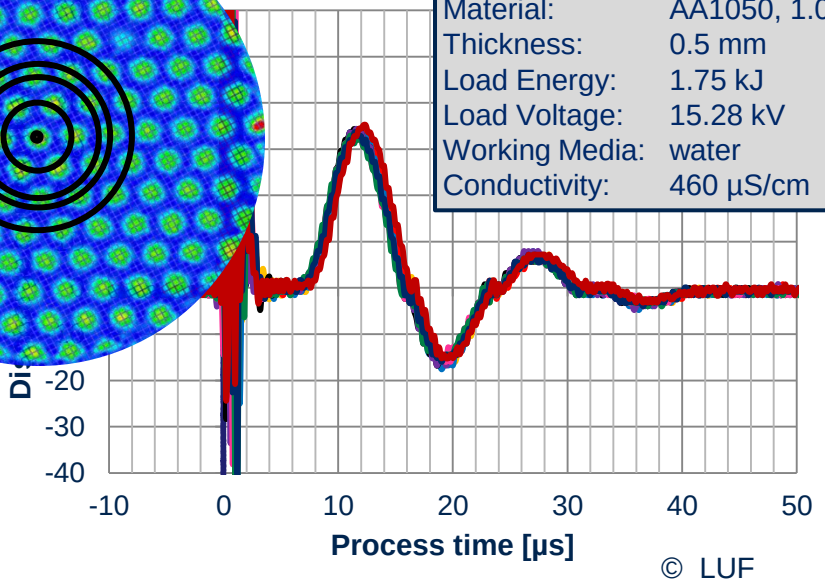


Material:	1.0338
Thickness:	0.5 mm
Load Energy:	1.75 kJ
Voltage:	15.28 kV
Working Media:	water
Conductivity:	460 µS/cm



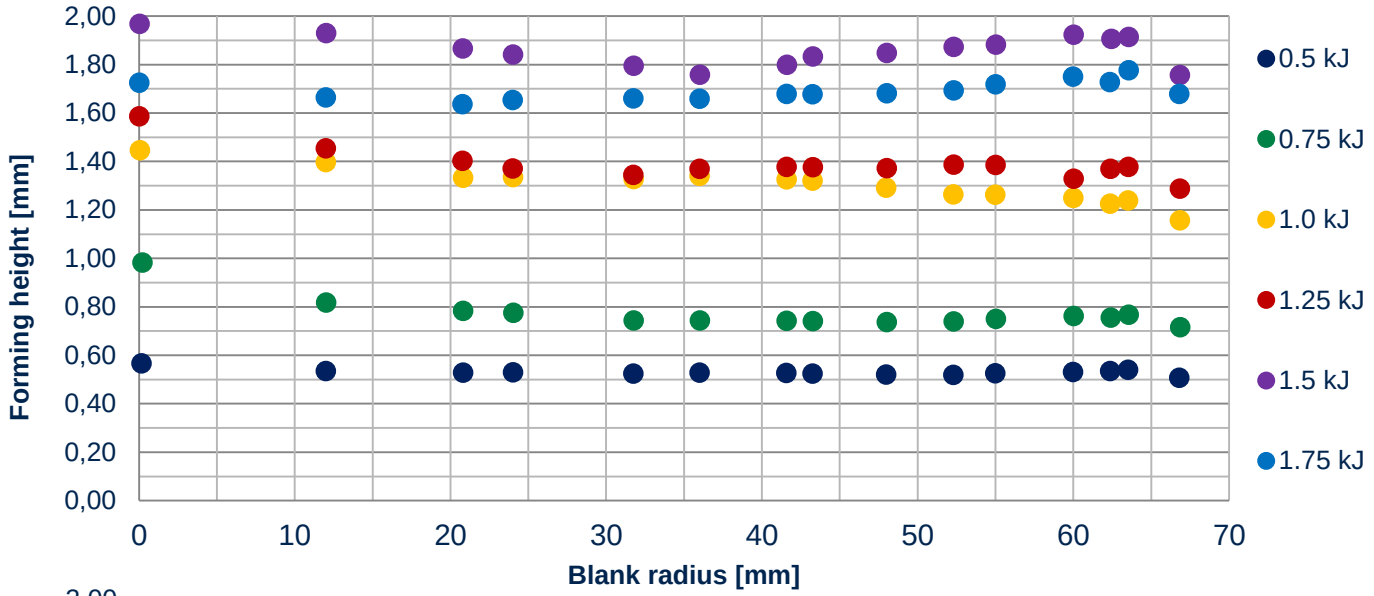


Material:	AA1050, 1.0338
Thickness:	0.5 mm
Load Energy:	1.75 kJ
Load Voltage:	15.28 kV
Working Media:	water
Conductivity:	460 µS/cm

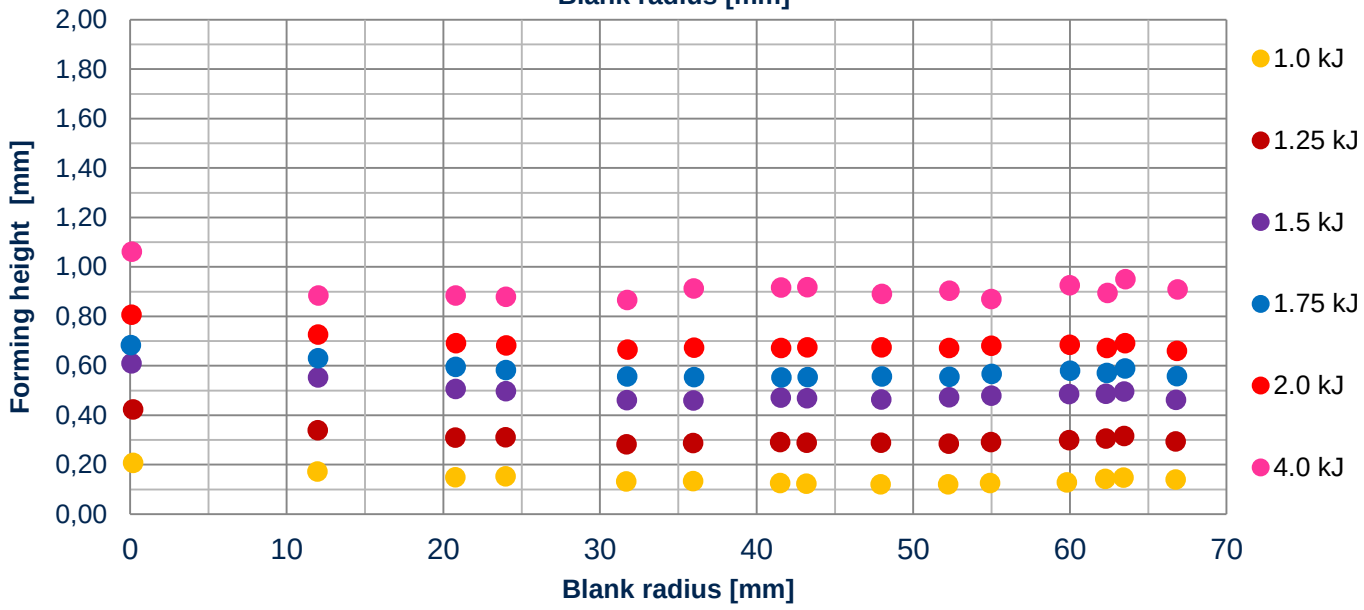


Influence of load energy/voltage on the forming hight

Chair of Forming and
Machining Technology
University of Paderborn



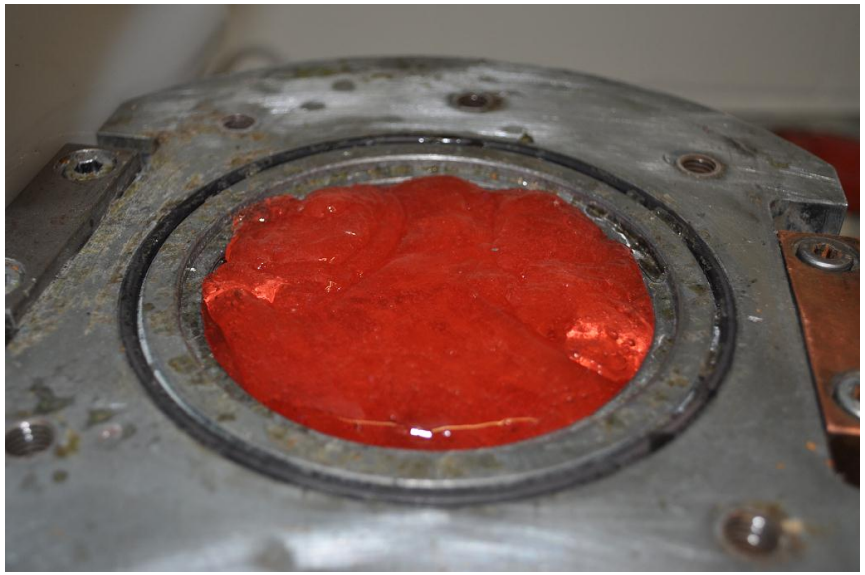
Material:	AA1050
Thickness:	0.5 mm
Load Energy:	0.5 …1.75 kJ
Working Media:	water
Conductivity:	460 µS/cm

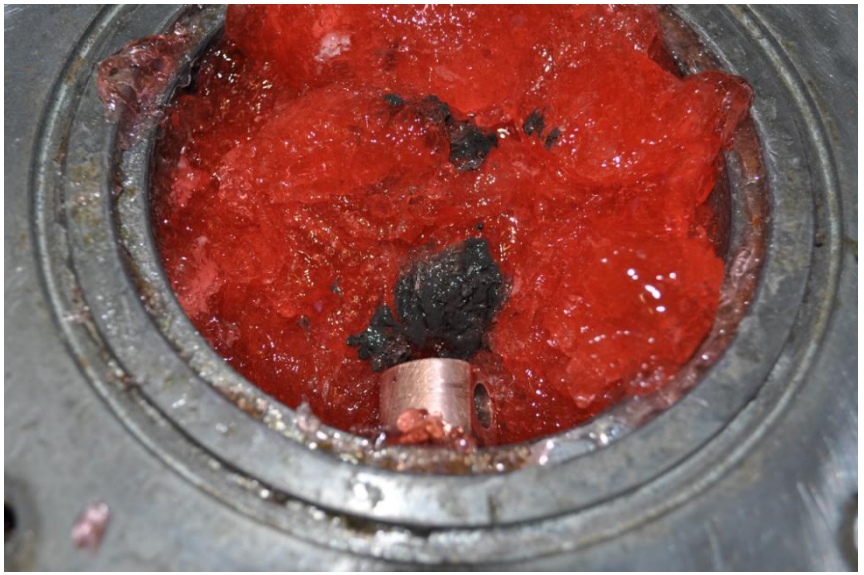


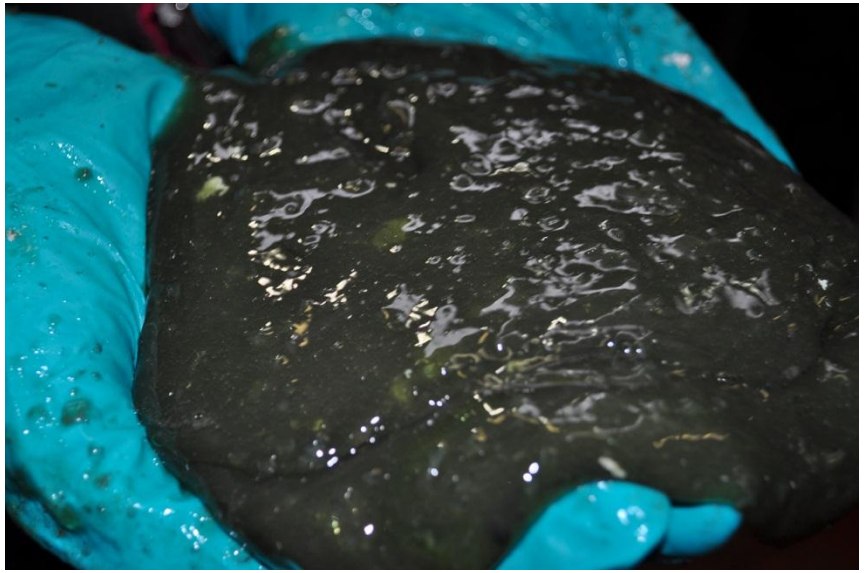
Material:	1.0338
Thickness:	0.5 mm
Load Energy:	1 kJ …4 kJ
Working Media:	water
Conductivity:	460 µS/cm

Working medium - Slime

Chair of Forming and
Machining Technology
University of Paderborn

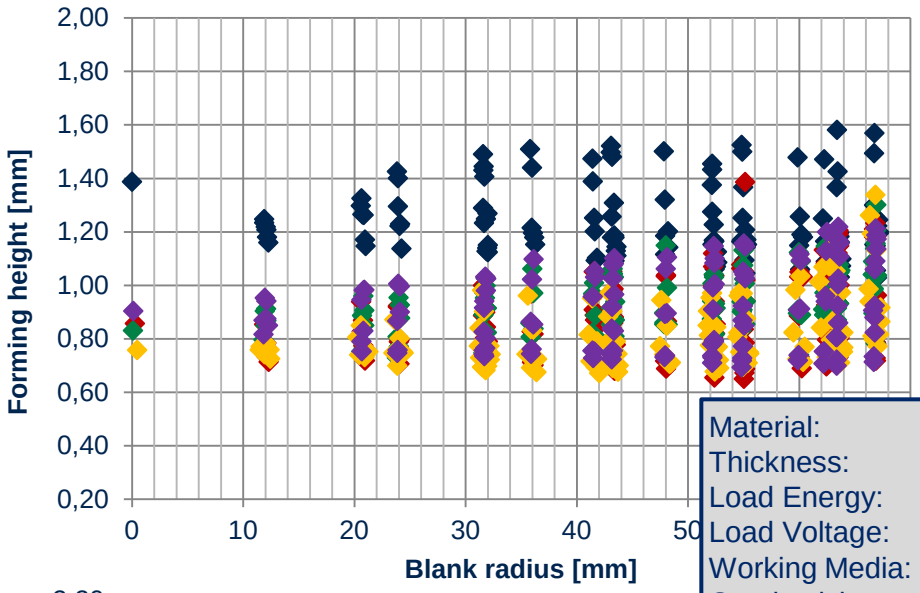


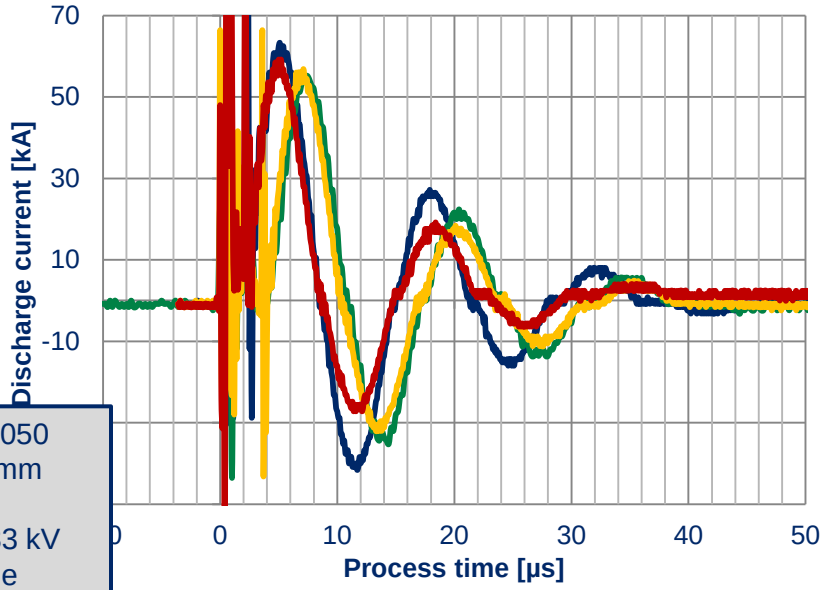




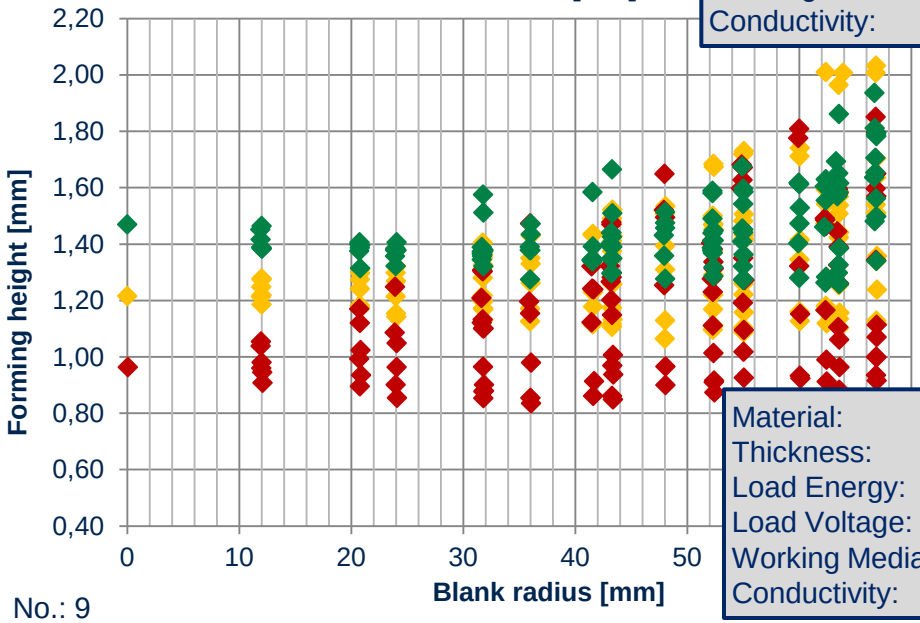
Reproducibilily and pressure distribution using Slime

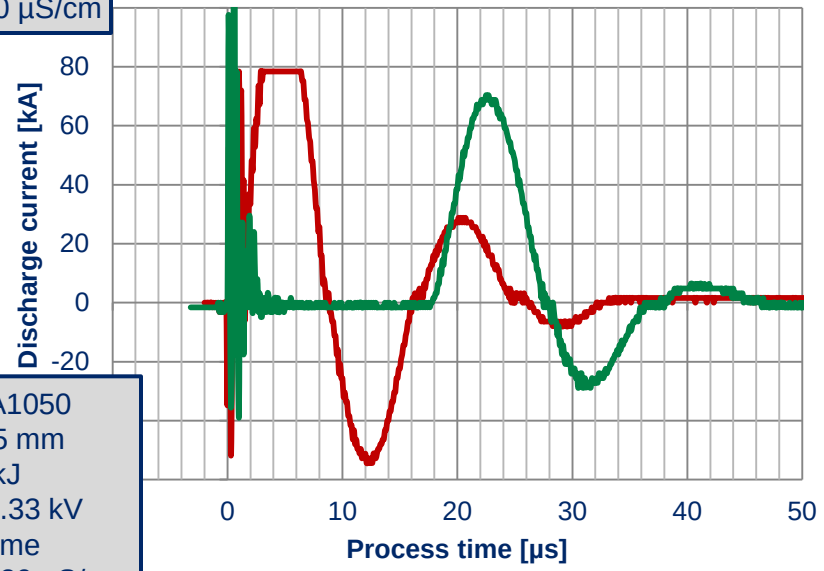
Chair of Forming and Machining Technology
University of Paderborn





Material:	AA1050
Thickness:	0.5 mm
Load Energy:	2 kJ
Load Voltage:	16.33 kV
Working Media:	Slime
Conductivity:	1820 µS/cm

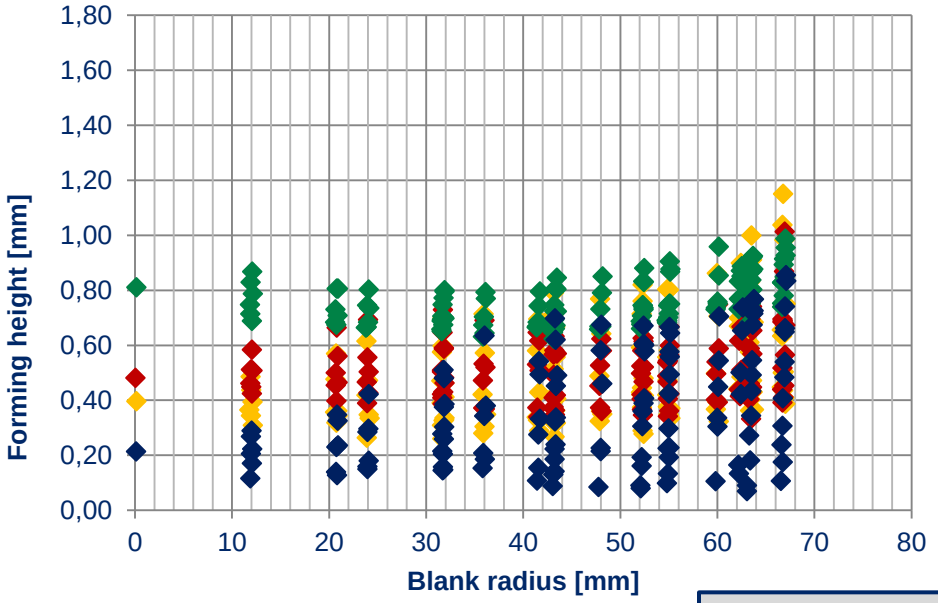


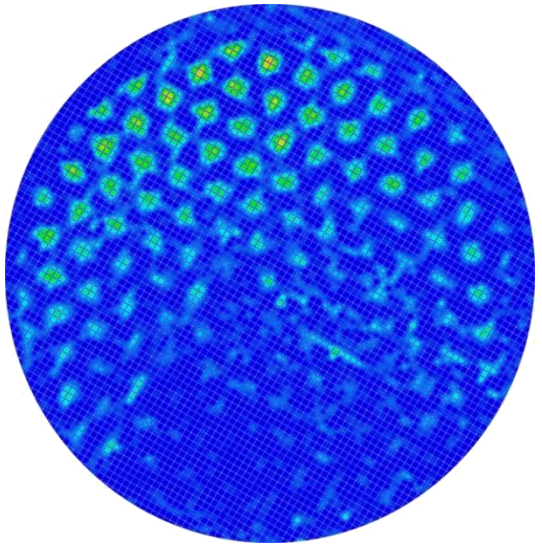


Material:	AA1050
Thickness:	0.5 mm
Load Energy:	4 kJ
Load Voltage:	16.33 kV
Working Media:	Slime
Conductivity:	1820 µS/cm

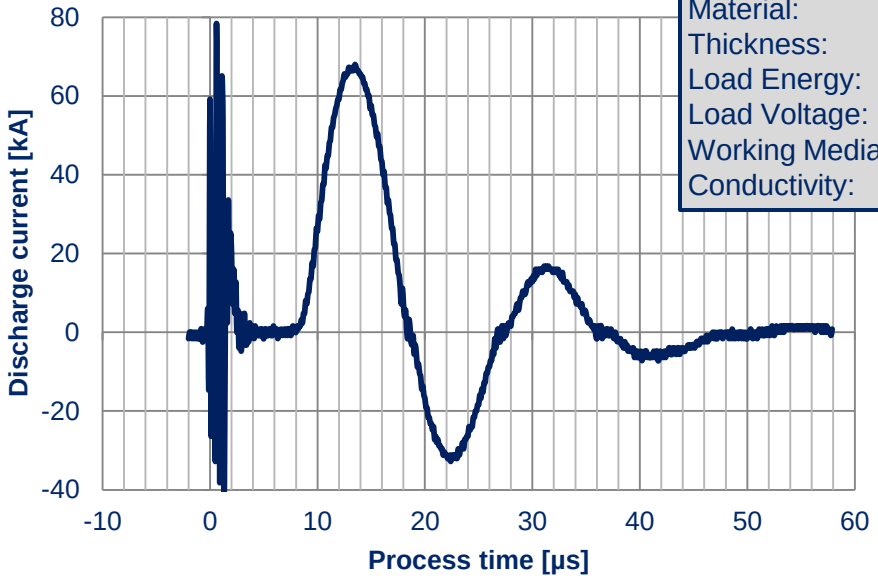
Reproducibilily and pressure distribution using Slime

Chair of Forming and Machining Technology
University of Paderborn



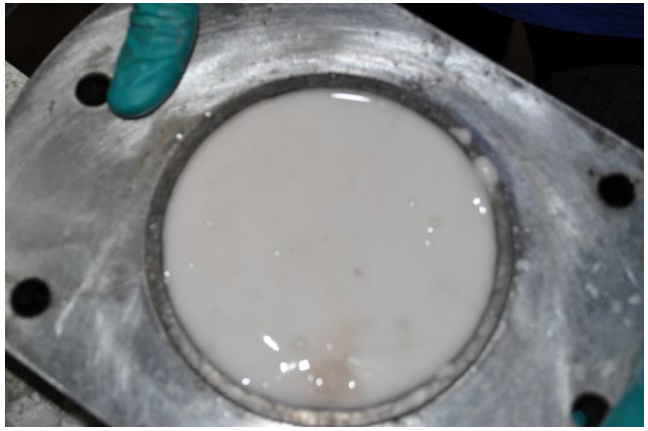


Material:	1.0388
Thickness:	0.5 mm
Load Energy:	4 kJ
Load Voltage:	16.33 kV
Working Media:	Slime
Conductivity:	1820 µS/cm



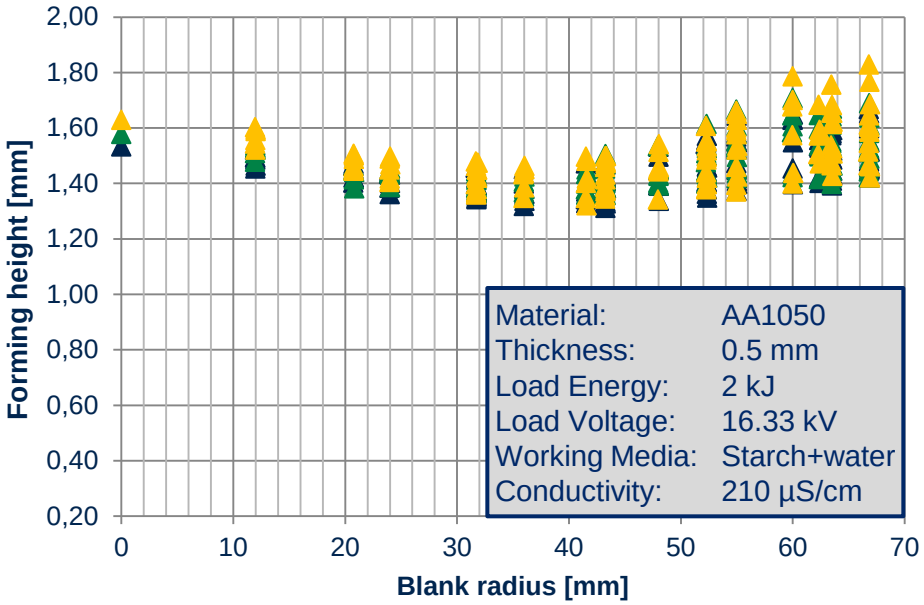
Working medium - Starch+Water

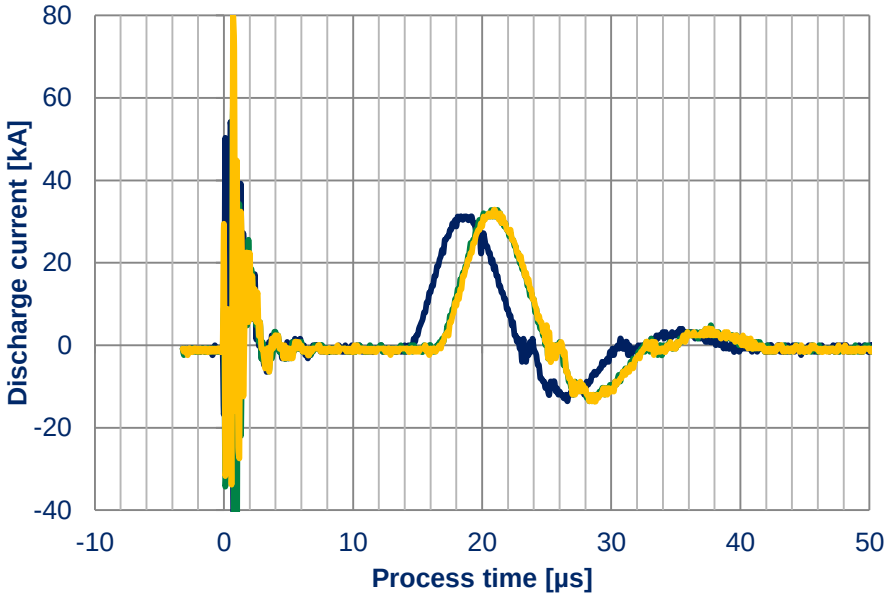
Chair of Forming and
Machining Technology
University of Paderborn

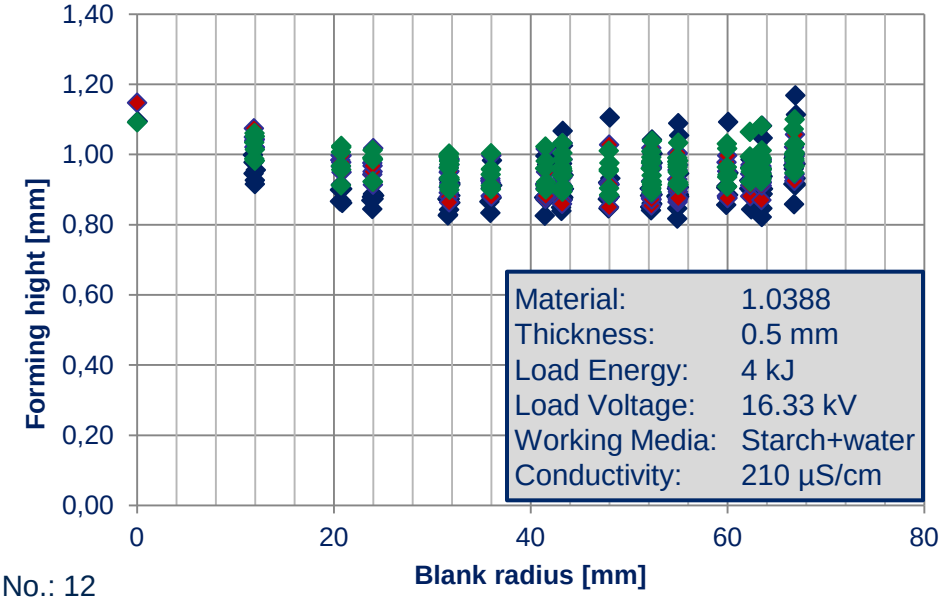


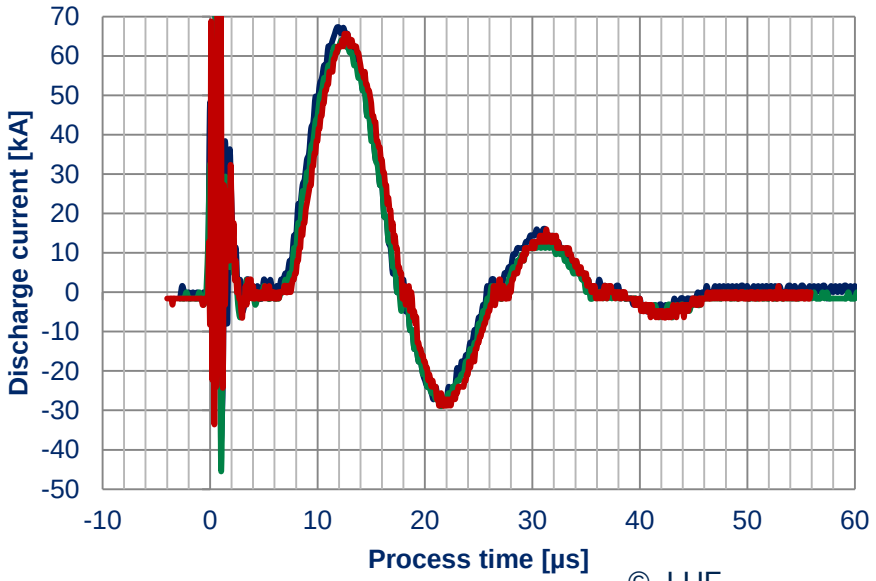
Starch+Water (non-Newtonian fluid)

Chair of Forming and
Machining Technology
University of Paderborn



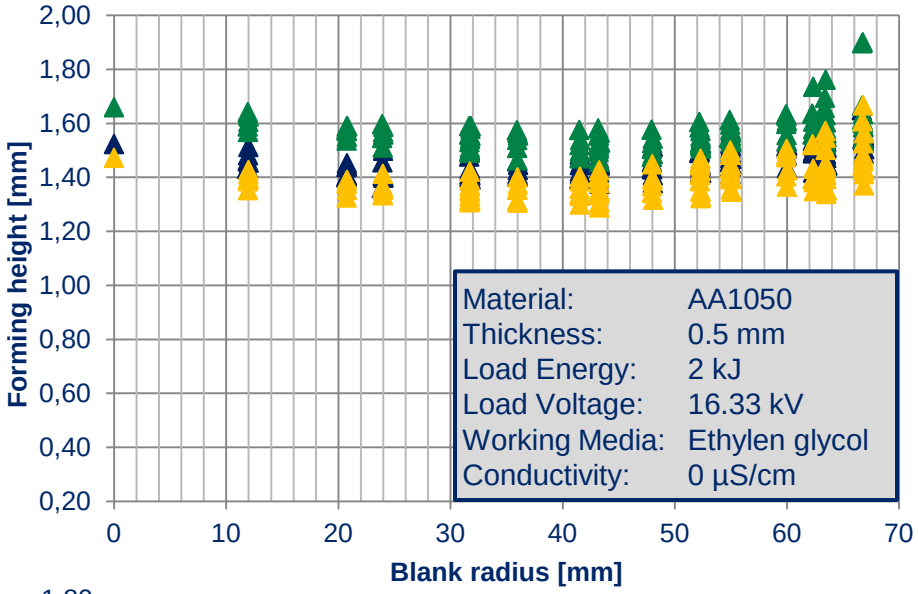


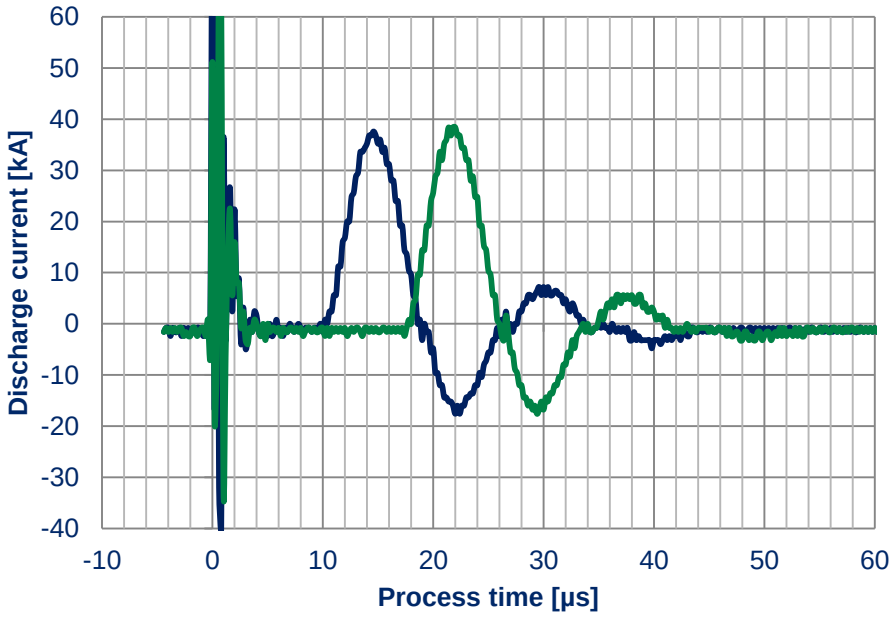


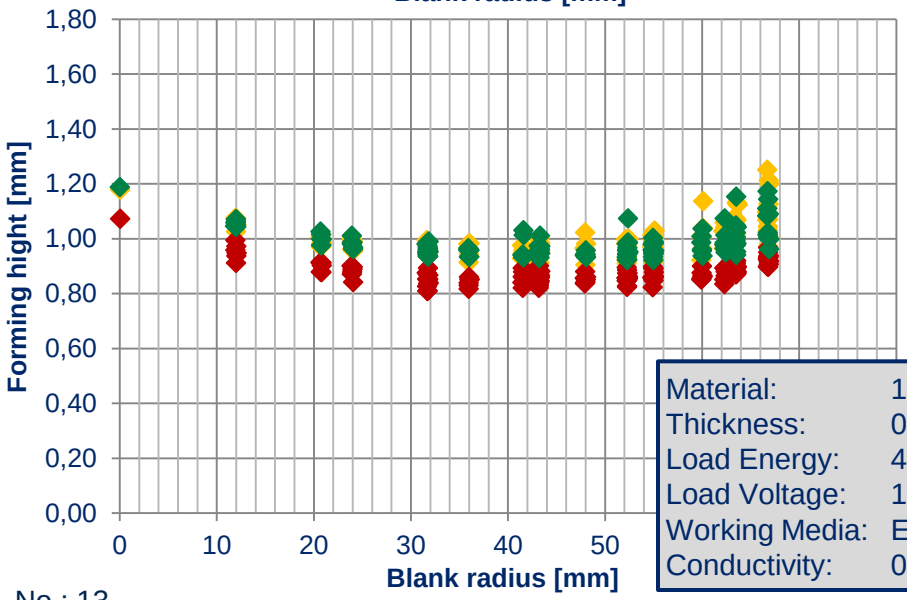


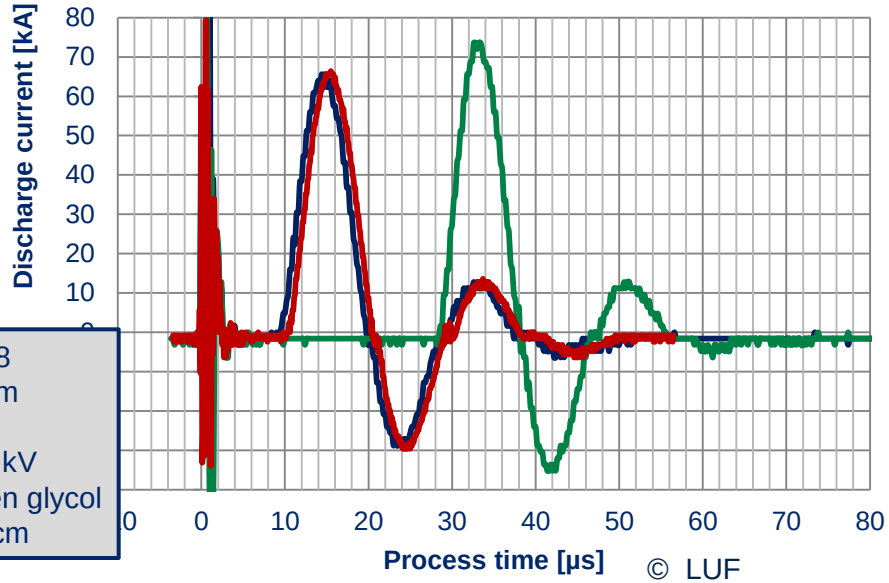
Ethylen glycol

Chair of Forming and
Machining Technology
University of Paderborn



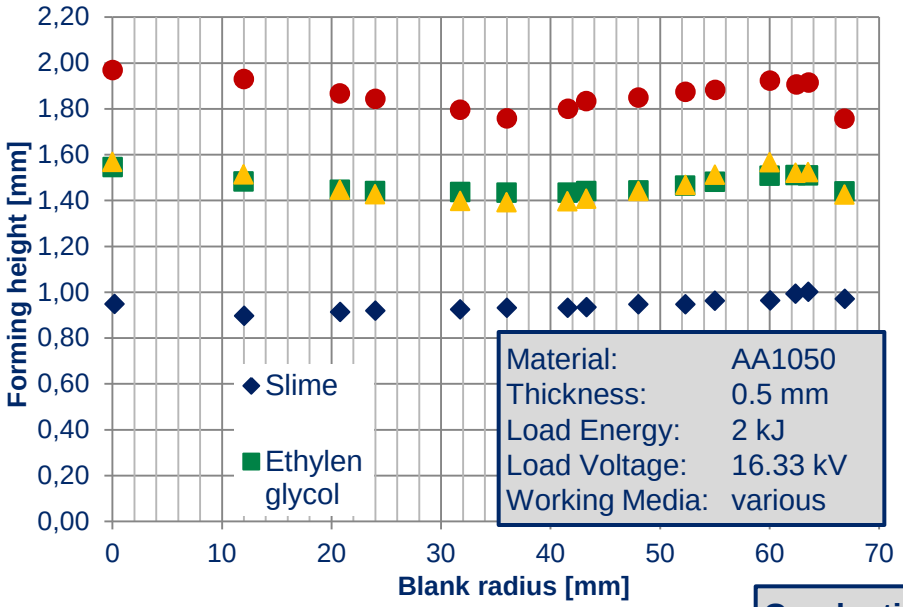


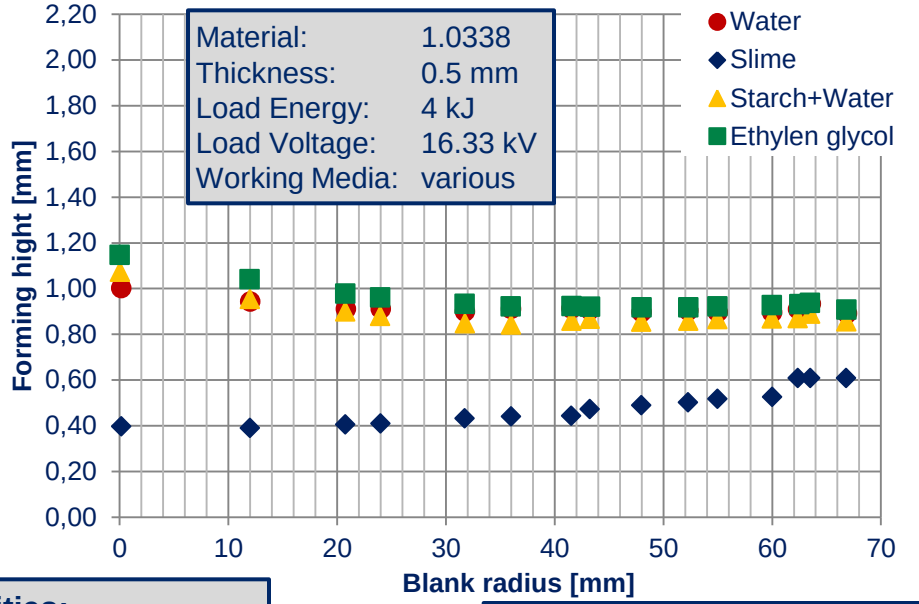


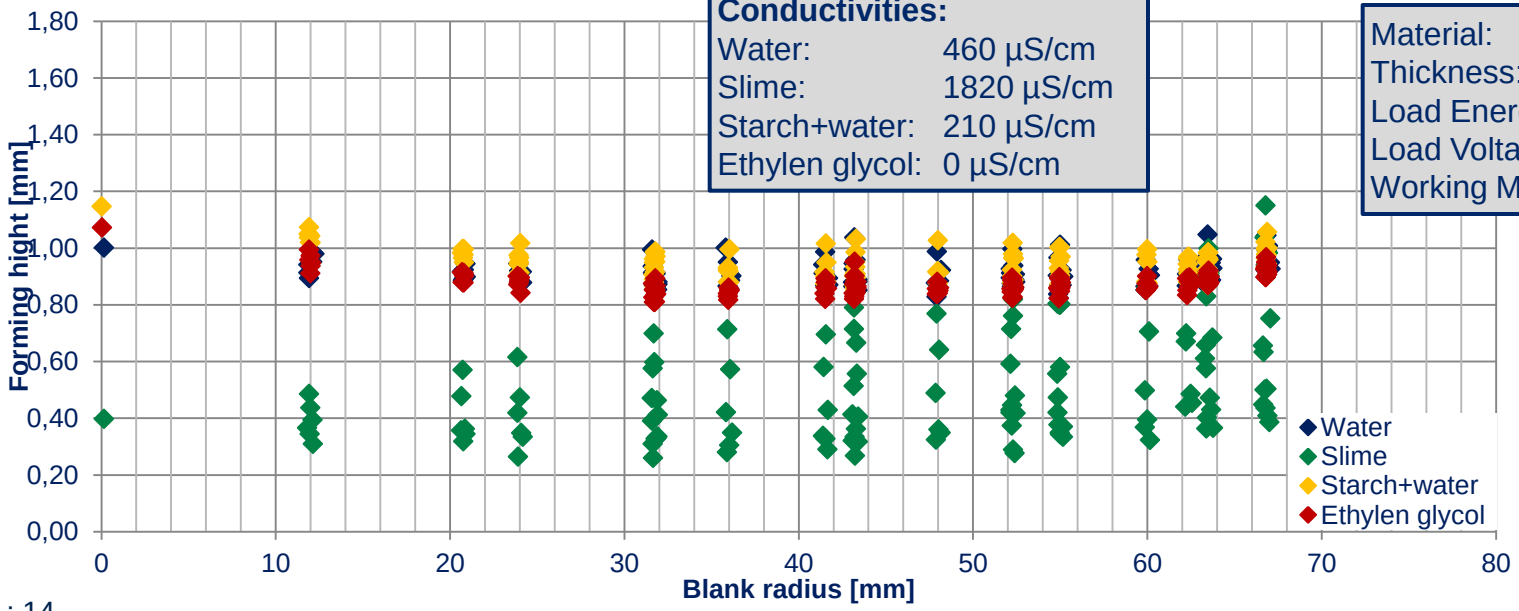


Comparison of different working media

Chair of Forming and
Machining Technology
University of Paderborn







Content

Chair of Forming and
Machining Technology
University of Paderborn

- Electrohydraulic Forming
  - Influence of the load energy on the repeatability of the forming hight and the pressure distribution on the blank
  - Influence of the working medium on the forming result

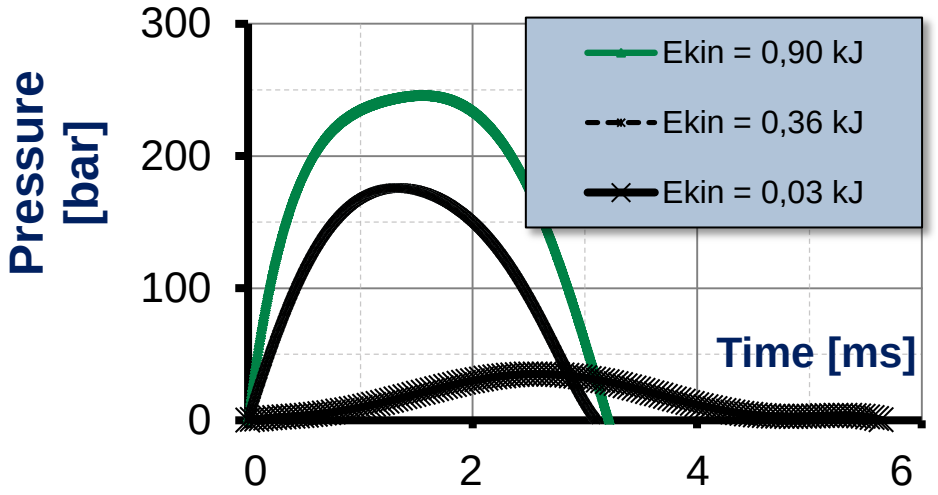
- Pneumo-mechanic Forming
  - Forming of tubes by pneumo-mechanic Forming compared to conventional forming processes
  - influence of different process parameters on tube forming

Motivation and Aims

Chair of Forming and
Machining Technology
University of Paderborn

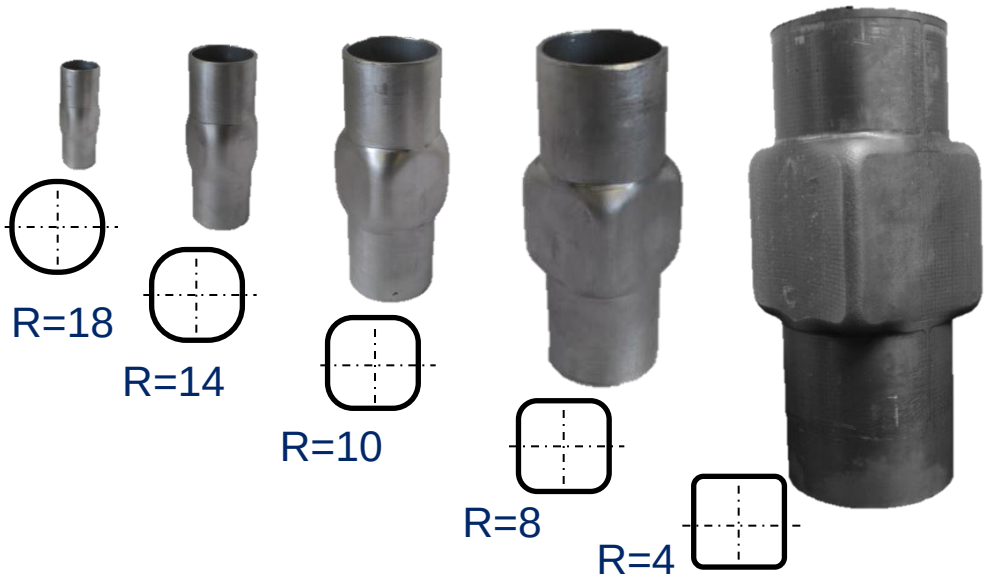
Investigation of important process parameters

- Pressure
- Pressure distribution
- Working media
- Kinetic energy



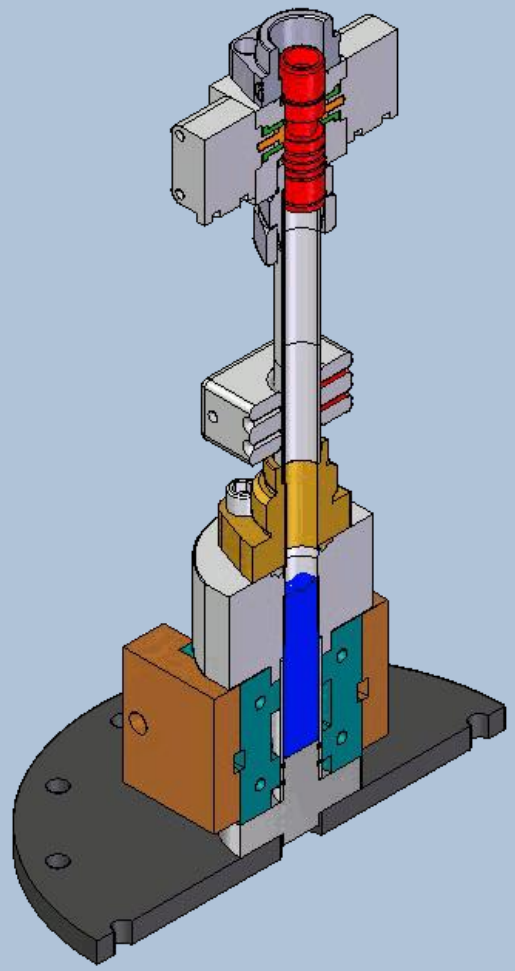
Aims

- Understanding of the process phenomena
- Efficient production of complex, multifunctional part geometries
- Preparation for the industrial use



Pneumomechanical setup

Chair of Forming and
Machining Technology
University of Paderborn



Working principle

Parameter

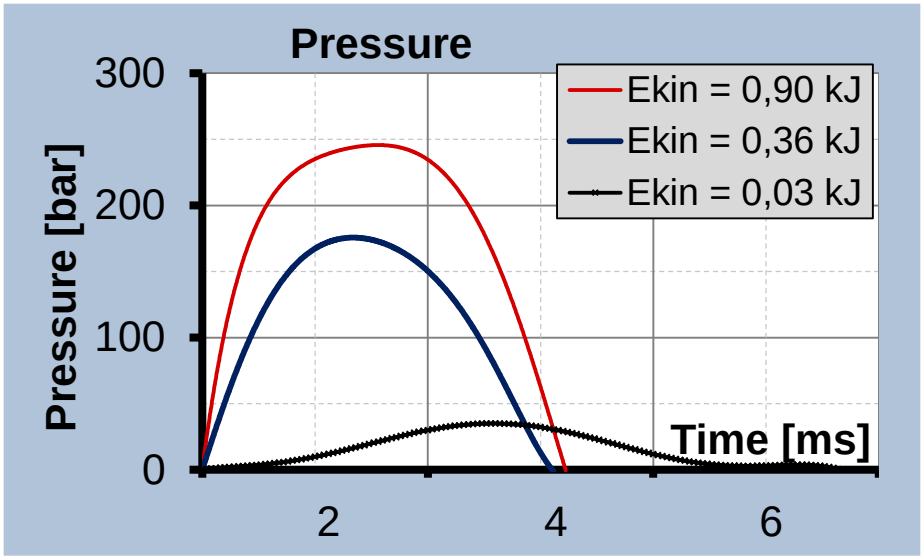
- Accelerating distance
- Accelerating pressure
- Plunger mass
- Working media
- Filling level

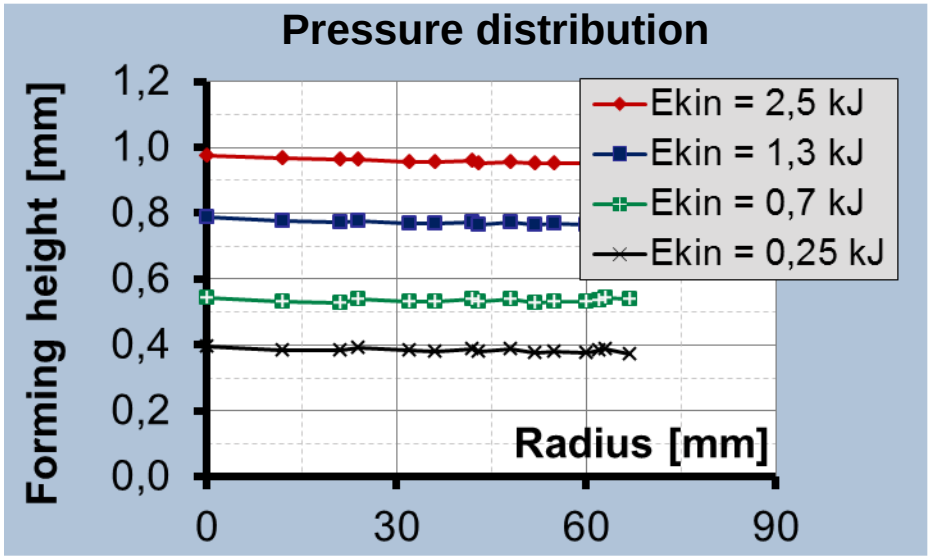
Specification

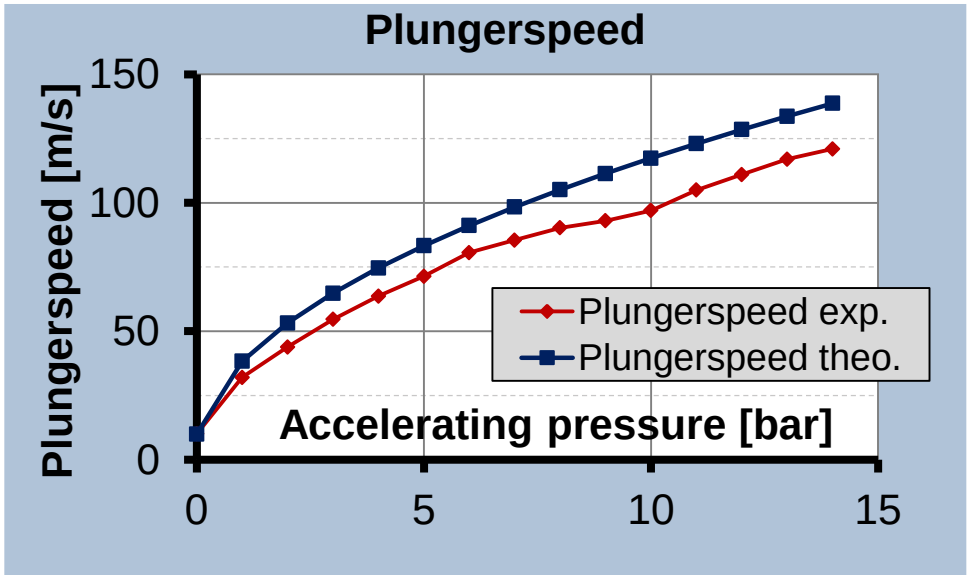
- Overall height: 5.2 m
- Plunger diameter: 33 mm
- Plunger mass: 620 g
- Air pressure: 1.5 MPa
- Typical plunger speed: 0-135 m/s
- Typical kinetic energy: 5.6 kJ

Process characteristic

Process parameters

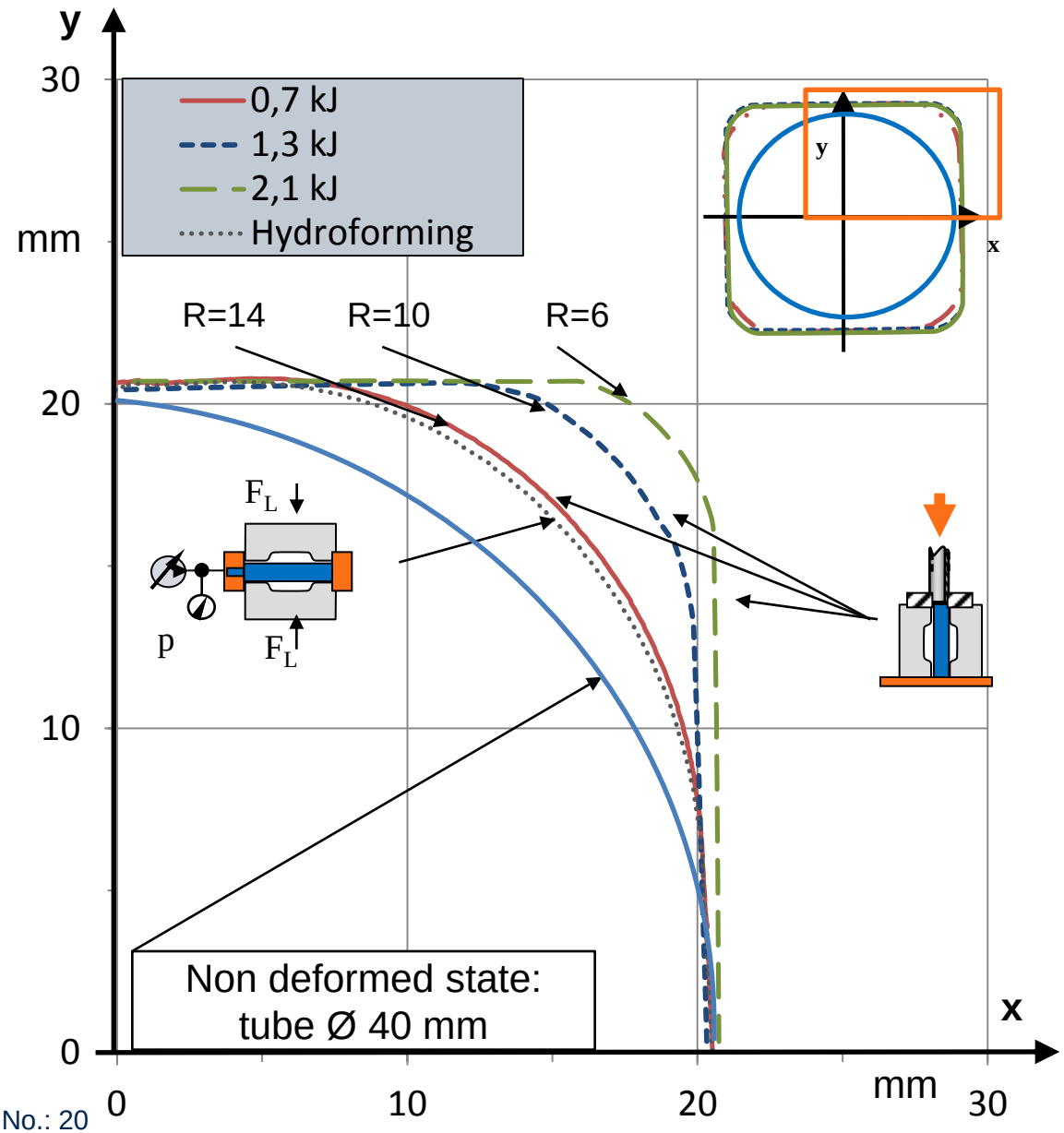






Influence of kinetic energy

Chair of Forming and
Machining Technology
University of Paderborn



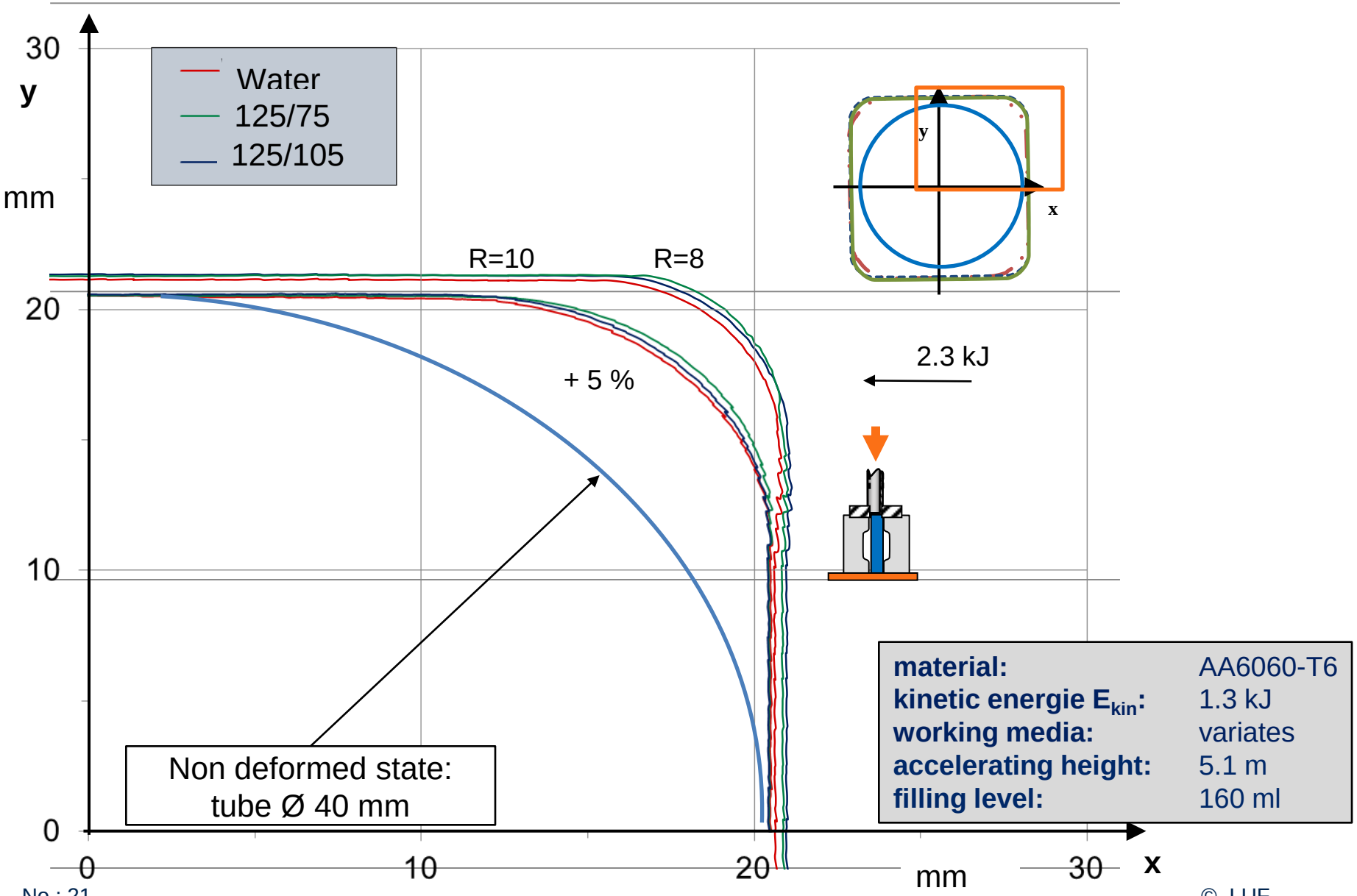
Hydroforming | PMF 0.7 kJ

PMF 1,3 kJ | PMF 2.1 kJ

material:	AA6060-T6
kinetic energy E_{kin}:	variates
working media:	water
accelerating height:	5.1 m
filling level:	160 ml

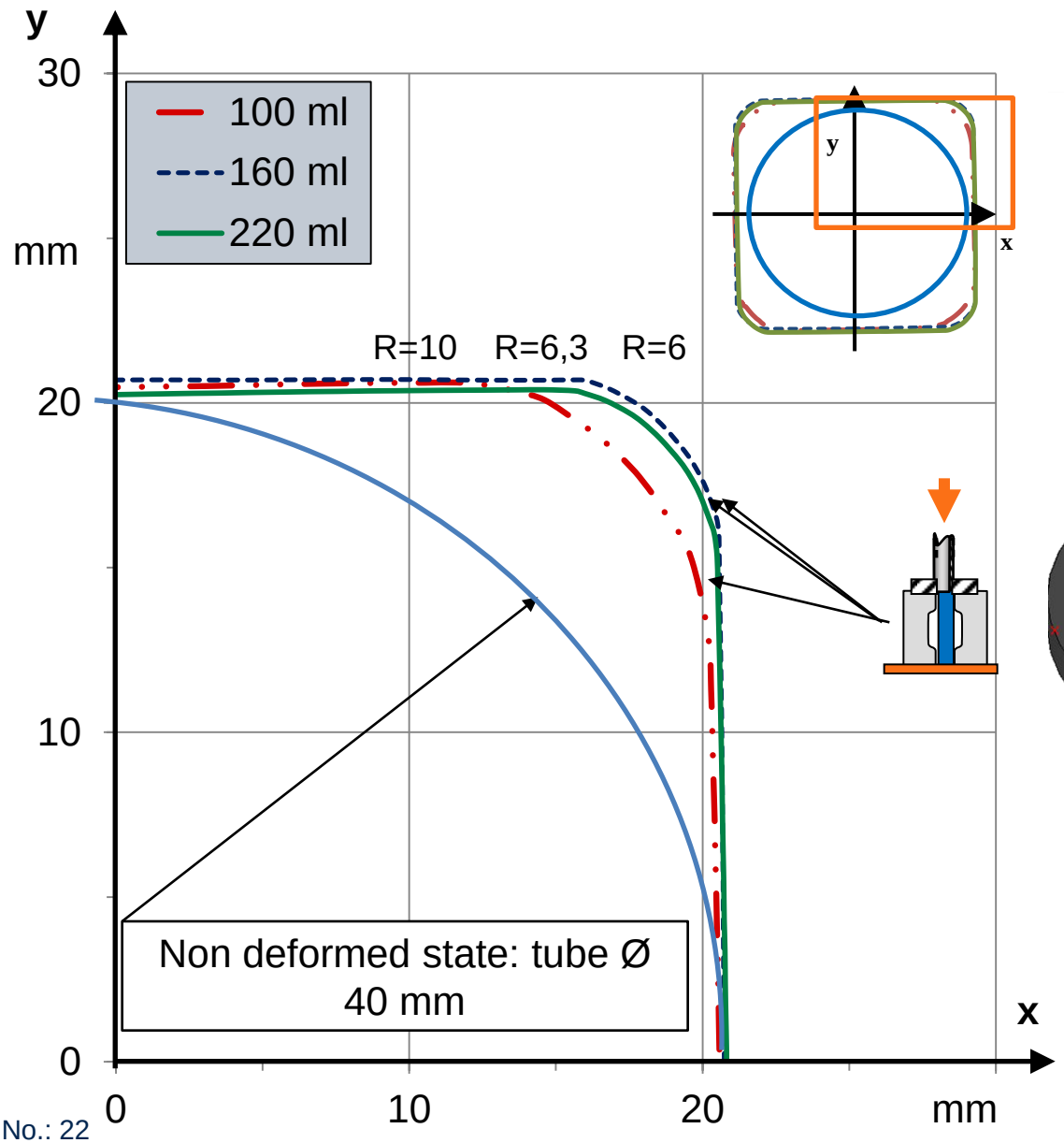
Influence of working media consistence

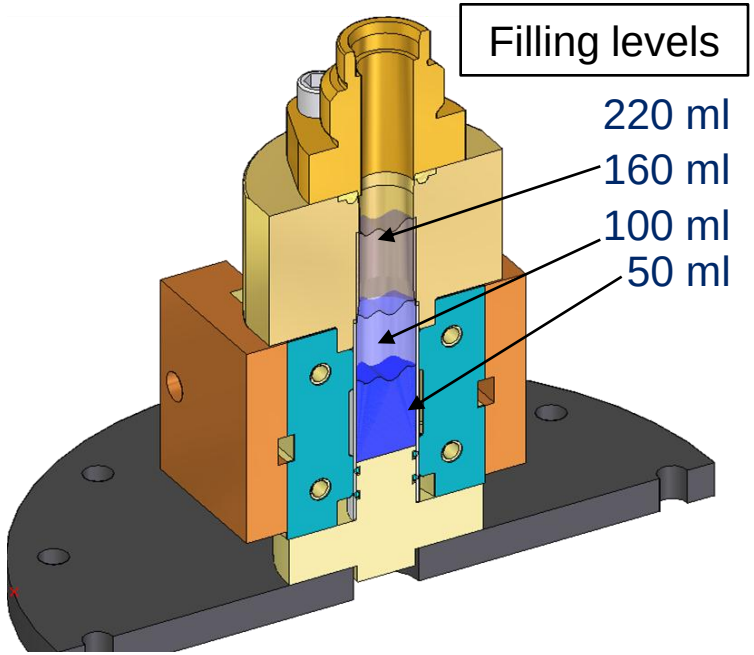
Chair of Forming and
Machining Technology
University of Paderborn



Influence of filling level

Chair of Forming and
Machining Technology
University of Paderborn





material:	AA6060-T6
kinetic energie E_{kin}:	1.8 kJ
working media:	water
accelerating height:	5.1 m
filling level:	variates

Conclusion and Outlook

Chair of Forming and
Machining Technology
University of Paderborn

Electrohydraulical forming

- Load energy, Working medium, Kinetic energy as well as the chosen material has an major influence on the forming result
- The Reproducibility of the process is given, but the pressure distribution is not satisfactory

Pneumo-mechanic Forming

- The pressure effect can effectively increase by varying the working media density
- It could be shown that a minimum filling level is absolutely necessary for the homogeneous forming of tubular geometries

Outlook

- Investigation on process parameter
- Forming of semi finished parts
- Development of new setups

Thank you for your attention