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ICHSF2012

5th International Conference on High Speed Forming

April 24th – April 26th, 2012
Dortmund, Germany

Process Model and Design for Magnetic Pulse Welding by Tube Expansion

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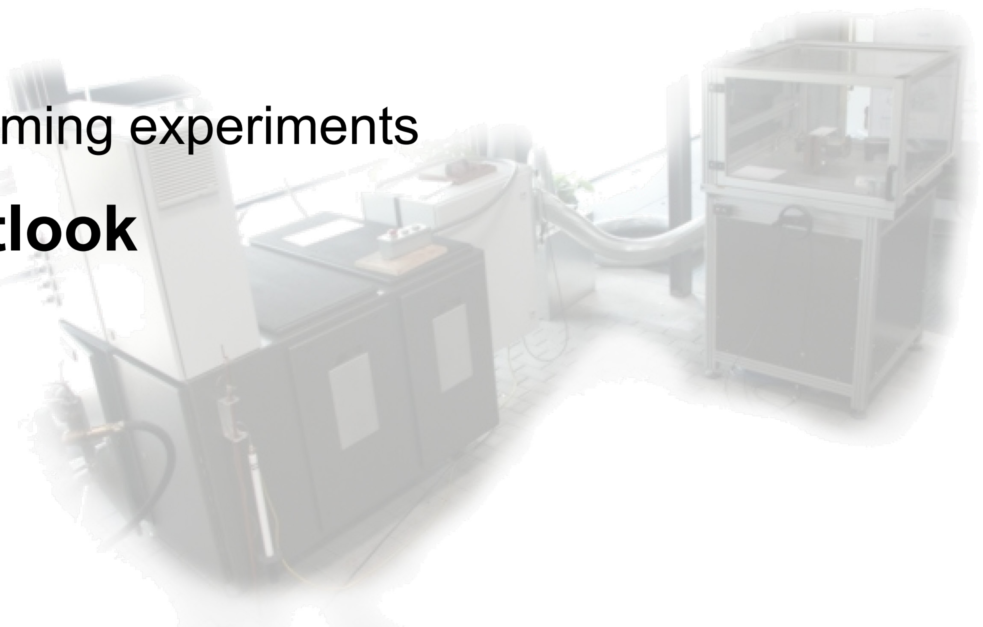
Agenda

- **Introduction**
- **Joining by Electromagnetic Forming**
- **Design Strategy for MPW**
  - Model Experiment
  - Electromagnetic forming experiments
- **Summary and Outlook**



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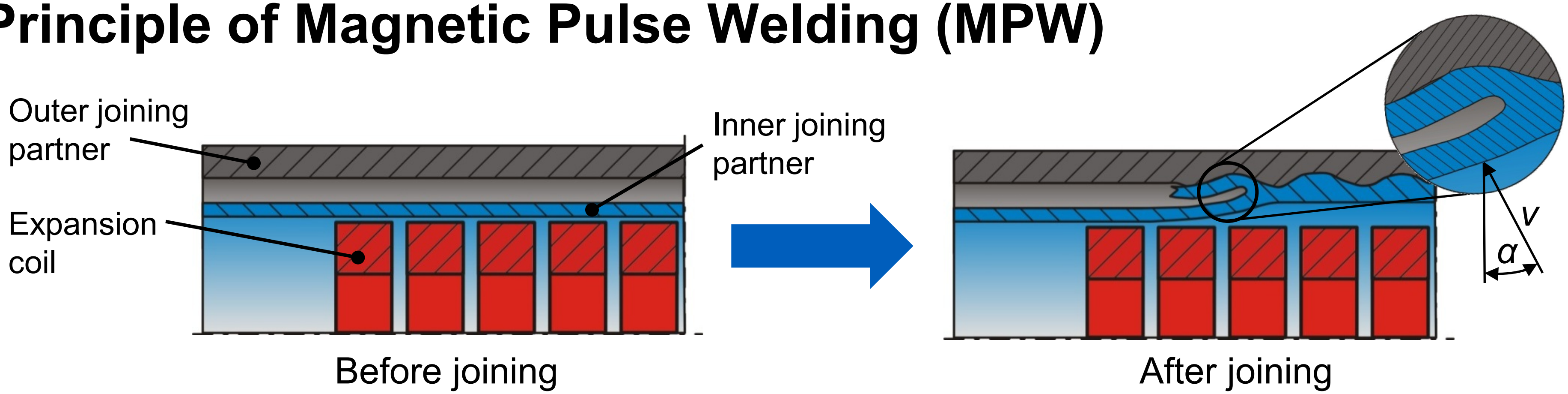
Principle of Magnetic Pulse Welding (MPW)



Advantages of MPW

- Metallic bonding in case of **proper impacting parameters**
- Joining without mechanical contact
- Joining of similar and dissimilar metalls
- Avoidance / Reduction of:
  - heat-affected zones
  - intermetallic phases

Current problems in MPW

- Which impacting parameters are required?
- How can the process be adjusted to reach the required parameters?

<u>Research objective:</u>

Design strategy for MPW by electromagnetic tube expansion

- Determination of the required collision parameters (values for α and *v*)
- Instruments for a proper adjustment of the collision parameters

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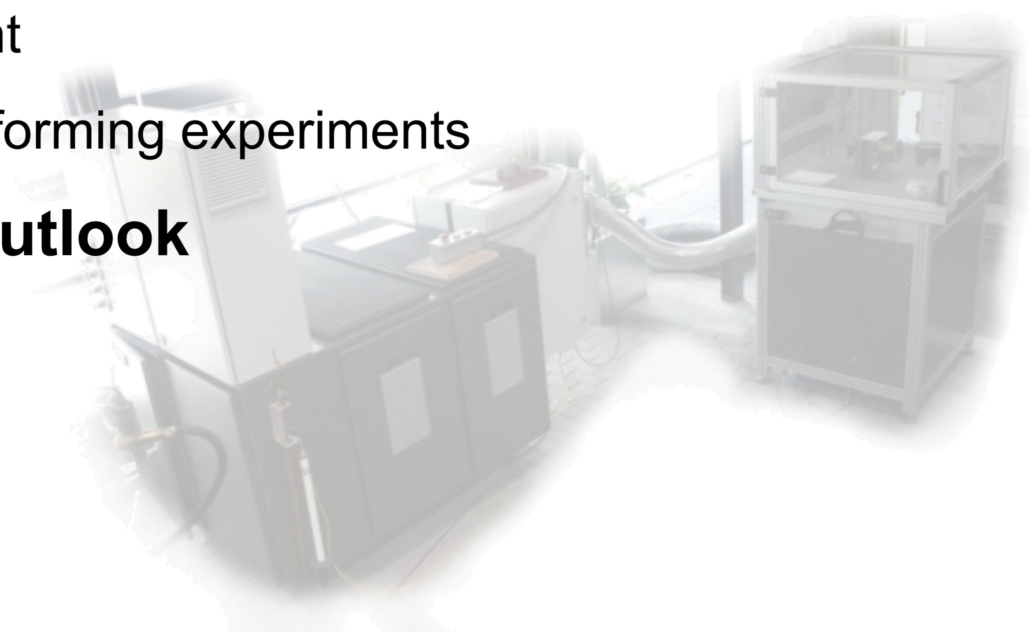
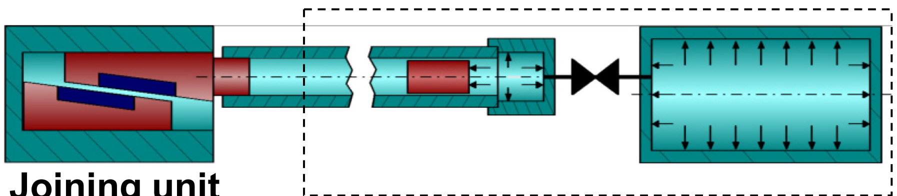


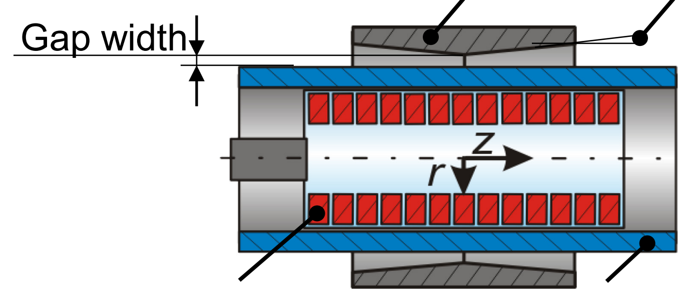
Model experiment
High-speed joining



Sub-target I: Identification of suitable impact parameters:

angle and **velocity**

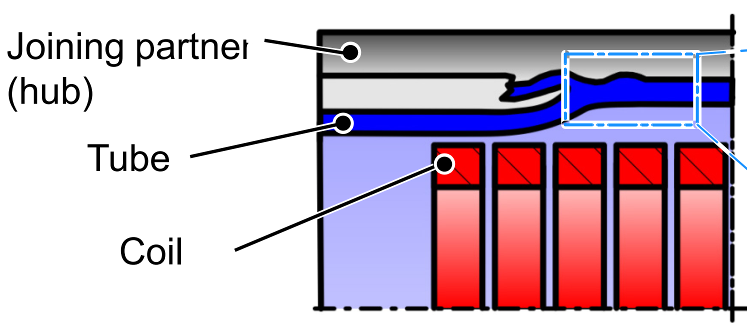
Electromagnetic forming experiments

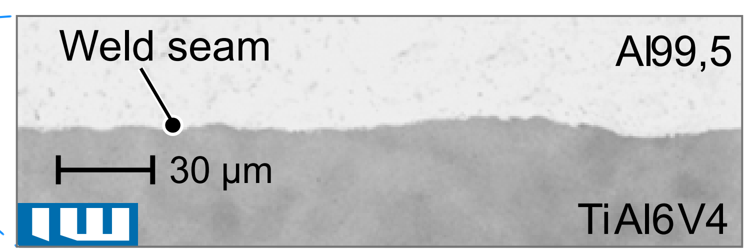


Sub-target II: Systematic adjustment of impact parameters via process parameters

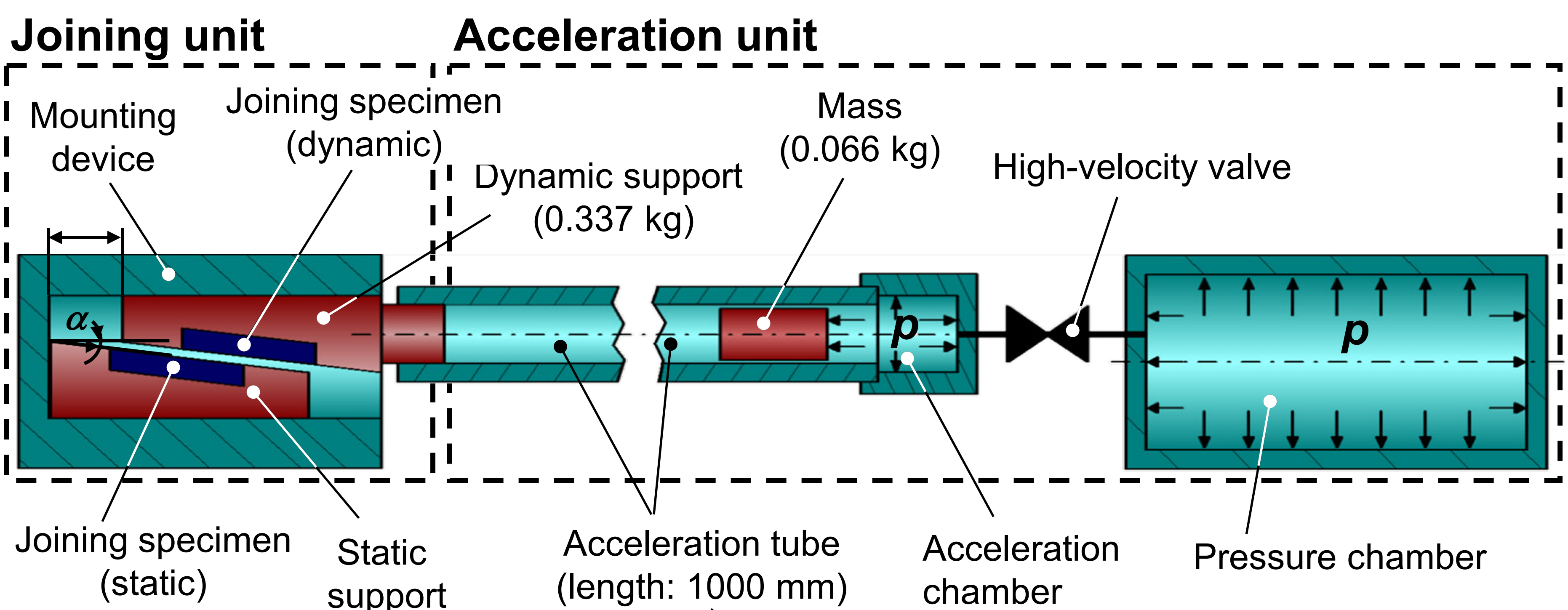
equipment and **charging energy**

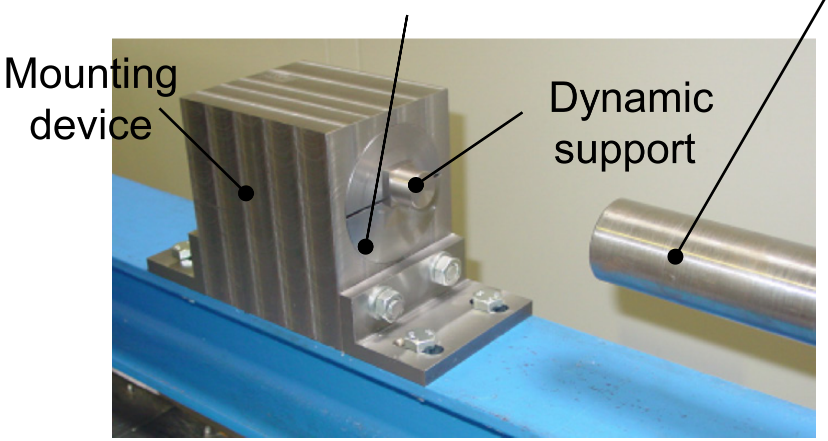
Process design strategy: Magnetic pulse welding





Model Experiment
- Setup -

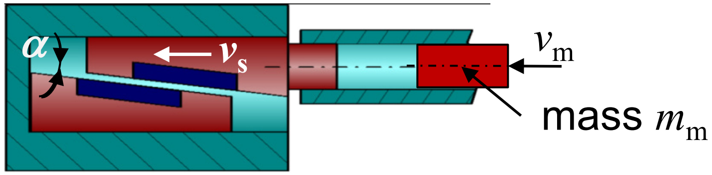




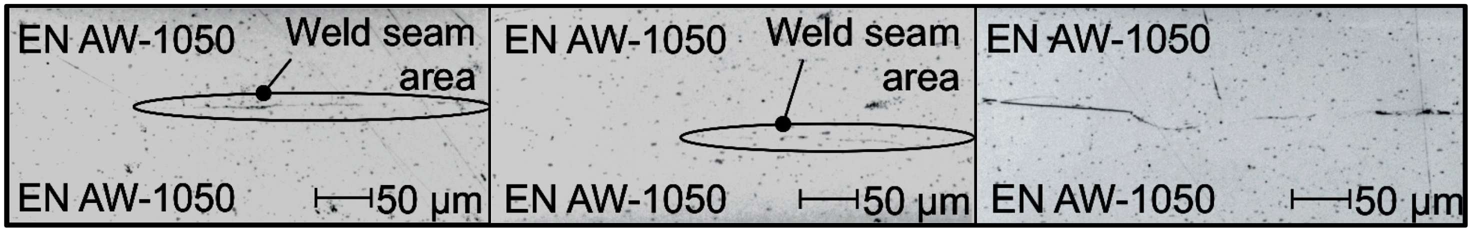
Influencing parameters:

- Angle
- Impact velocity
- Material

Model High Speed Joining Experiment
- Exemplary Results -



Specimen material: EN AW-1050
Specimen thickness: 0.3 mm



Workpiece material		**Acceleration mass parameters**			**Support parameters**		**Impact angle**	**Weld quality**
Specimen I	Specimen II	Material	Weight m_m in kg	Velocity v_m in m/s	Weight m_s in kg	Velocity v_s in m/s		
EN AW-1050	EN AW-1050	Steel	3.2	8	0.31	16	3.2°	++

Joint geometry and process design to reach this collision parameters?

Electromagnetic Experiments - Setup -

Machine: SMU 1500	
maximum charging energy E_{max}	1.5 kJ
maximum charging voltage U_{max}	6.1 kV
capacitance c	80 µF
inner inductance L_i	75 nH
inner resistance R_i	6.8 mΩ
short circuit frequency f	67 kHz

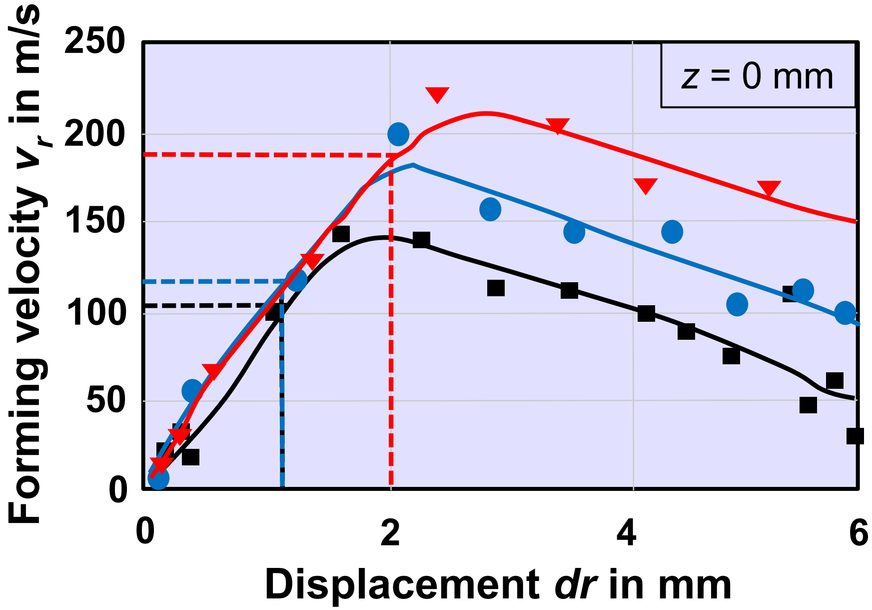
Tool coil: expansion coil

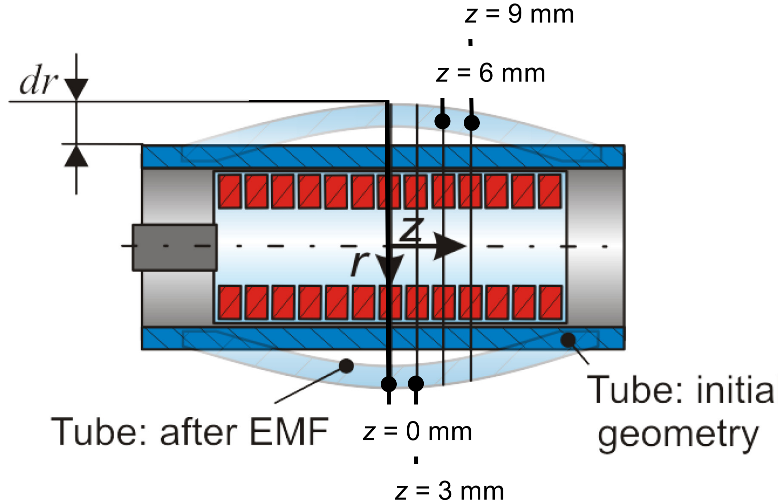
outer diameter:	36 mm
effective length:	27 mm
number of turns:	13

Workpiece: EN AW-1050

outer diameter:	40 mm
wall thickness:	2 mm
length:	100 mm

Electromagnetic Experiments - Free Forming -



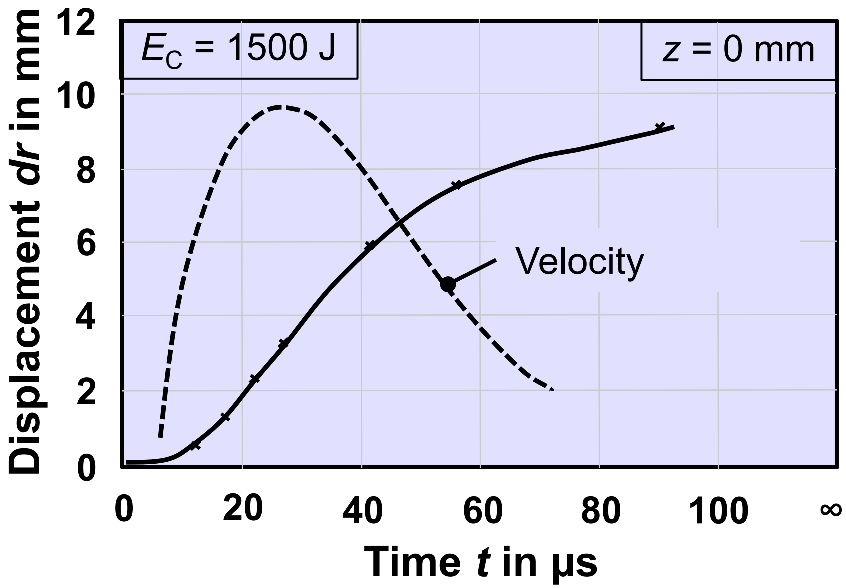


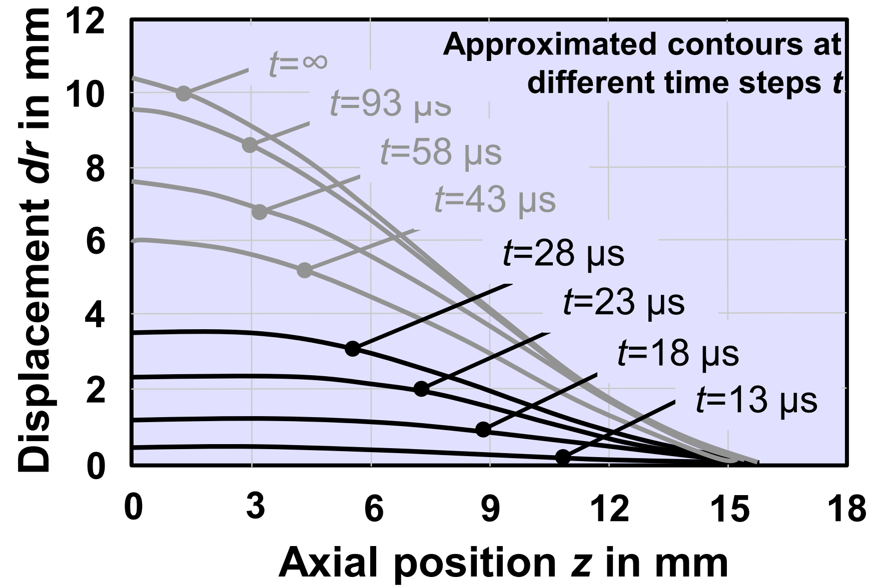
charging energy	1000 J	1250 J	1500 J
velocity	108 m/s	120 m/s	186 m/s
gap width	1.2 mm	1.2 mm	2.0 mm
inner diameter of hub	42.4 mm	42.4 mm	44.0 mm

Forming machine: SMU 1500

Tool coil:
- outer diameter: 36 mm
- length: 27 mm
- turns: 13

Tube: EN AW- 1050
- diameter: 40 mm
- wall thickness: 2 mm
- length: 100 mm

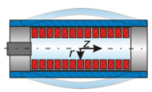


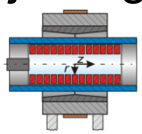


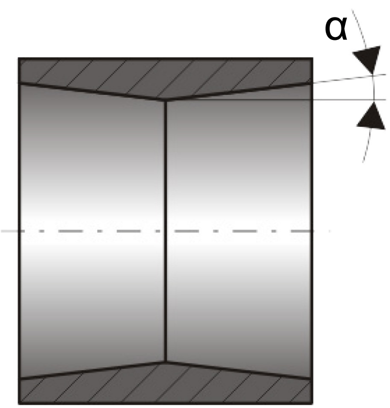
Nearly parallel expansion of the tube wall ($z \approx 0$ - 6 mm)

Assumption: Same deformation in joining experiments before impact

Electromagnetic Experiments
- Joining -

Phase	Process parameters		
free forming 	charging energy	gap width	
	1000 J, 1250 J, 1500 J	1.2 mm, 2.0 mm	

joining 	Impact velocity	angle
	120 m/s, 156 m/s, 186 m/s	0°, 3°, 5°

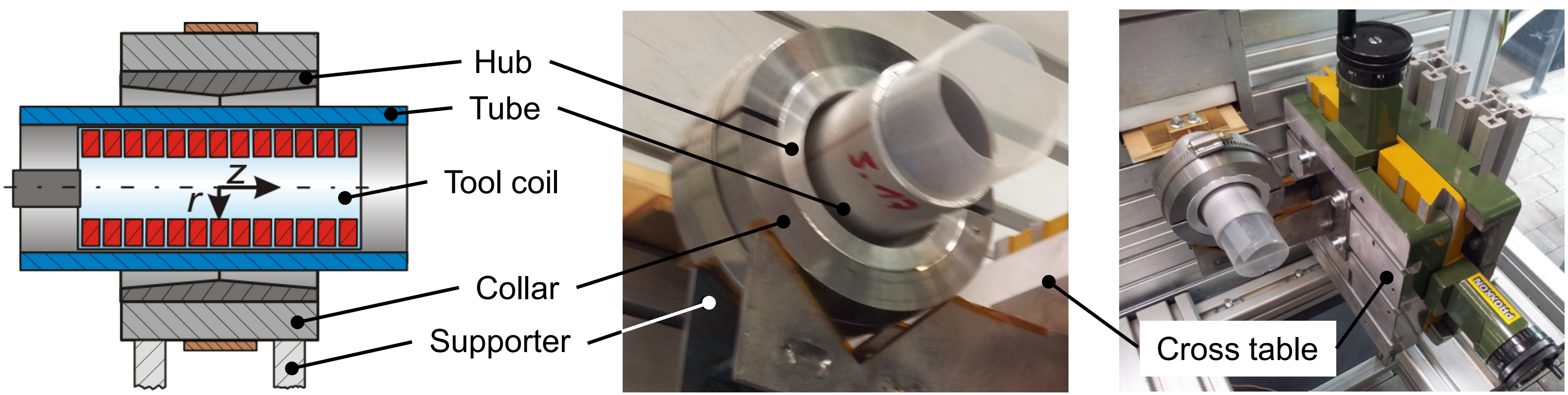


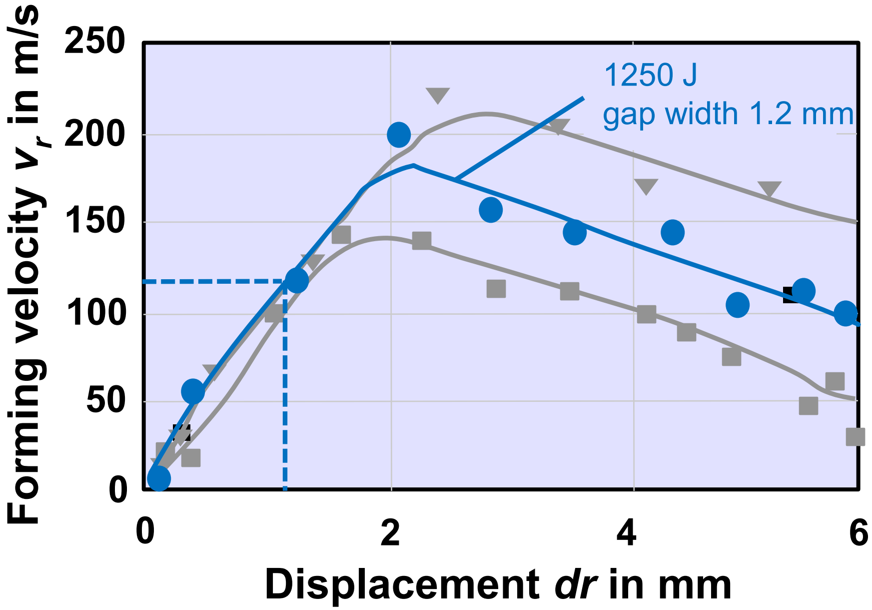
charging energy	gap width	impact velocity	impact angle α
1250 J	1.2 mm	120 m/s	0°, 3°, 5°
1250 J	2.0 mm	156 m/s	0°, 3°, 5°
1500 J	2.0 mm	186 m/s	0°, 3°, 5°

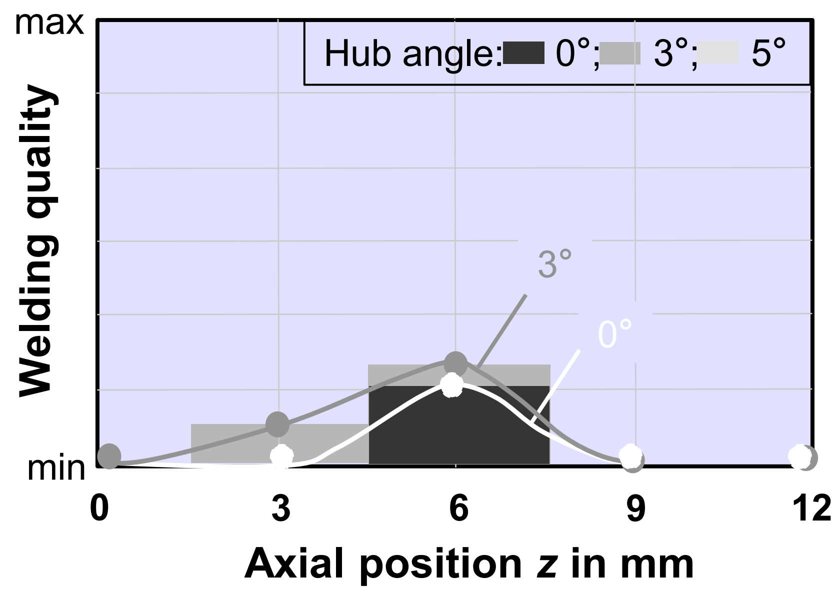
Electromagnetic Experiments
- Joining -

tube	
material:	EN AW-1050
outer diameter:	40 mm
wall thickness:	2 mm
length:	100 mm

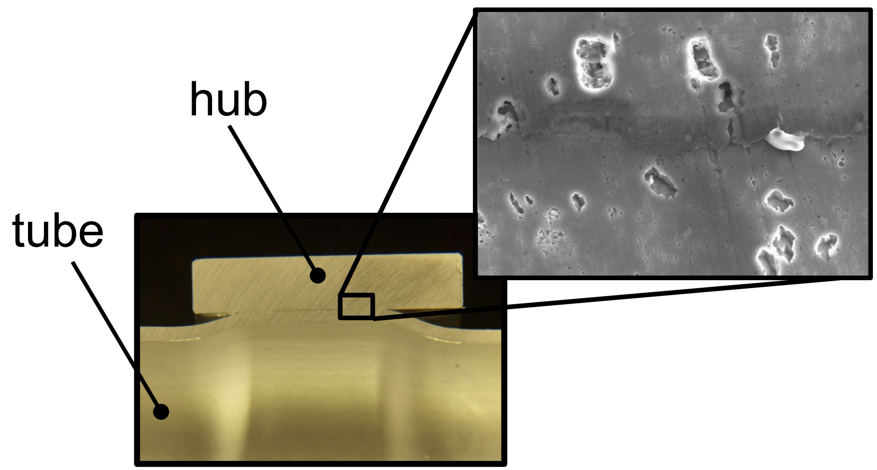
hub	
material:	EN AW-1050
inner diameter:	42.4; 44.0; 51.0 mm
hub angle:	0°; 3°; 5°
length:	40 mm

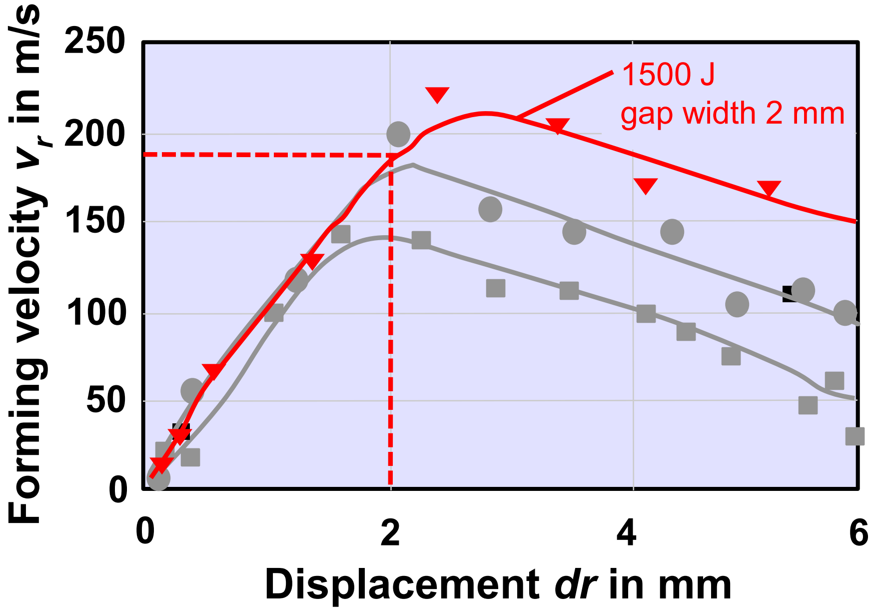


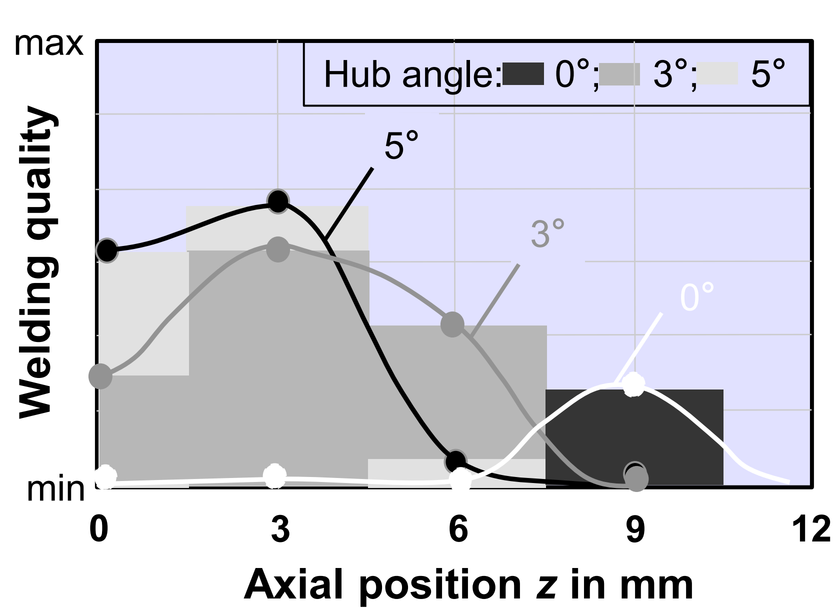




Forming machine:		SMU 1500
Tool coil:	outer diameter:	36 mm
	length:	27 mm
	turns:	13
Tube:	EN AW- 1050	
	diameter:	40 mm
	wall thickness:	2 mm
	length:	100 mm







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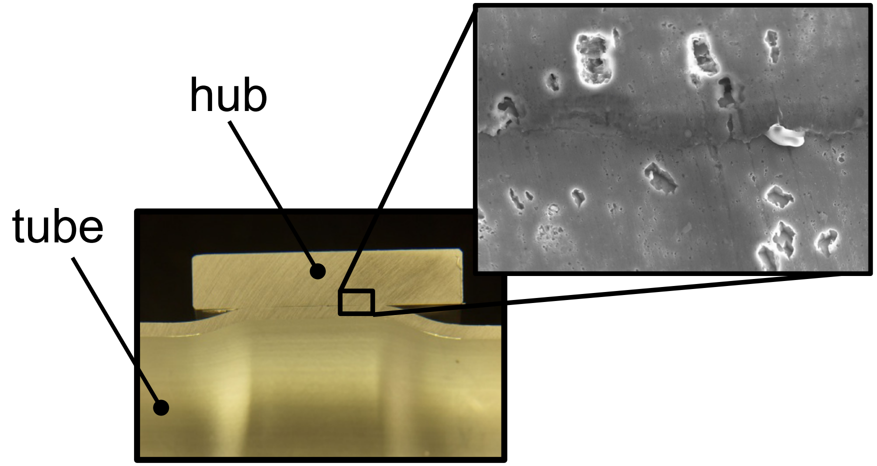

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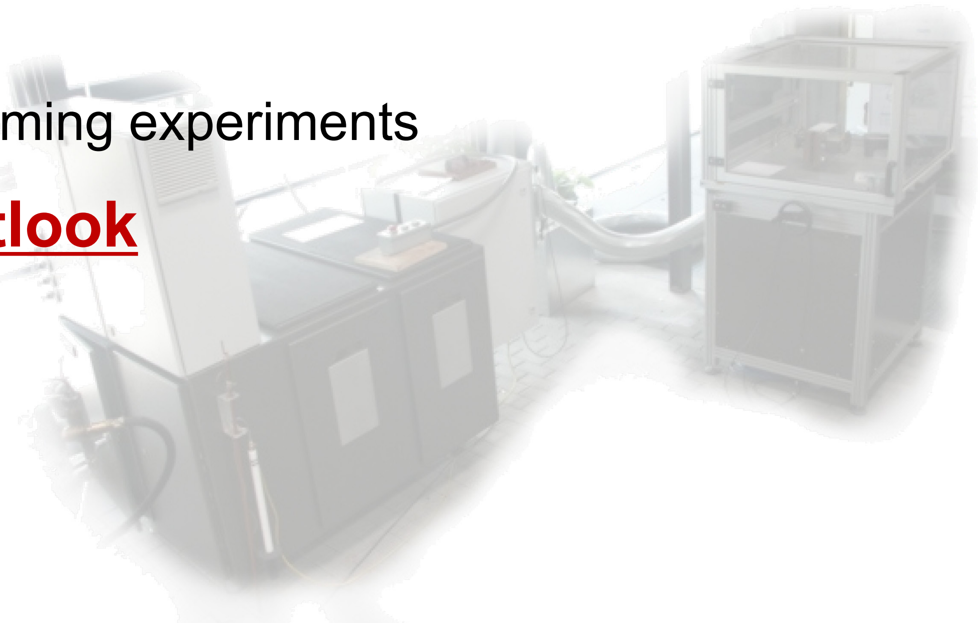

Summary and Outlook

- **Model experiment for the determination of suitable impacting parameters for MPW**
- **Joining experiments proved that model experiment is especially suitable to determine the optimum collision angle**
- **Tapered joining partner for a proper adjustment of the collision angle during MPW process**
- **Further investigations should concentrate on an improved prediction quality for the impacting velocity**