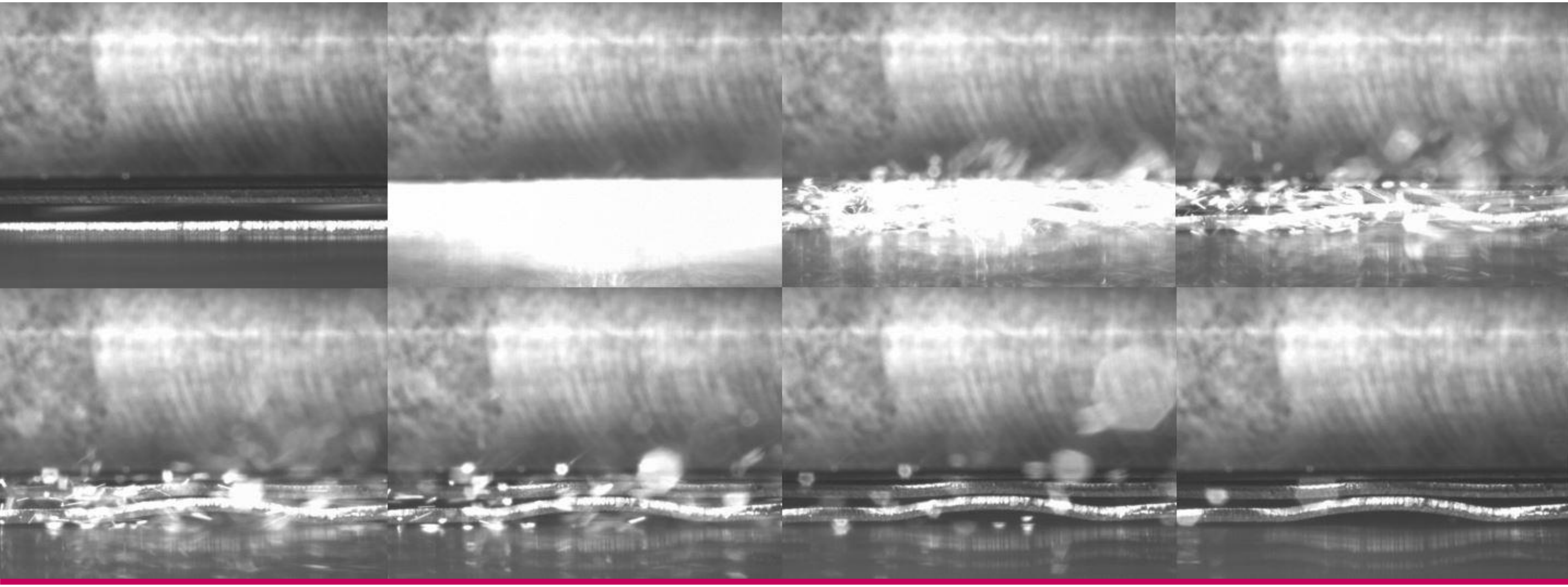
Influence of the Collision Speed and Collision Angle in Magnetic Pulse Sheet Welds

Anatoli Rebensdorf, M.Sc. IWE; Univ.-Prof. Dr.-Ing. Stefan Böhm

Institute for Production Technology and Logistics (IPL)
Department for Cutting and Joining Manufacturing Processes (tff)

International Impulse Forming Group (I²FG)
Dortmund, October 5-6, 2015

DFG Deutsche Forschungsgemeinschaft



UNI KASSEL VERSITÄT

tff trennen, fügen, fertig

Introduction

Motivation

Aim: Increasing the reproducibility of MPW on asymmetric impact

Proceed:

- Integration of the surface characterization to calculate the **low boundary** of the magnet pulse welding process window
- Focus lies on topography and **grain size** (in collaboration with PTU and IWW)
- **Measurement** of collision point velocity and collision angle for calculation of the pressure impact
- Definition as well as gradation of **surface structure**

Close collaboration within SPP 1640:

- **IWW Chemnitz:** Material and surface characterization as well as provided micro structured alloys
- **PTU Darmstadt:** Simulation of the pressure impact and verification of the influence of collision point velocity and collision angle

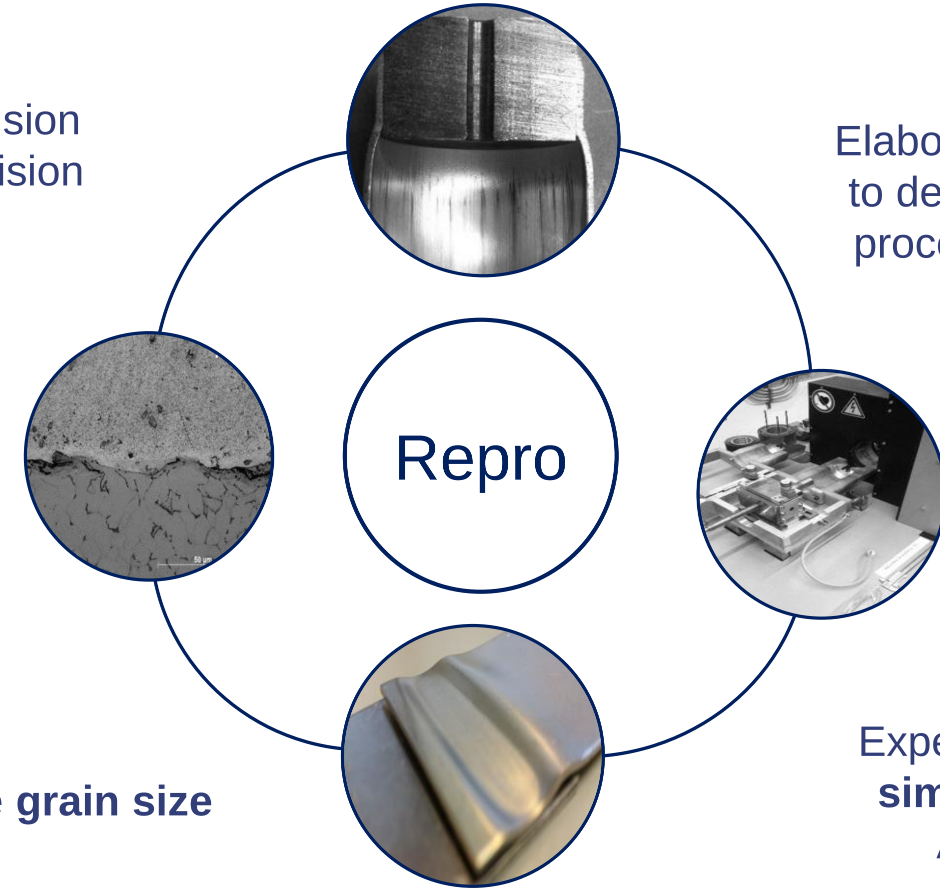
Introduction

Aim: Increasing the reproducibility of MPW on asymmetric impact

Measurement of collision point velocity and collision angle

Elaboration of surface impact factor to define the **low boundary** of the process window for magnet pulse welding

Investigation of the **influence of interfering contours** (transverse to the direction of weld progression)



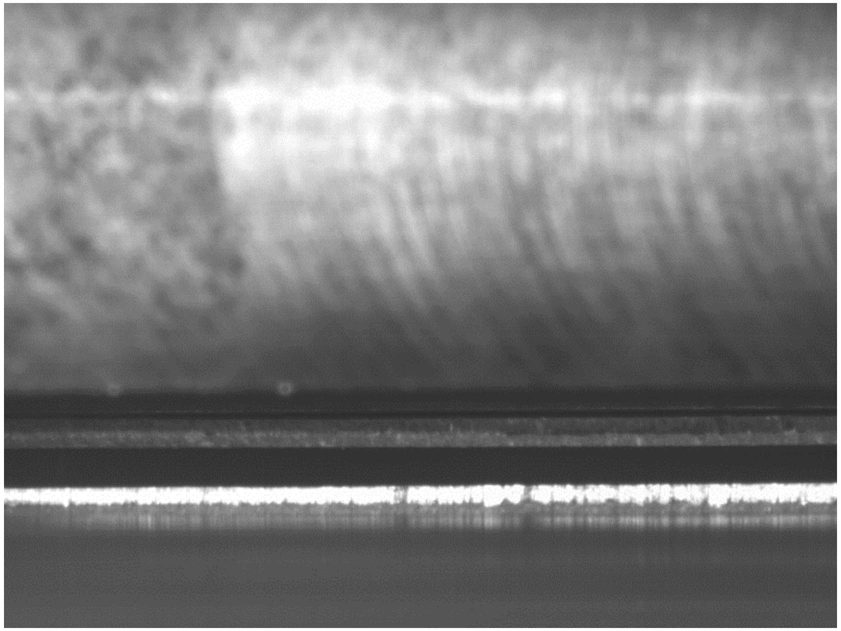
Increasing of the **width on weld seam** through graded **surface topography**

Influence of the **grain size**

Experimental verification of the **simulation** out of the project A5 (SPP1640 by PTU)

Introduction

State of the Art



Picture taken with the high-speed camera Optronis CR3000X2 /M /8GB /UF

Resolution:

- 540 fps with 1696 x 1710 Pixel
- 1000 fps with 1200 x 1200 Pixel
- 5000 fps with 480 x 480 Pixel

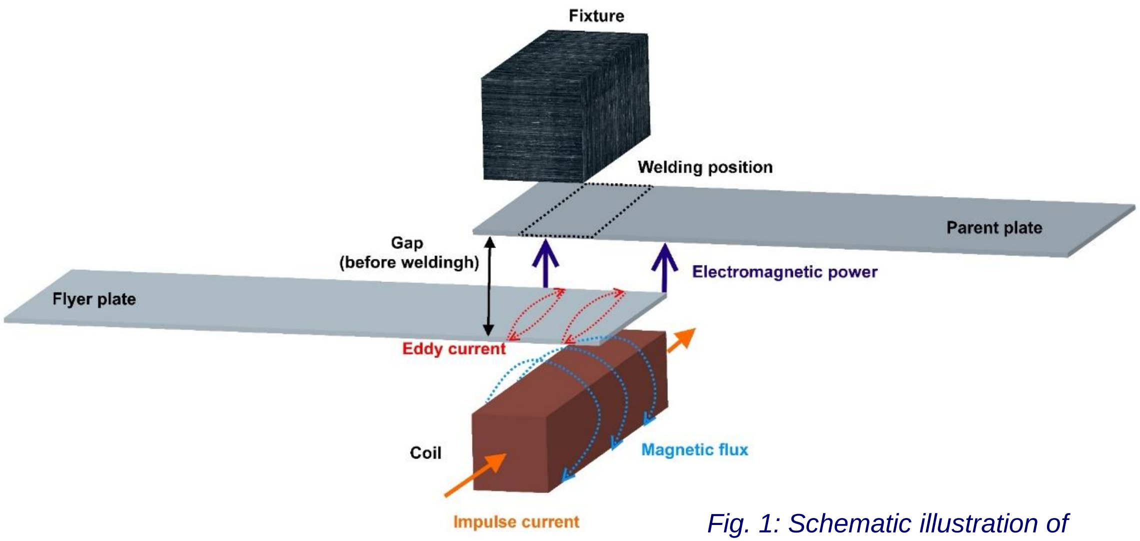


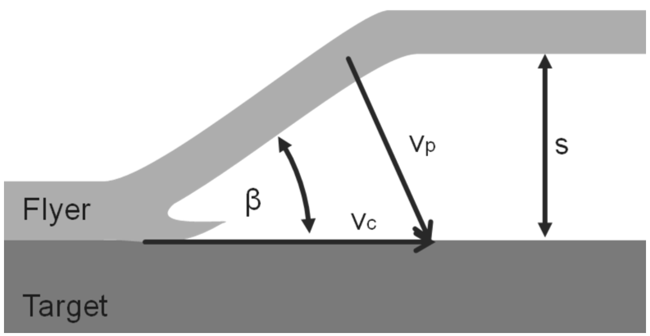
Fig. 1: Schematic illustration of Magnetic Pulse Welding [Lee07]

Boundary conditions:

- Discharge energy: 13 kJ
- Discharge frequency: ca. 19.7 kHz
- Surge: 320 kA
- Flyer AW1050, 1.5 mm sheet thickness and target S235JR,
- Acceleration gap: 1.5 mm
- Selected resolution of the camera: 400*800 @ 3687.8 FPS

Introduction
State of the Art

asymmetric impact



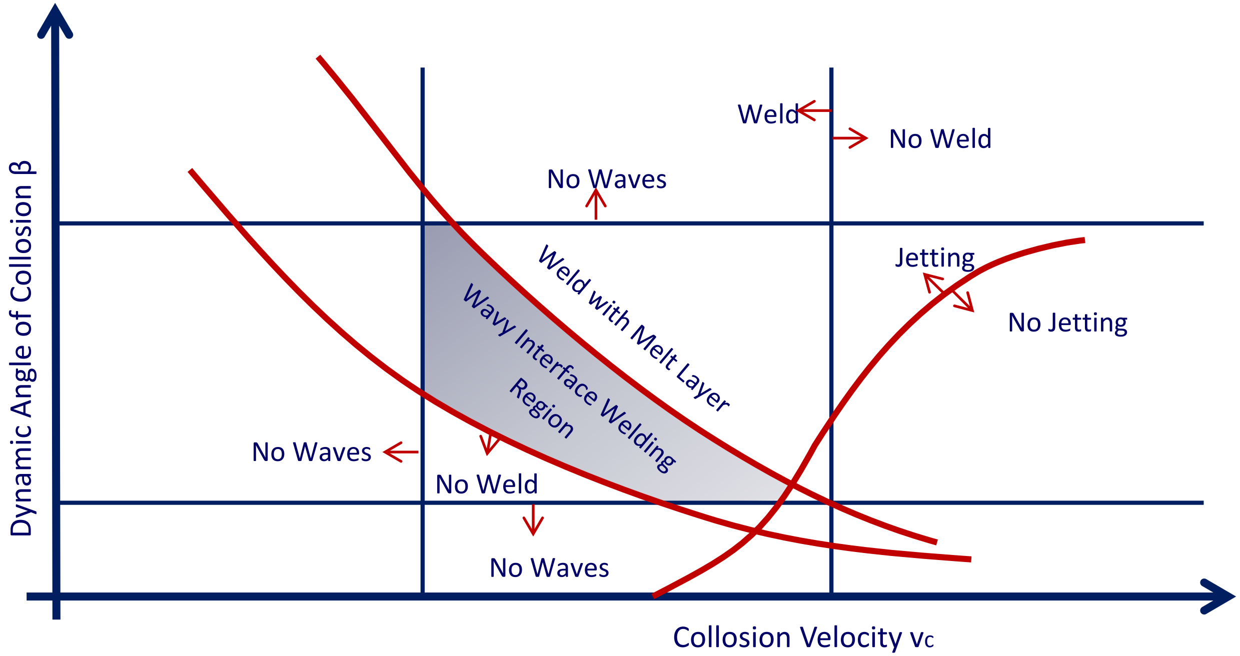


Fig 2.: General process window for impact welding (Experimental investigation of explosive welding) [Mou09]

- Walsh, J.; Shreffer, R.; Willig, E.: Limiting Conditions for Jet Formation in High Velocity Collisions: Journal of Applied Physics, Vol 24, 1953; S. 349–359.
- Crossland, B.: Explosive welding of metals and its application. Clarendon Press, Oxford, 1982.
- Deribas, A. A.; Zakharenko, I. D.: Determination of limiting collision conditions ensuring the welding of metals by explosion: Combustion Explosion and Shock Waves, Vol. 11, 1975; S. 133–135
- Lysak, V.; Kuzmin, S.: Lower boundary in metal explosive welding. Evolution of ideas: Journal of Materials Processing Technology, 2012; S. 150–156.

Experimental Setup
System Technology

BlueWave PS 48-16 at the FG tff

charging energy 48 kJ
charging voltage of 16 kV
charging current by 480 kA

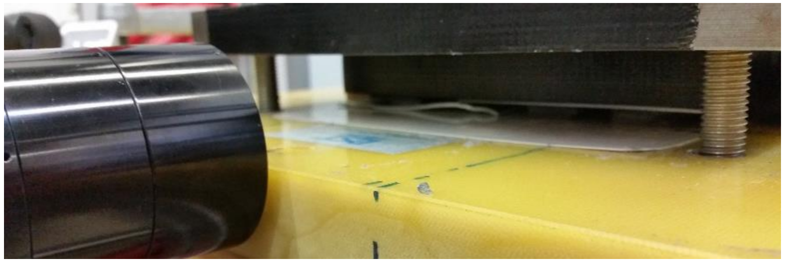
round coil: Ø 148,5 mm
frequency by 22 kHz

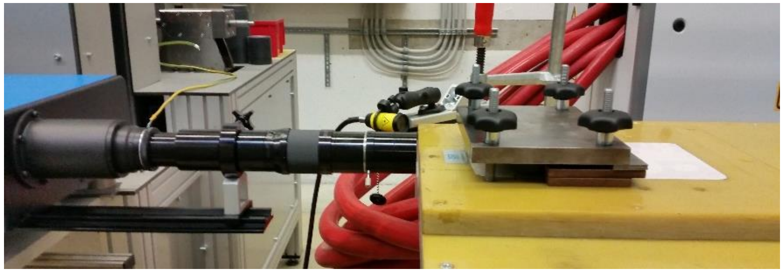
flat coil:
B80/5 (max. 300 kA)
B80/10 (max: 500 kA)
frequency of 20 kHz

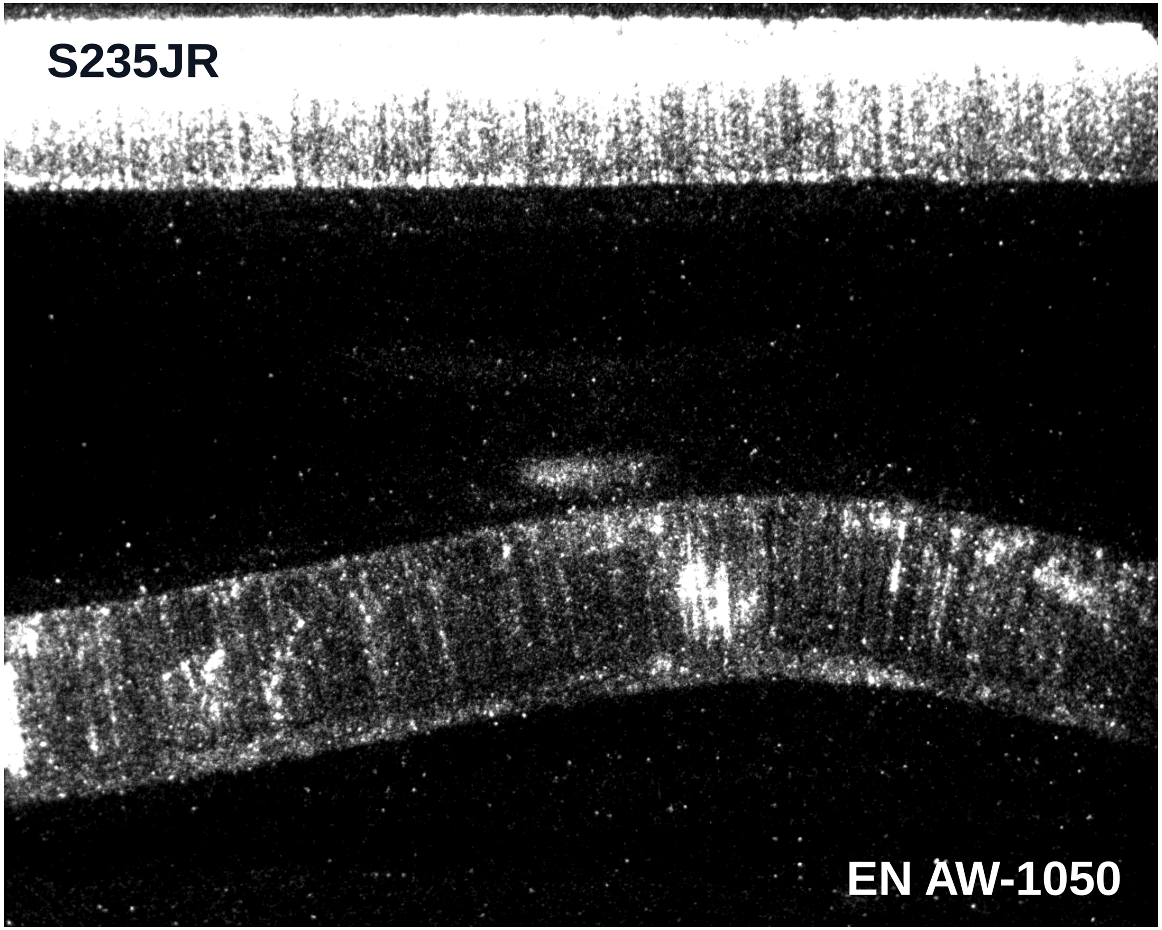
Magnetic-Pulse-Technology (MPT)

Experimental Setup
Specimen Material and Preparation

EN AW-1050 / S235JR		
Boundary conditions:		
•	Flat coil B80/5 (max. 300 kA)	
•	Acceleration distance:	2,5 mm
•	Discharge energy:	11 kJ
•	Current:	296 kA







Experimental Setup
Specimen Material and Preparation

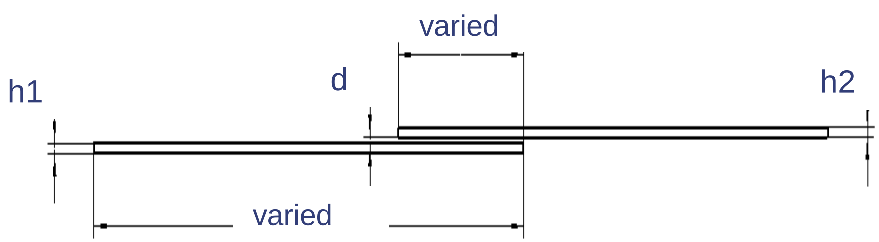
Overview of the Aplied Materials

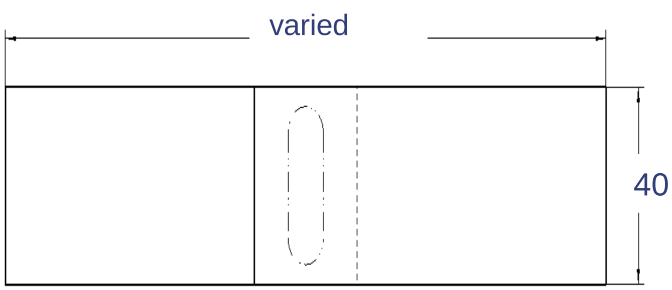
numerical designation	anisotropy	surface treatment
EN AW-1050 A	0° and 90° comparison to V_c	+/- laser ablation
S235JR	90° comparison to V_c	+/- laser ablation / laser structuring
SF-Cu F24	90° comparison to V_c	-
CuOF	90° comparison to V_c	-

Dimensions and Positioning of the Bonding Partners

Geometry of the Sample: (100 x 40 x 1,5-2) mm

Overlap: (10,20,30) mm, V-Nut (4V), ramp (4V)





Experimental Setup
Specimen Material and Preparation

Overview of the Applied Materials		
similar	dissimilar	
CuOF	EN AW-1050	EN AW-1050
CuOF	S235JR	CuOF

Process Parameters and Boundary Conditions

Parameters	Amount of Variations
Acceleration distance	1,0 mm / 1,5 mm / 2,0 mm / 2,5 mm
Discharge energy of the capacitor	11 kJ / 13 kJ / 15 kJ / 17 kJ / 19 kJ
Repetitions per set of parameters	min. 3

Flat coil B80/5 (max. 300 kA) and B80/10 (max. 500 kA)

Experimental Setup
Determination of Collision Point Velocity

EN AW-1050 (90° according to V_c) / S235JR

Approach: According to Crossland, Deribas, Lysak

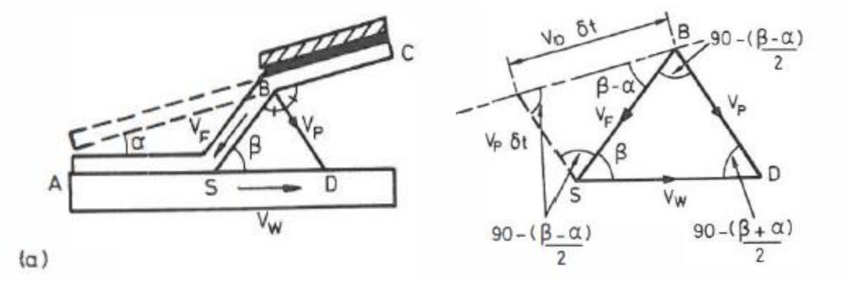
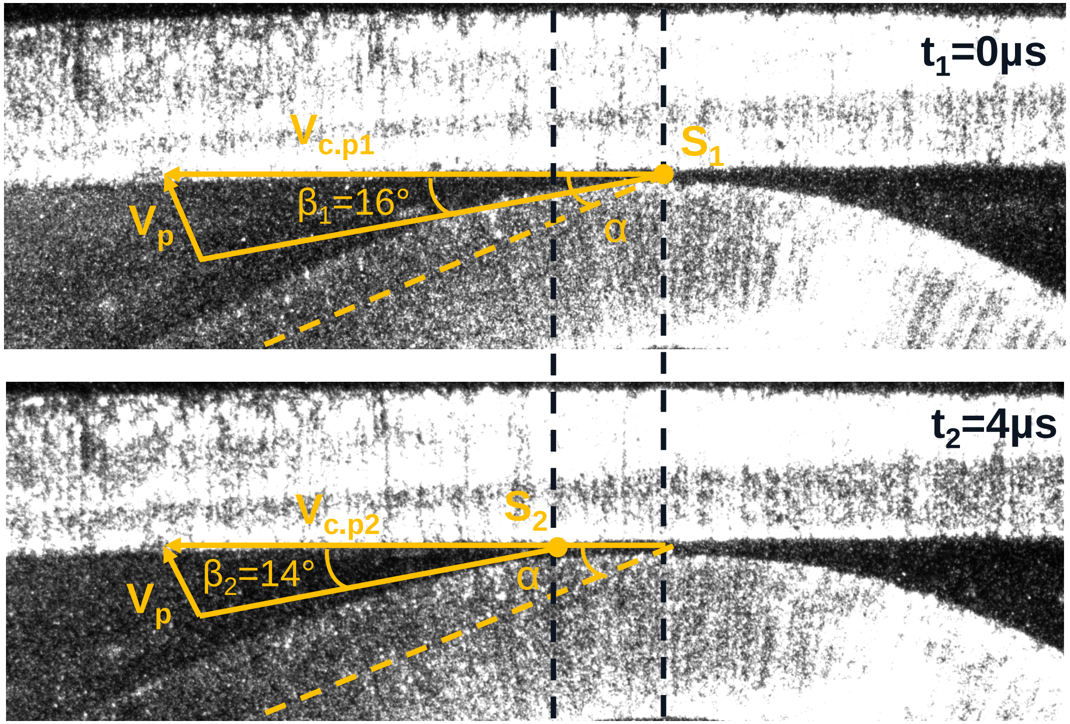


Figure 3: Kinematic diagram of collision of the flyer according to Crossland



$$V_{cp} = Vp \frac{\cos\frac{1}{2}(\beta - \alpha)}{\sin\beta}$$

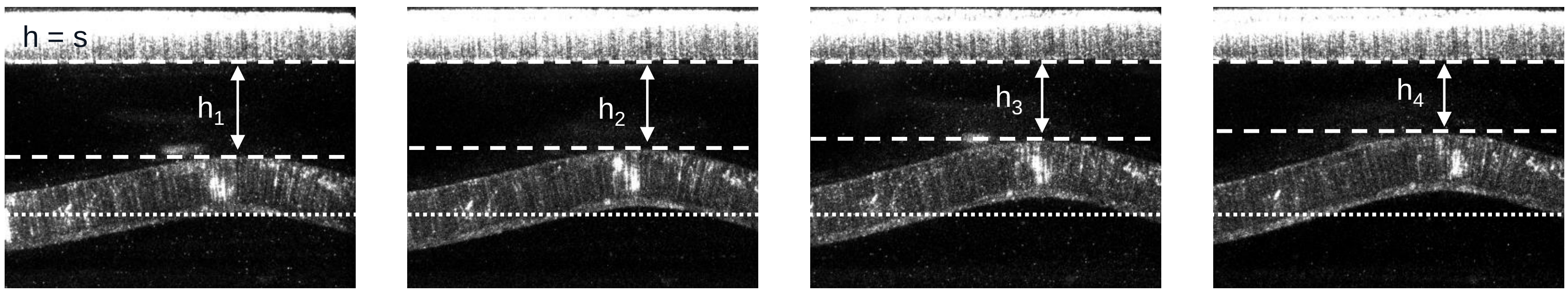
Experimental Setup

Determination of the Velocity of the Flyer Plate

EN AW-1050 (90° according to V_c) / S235JR

Approach: Equally accelerated movement $$v_p(t) = at + v_0$$

$$mit \quad a = konstant \quad s(t) = \frac{a}{2}t^2 + v_0 t + s_0 \quad \rightarrow v_{p(t)} = \frac{2(s_1 - v_0 t - s_0)}{t} + v_0$$



process time: t_0=0µs | **t_1=4µs** | **t_2=8µs** | **t_3=12µs** | **t_4**

Investigation of the velocity of the flyer plate regarding to :

- Material and thickness
- Acceleration distance and discharge energy

Experimental Work

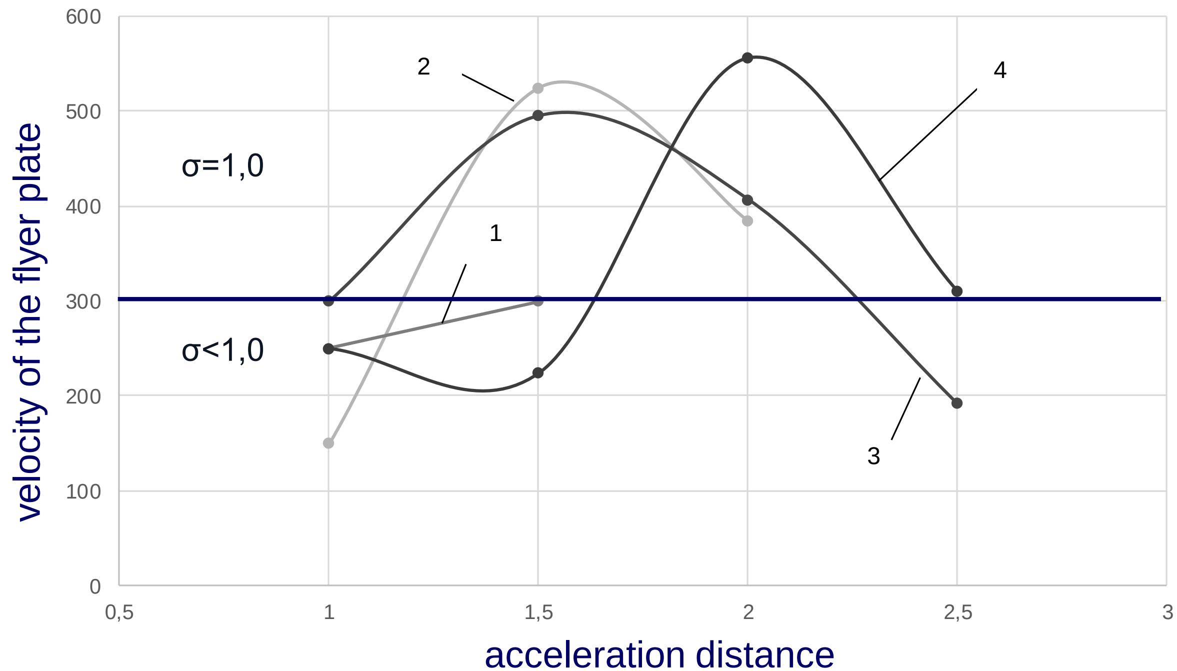
Determination of the Velocity of the Flyer Plate

EN AW-1050 (90° according to V_c) / S235JR

Approach: Influence of the velocity of flyer plate to acceleration distance and discharge energy

- To realize a relative strength of **σ =1,0** are velocities of the flyer plate up to **300 m/s** required.
- Increasing of acceleration distance lead to the need to increase the discharge energy (up to 1.5 mm)
- **Process window:**

  1,0 mm ≤ d ≤ 1,5 mm



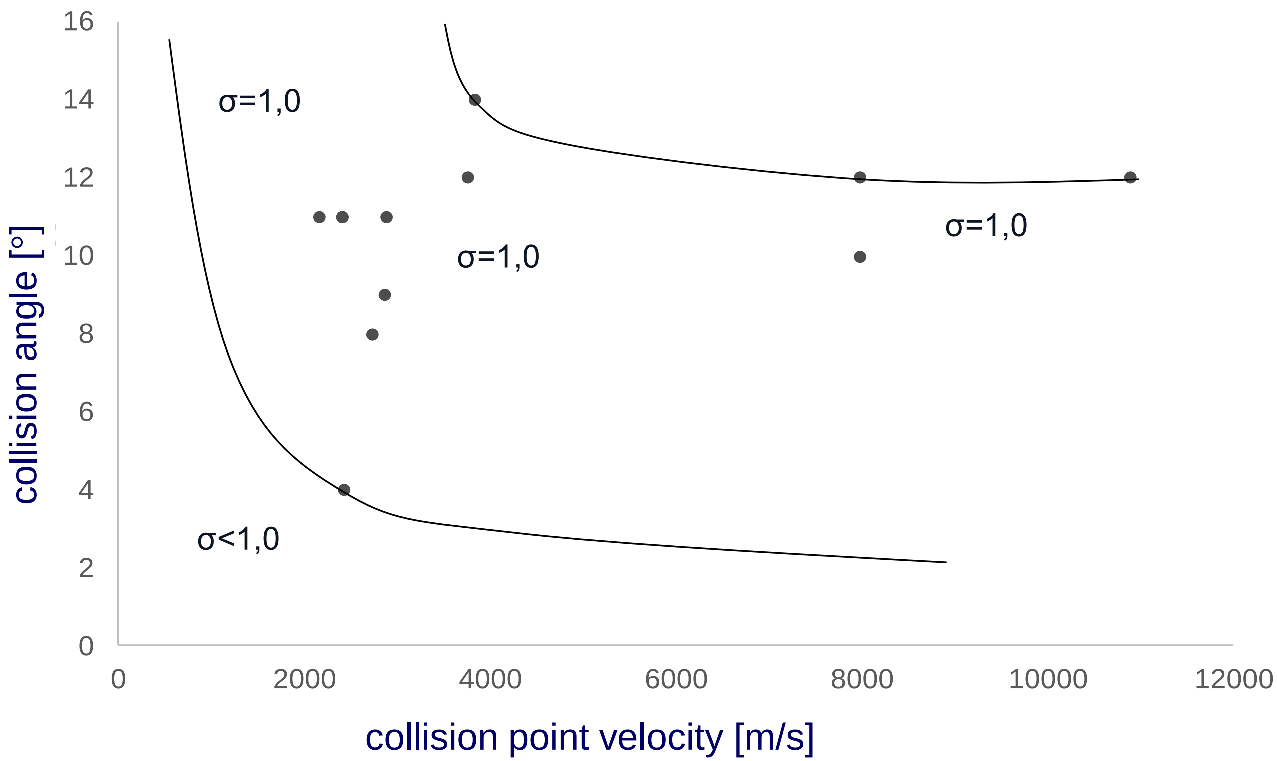
① Discharge energy 11 kJ ② Discharge energy 13 kJ ③ Discharge energy 15 kJ ④ Discharge energy 17 kJ

Experimental Work

Collision Point Velocity versus Collision Angle (V_{cp} - β)

EN AW-1050 (90° according to V_c) / S235JR

Approach: According to Crossland, Deribas, Lysak



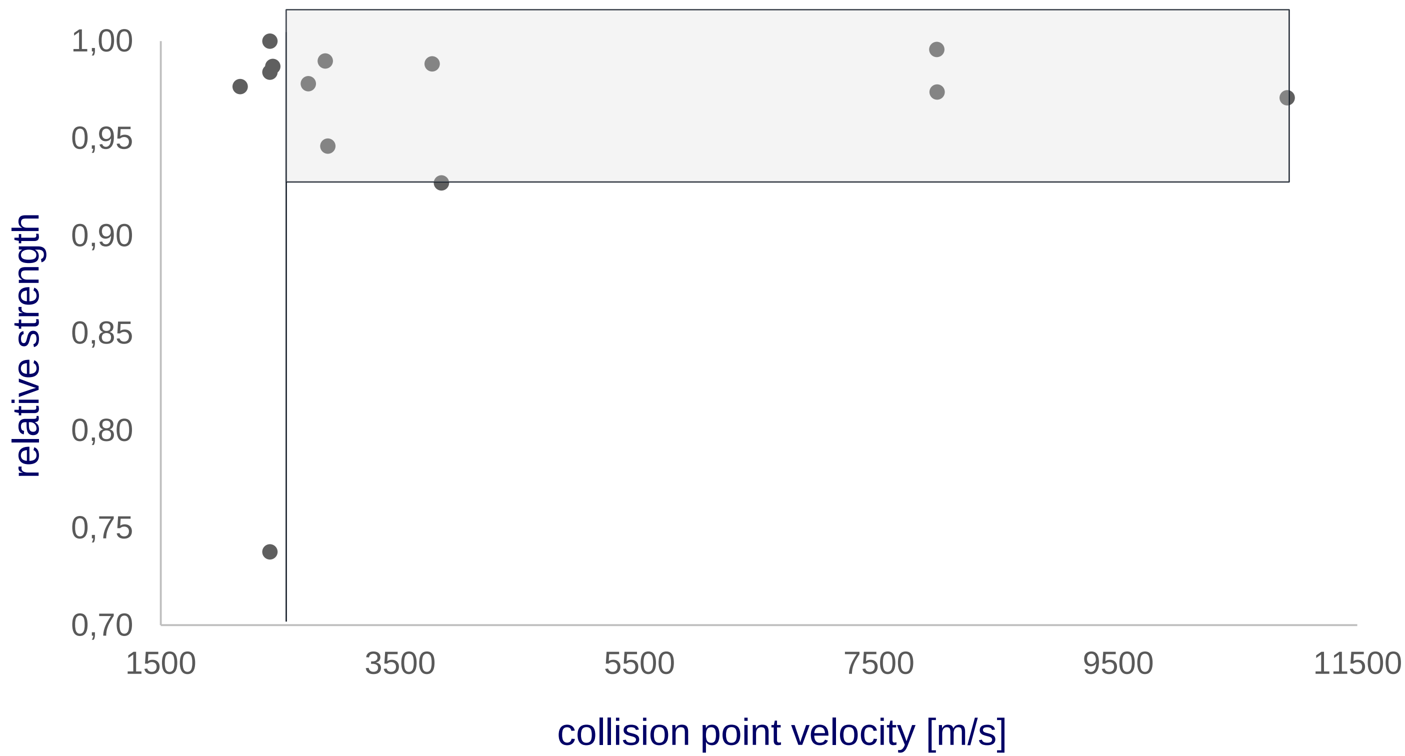
σ=relative strength

Experimental Work

Effect of the Collision Point Velocity and Relative Strength (V_{cp} - σ)

EN AW-1050 (90° according to V_c) / S235JR

Approach: According to Lysak

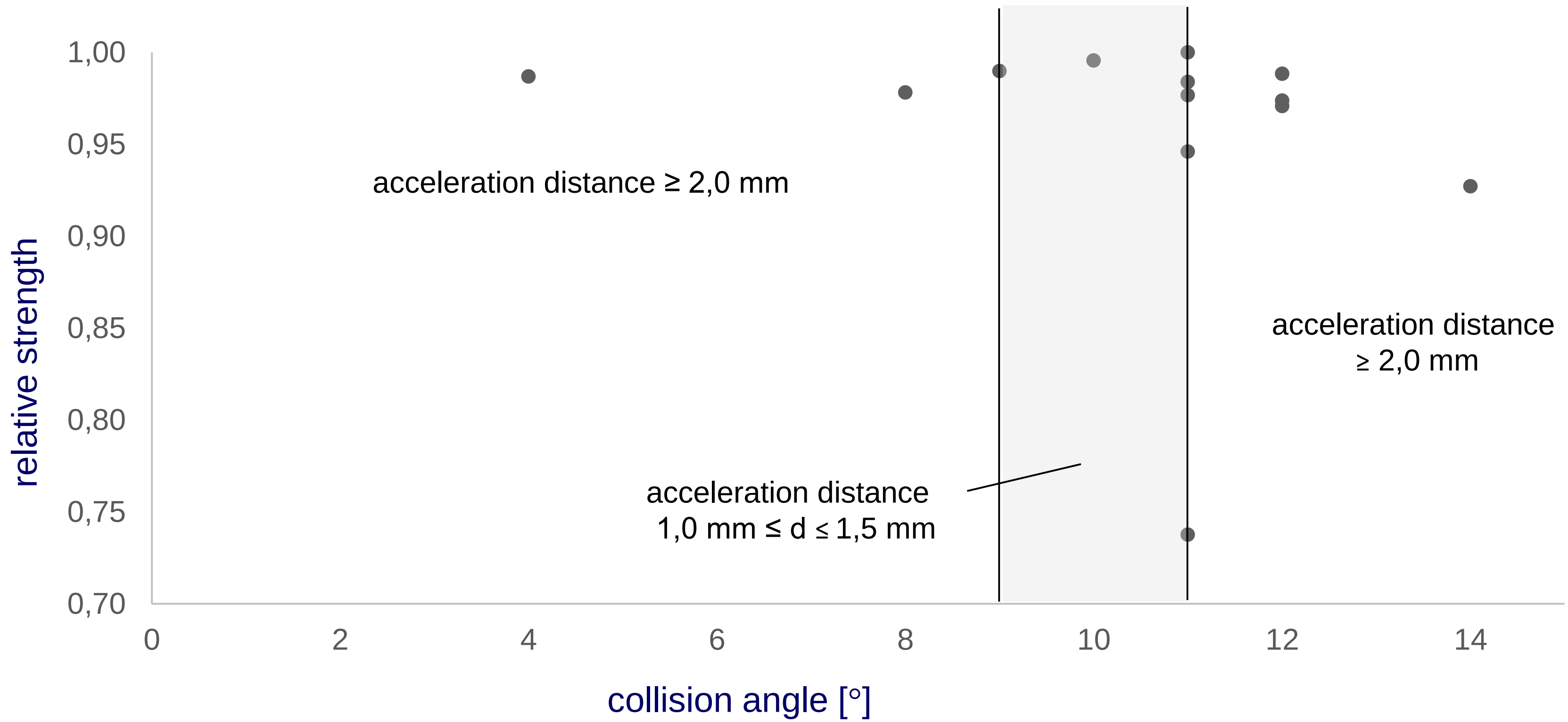


Experimental Work

Effect of the Collision Angle and Relative Strength (β - σ)

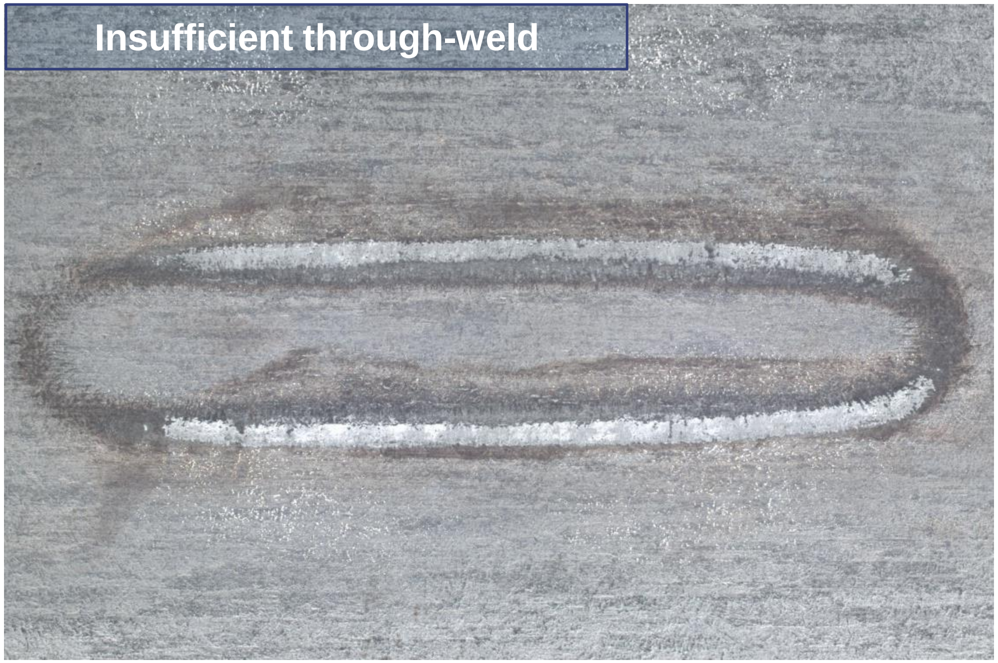
EN AW-1050 (90° according to V_c) / S235JR

Approach: According to Lysak



Experimental Work
Weld Properties

EN AW-1050 (90° according to V_c) / S235JR



Pulse number:	**6970**
Acceleration distance:	**1,0 mm**
Discharge energy:	**11 kJ**
Surface pre-treatment:	**laser ablation (EN AW-1050/S235JR)**
Fmax:	**5060 N**
relative strength σ:	**0,74**

Pulse number:	**6985**
Acceleration distance:	**1,5 mm**
Discharge energy:	**11 kJ**
Surface pre-treatment:	**laser ablation (EN AW-1050/S235JR)**
Fmax:	**6490 N**
relative strength σ:	**0,95**

Summary
Conclusion and Outlook

Conclusion

1. Velocities of the flyer plate up to **300 m/s** are necessary to reach the relative strength of **σ =1,0**.

2. Optimum acceleration distance lies between **1,0 mm ≤ d ≤ 1,5 mm and** lead to collision angle of **9° - 11°** degree.

3. There is a relationship between the relative strength of the connection and the collision angle.

4. **Collision point velocity starting by 2400 m/s under collision angle** unter from **8° degree** lead to the transition to the stable process window.

Summary
Conclusion and Outlook

Further work

A. **Evaluation of the results** – Overlapp of (10,20,30) mm, SF-Cu F24, CuOF

B. Investigation of the **influence of the angle** α.

C. Comparison with **theoretical models** according to Lysak, Deribas, Crossland

D. Advance of the process window for the MPW and establishing the **correlation between the relative strength of the connection**, **mechanical and physical properties** of the base materials and the process variables collision point velocity and collision angle.

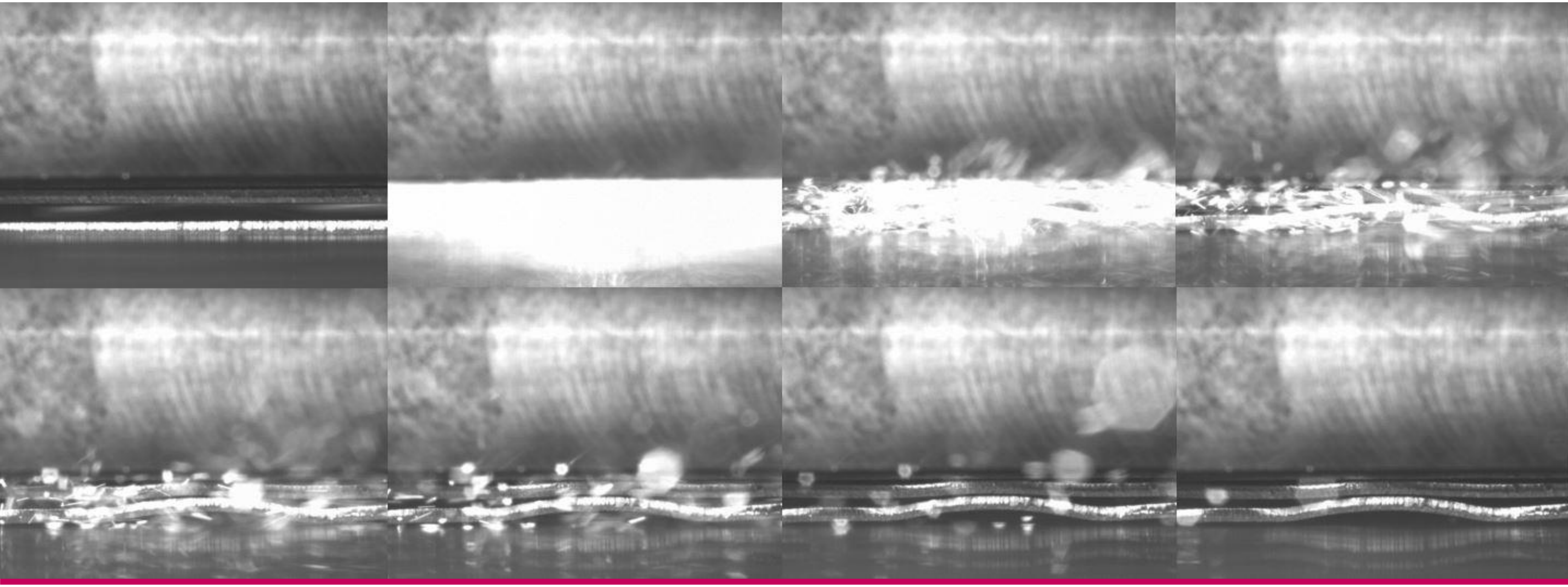
E. Characterization of the weld seam (e.g. waveness, height of the amplitudes) and integration in the process window of MPW.

Influence of the Collision Speed and Collision Angle in Magnetic Pulse Sheet Welds

Anatoli Rebensdorf, M.Sc. IWE; Univ.-Prof. Dr.-Ing. Stefan Böhm

Institute for Production Technology and Logistics (IPL)
Department for Cutting and Joining Manufacturing Processes (tff)
International Impulse Forming Group (I²FG)
Dortmund, October 5-6, 2015

DFG Deutsche Forschungsgemeinschaft



UNI KASSEL VERSITÄT

tff trennen, fügen, fertig