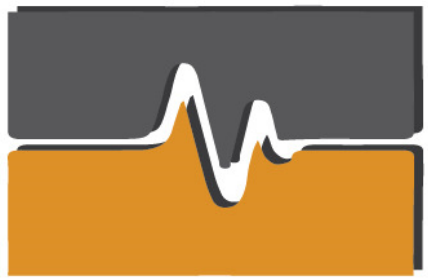


JOIN'EM

INDUSTRIAL TECHNOLOGIES FOR ADVANCED JOINING AND ASSEMBLY PROCESSES FOR MULTI-MATERIALS

Process analysis for magnetic pulse welding of aluminium-copper joints

Verena Psyk, Christian Scheffler, Maik Linnemann, Dirk Landgrebe

I²FG workshop on impulse metalworking 2016

December 1st-2nd, 2016

Nantes, France

Agenda

JOIN'EM
INDUSTRIAL TECHNOLOGIES FOR ADVANCED JOINING AND ASSEMBLY PROCESSES FOR MULTI-MATERIALS

- Introduction to the JOIN'EM project
- Process analysis for magnetic pulse welding of aluminium-copper joints
  - Setup and process parameters
  - Welding experiments
  - Characterisation of the joint
  - Correlation of adjustable process parameters and weld quality
  - Quantification of collision parameters via numerical simulation
  - Correlation of collision parameters and weld quality
  - Summary

JOIN'EM – facts and figures

JOIN'EM
INDUSTRIAL TECHNOLOGIES FOR ADVANCED JOINING AND ASSEMBLY PROCESSES FOR MULTI-MATERIALS

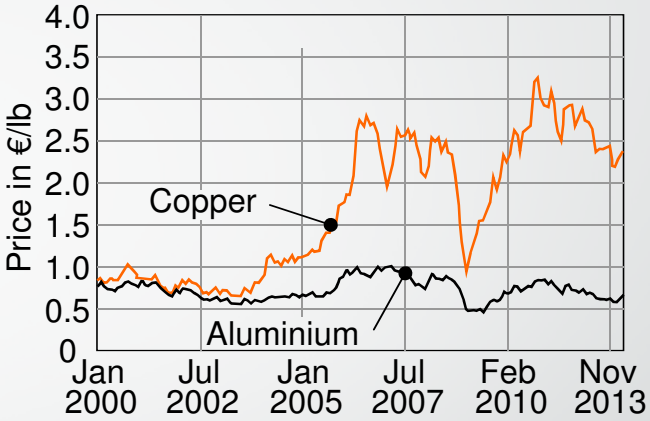
- Titel **JOIN**ing of copper to aluminium by **E**lectro**M**agnetic fields
- Acronym JOIN'EM
- Duration 01.09.2015 - 31.08.2018
- Budget 4.7 Mio. €
- Grant 4.1 Mio. €
- Coordinator Fraunhofer IWU (Dr.-Ing. Verena Psyk)
- Project partners

*Word cloud designed using Tagxedo

JOIN'EM – overall aims

JOIN'EM
INDUSTRIAL TECHNOLOGIES FOR ADVANCED JOINING AND ASSEMBLY PROCESSES FOR MULTI-MATERIALS

- Supplementing the heavy use of full copper components in applications related to electrical and thermal conductivity by hybrid copper – aluminium solutions
  - Reduce material costs
  - Reduce product weight
- Development of a flexible, highly productive, and cost effective joining process for high quality dissimilar material joints
  ➔ magnetic pulse welding (MPW)
- Enabling the industrial implementation of MPW and facilitating the exploitation of known process advantages in series production



(Source: www.infomine.com)

	Copper	Aluminium
Electrical conductivity	58 MS/m	36 MS/m
Thermal conductivity	401 W/mK	236 W/mK
Density	8.9 g/cm³	2.7 g/cm³
Price	4.478 €/ton*	1.550 €/ton*

(Source: http://www.boerse-online.de/rohstoffe; 2016-11-04)

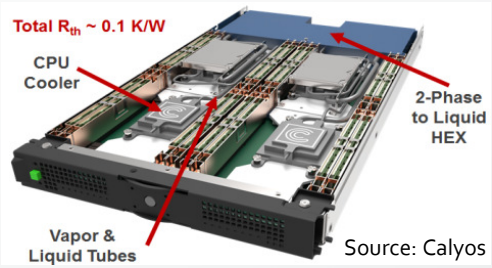
JOIN'EM – objectives

JOIN'EM
INDUSTRIAL TECHNOLOGIES FOR ADVANCED JOINING AND ASSEMBLY PROCESSES FOR MULTI-MATERIALS

- Experimental and numerical process analysis and design
- Development of validated process and joint design concepts
- Development of multiscale simulation strategies
- Development of optimized tools for industrial implementation
- Development and automation of non-destructive testing and quality control
- Design, realization, and evaluation of industrial demonstrators
- Economic process and product evaluation via life cycle cost analysis

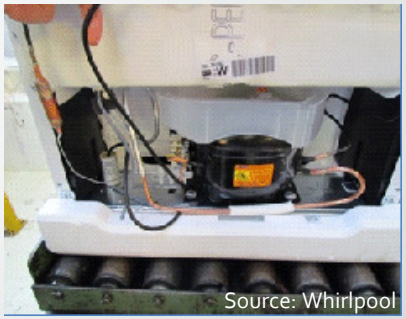
Fields of application and suggested demonstrators

High power electronics passive cooling



Source: Calyos

White goods


Source: Whirlpool

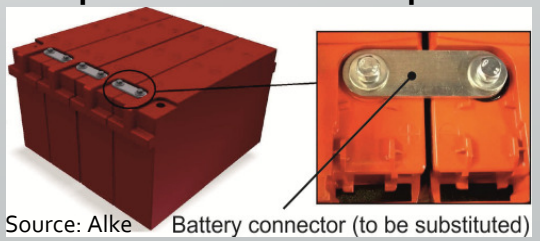
Battery systems


Source: Cegasa

HVAC


Source: Refco

Transport/automotive components


Source: Alke
Battery connector (to be substituted)

Setup and process parameters

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INDUSTRIAL TECHNOLOGIES FOR ADVANCED JOINING AND ASSEMBLY PROCESSES FOR MULTI-MATERIALS

Parameters considered for detailed investigation

Capacitor charging energy E (10 up to 40 kJ)

Flyer thickness t_{flyer} (0.3 up to 1.5 mm)

Initial gap between flyer and target $g_{initial}$ (1.0 up to 3.0 mm)

x-position of the flyer edge x_{flyer} (-2 up to +2 mm)

Fixed parameters

Capacitance C (300 µF)

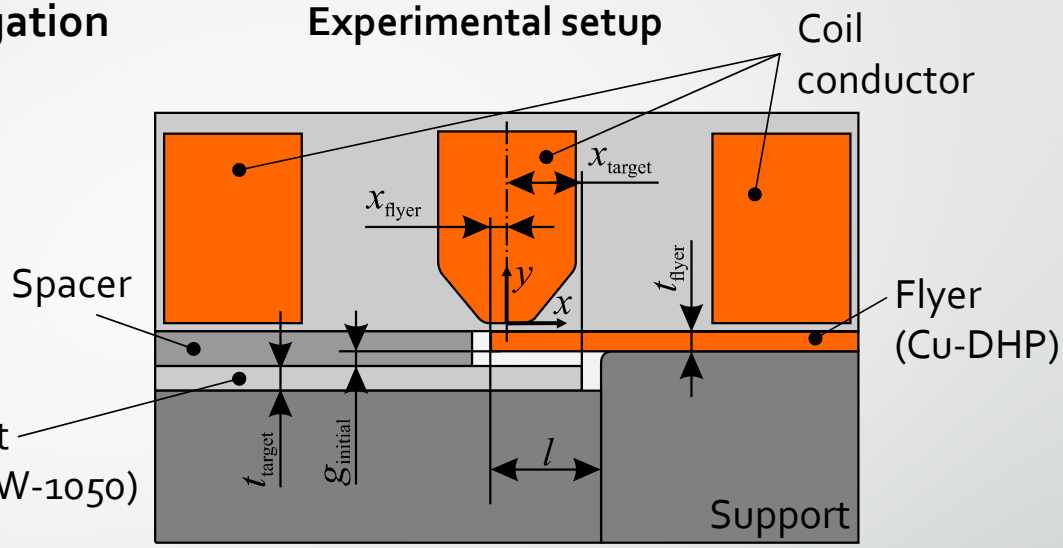
Target thickness t_{target} (2 mm)

x-position of target edge x_{target} (14 mm)

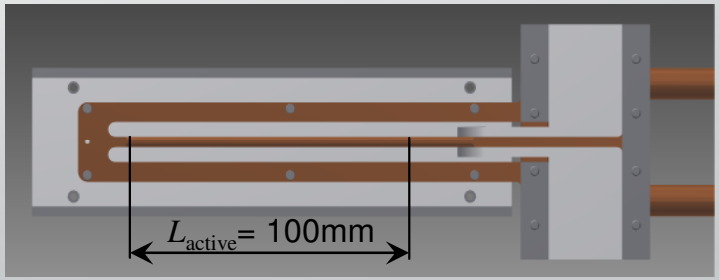
Free length l (16 mm)

Width of flyer and target $w_{flyer} = w_{target}$ (100 mm)

Experimental setup



Tool coil



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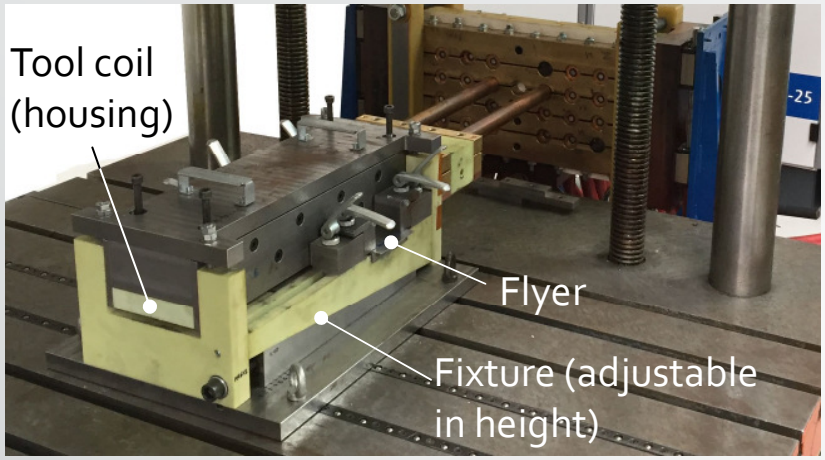
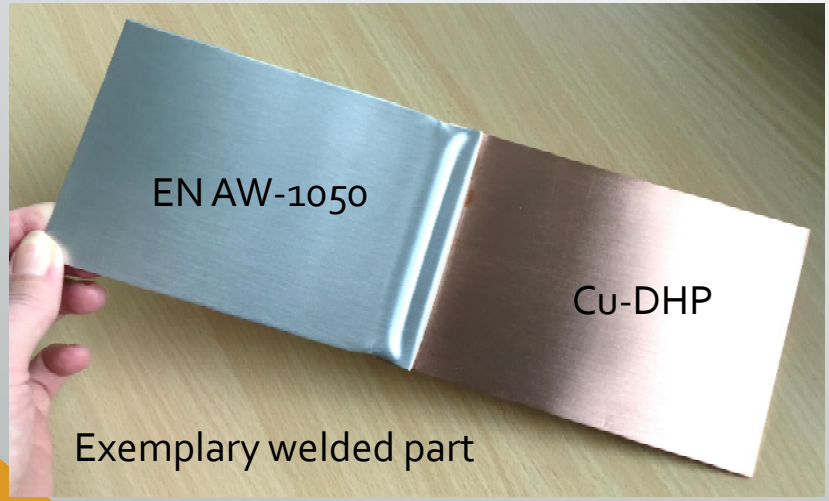
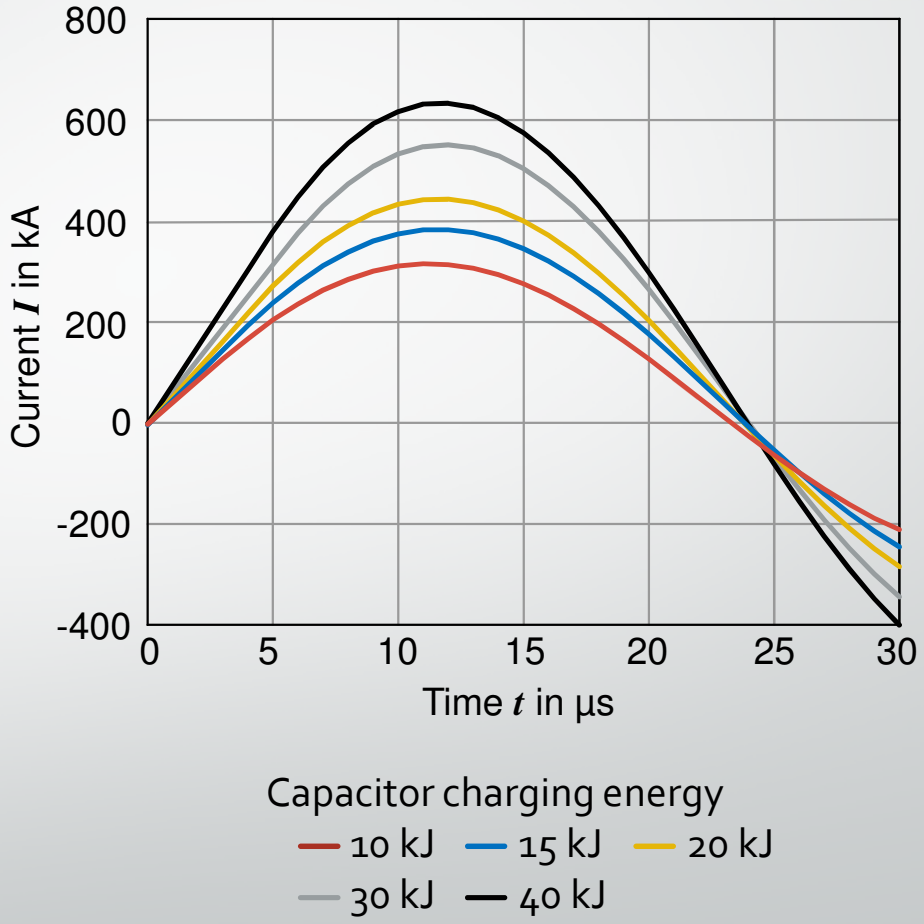
Welding experiments



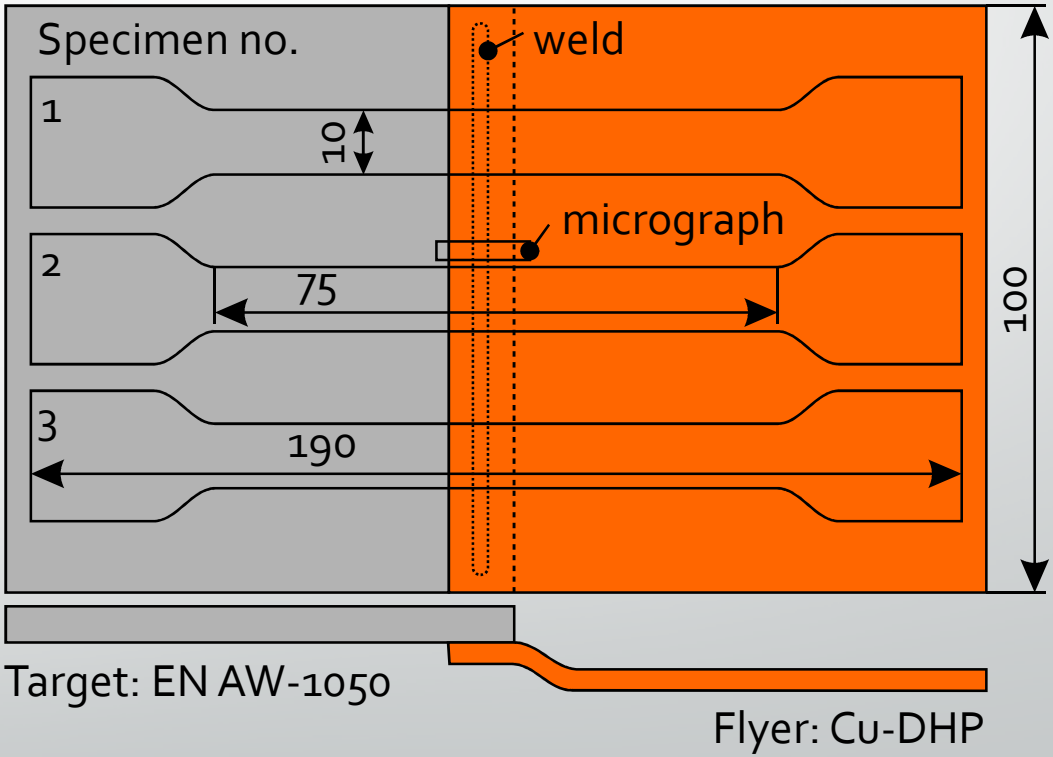




Characterization of the joint

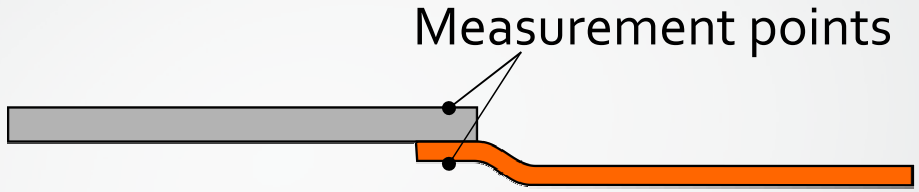
- Electrical resistance measurement
- Lap shear test
- Metallographic analysis

Position of specimens in the hybrid sheet



Characterization of the joint

- Electrical resistance measurement
- Lap shear test
- Metallographic analysis



Imposed current: I=4 A
Measurement of voltage drop U

Resistance $R = \frac{I}{U}$

Resistance of the joining partners is negligible if measurement points are close to the joining zone.

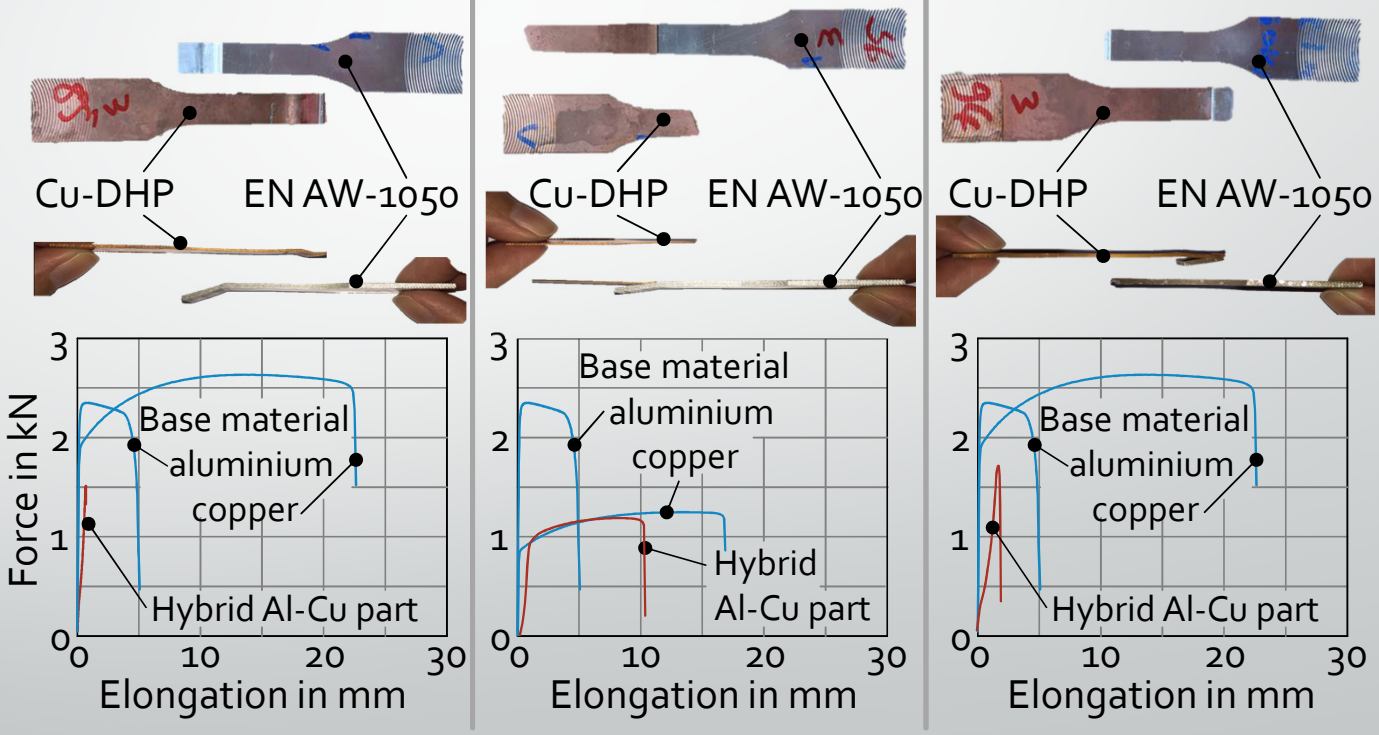
➔ Calculated resistance corresponds to resistance of the joint.

Characterization of the joint

- Electrical resistance measurement
- Lap shear test
- Metallographic analysis

Failure cases

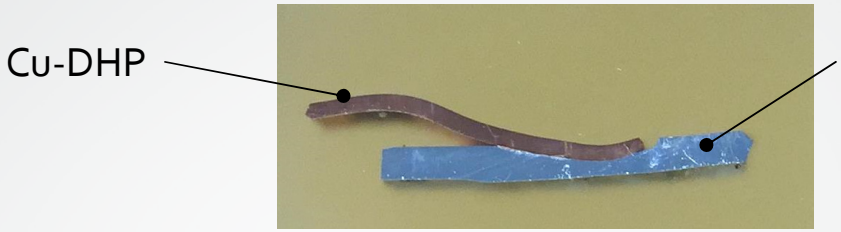
Failure in the joint (occurs for all flyer thicknesses)	Failure in the copper base material (occurs for flyer thicknesses of 0.5 mm only)	Failure in the aluminium base material (occurs for flyer thicknesses ≥ 1 mm)



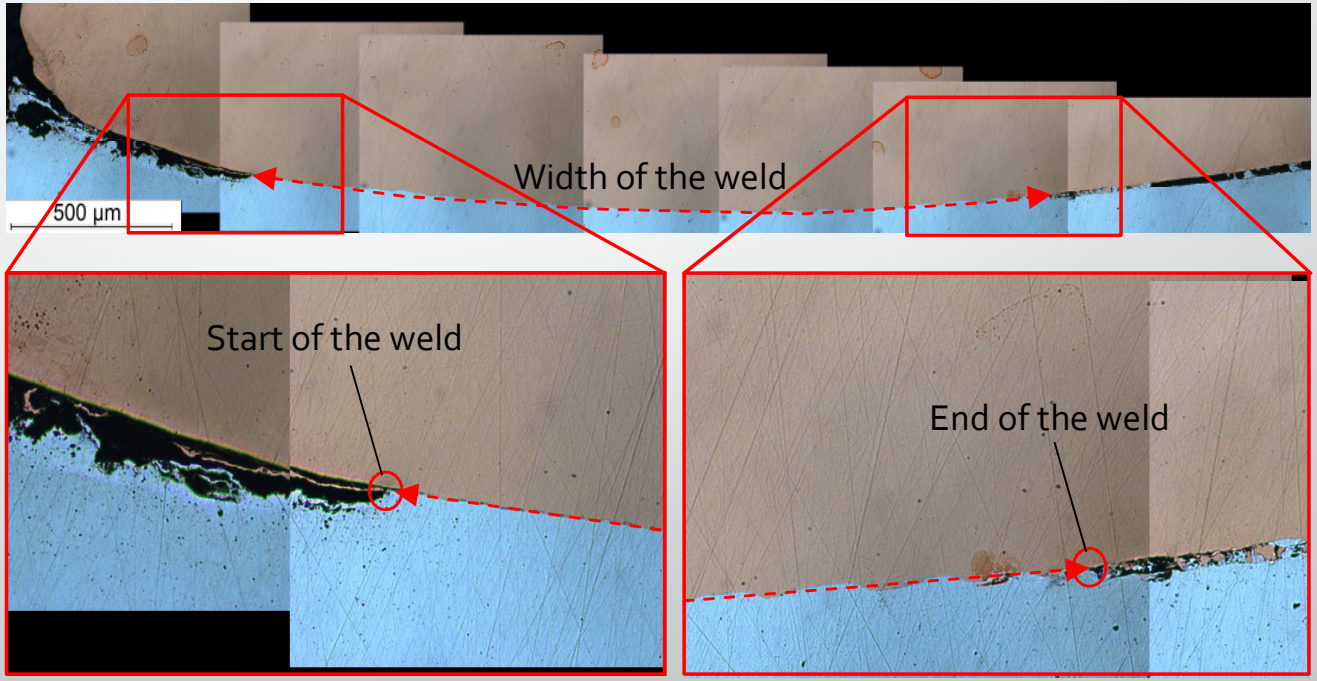
All cases: Welding of copper flyers to aluminium targets

Characterization of the joint

JOIN'EM
INDUSTRIAL TECHNOLOGIES FOR ADVANCED JOINING AND ASSEMBLY PROCESSES FOR MULTI-MATERIALS



- Electrical resistance measurement
- Lap shear test
- Metallographic analysis



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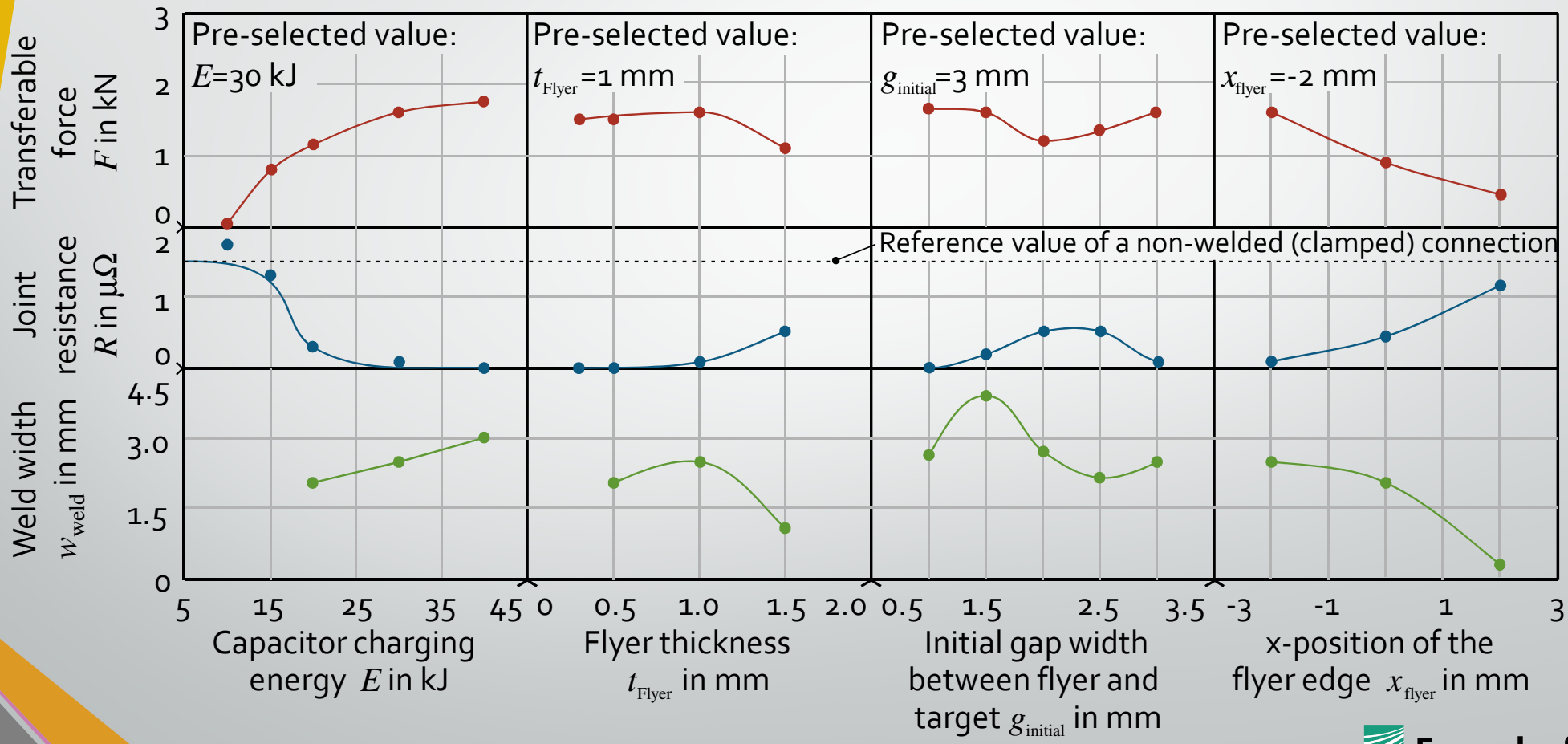
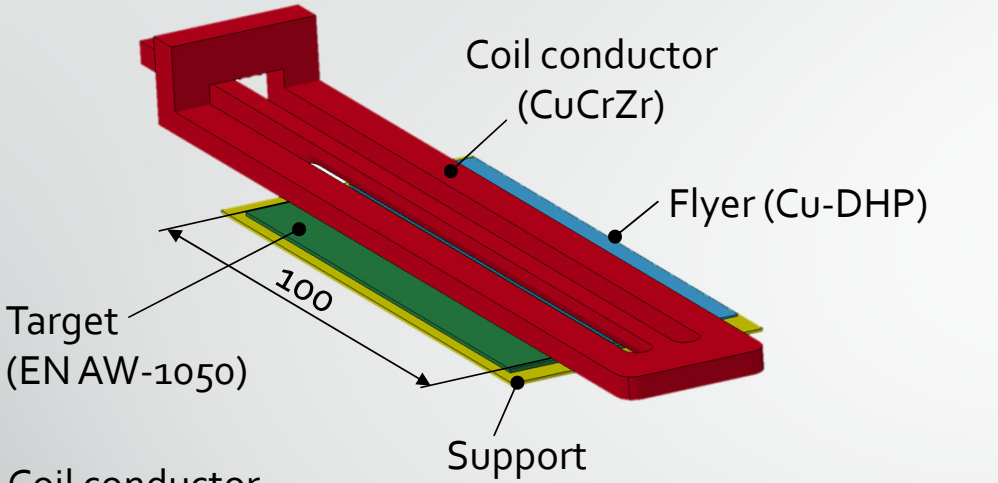
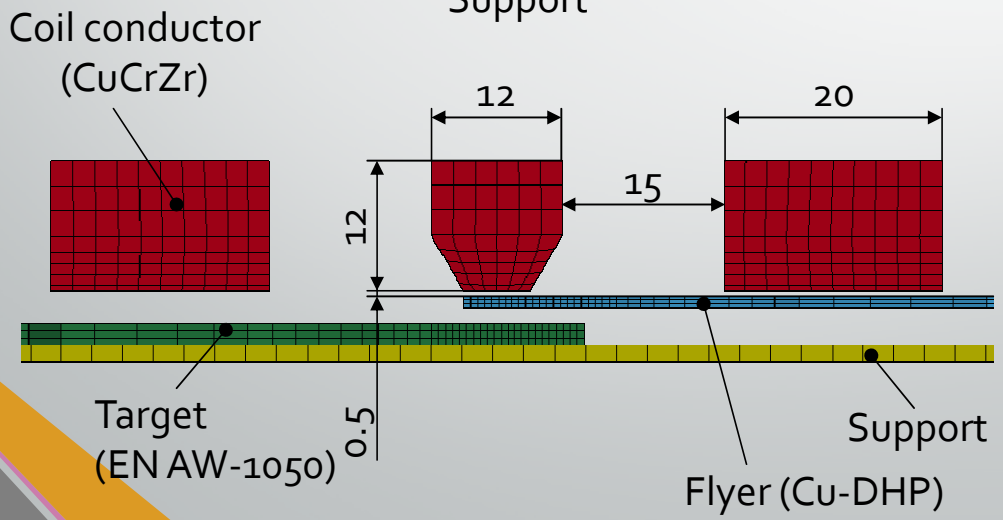
Correlation of adjustable process parameters and weld quality

Maximum transferable force in a lap shear test is considered for mechanical joint characterisation

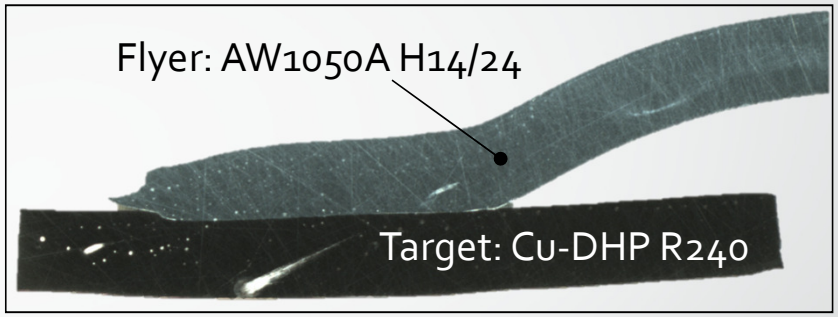


Numerical modelling



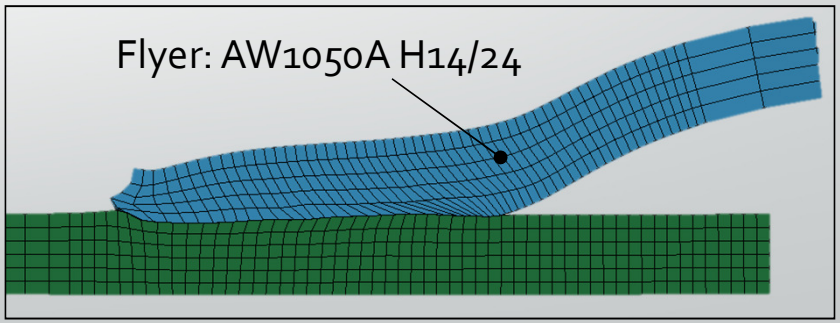


Experiment



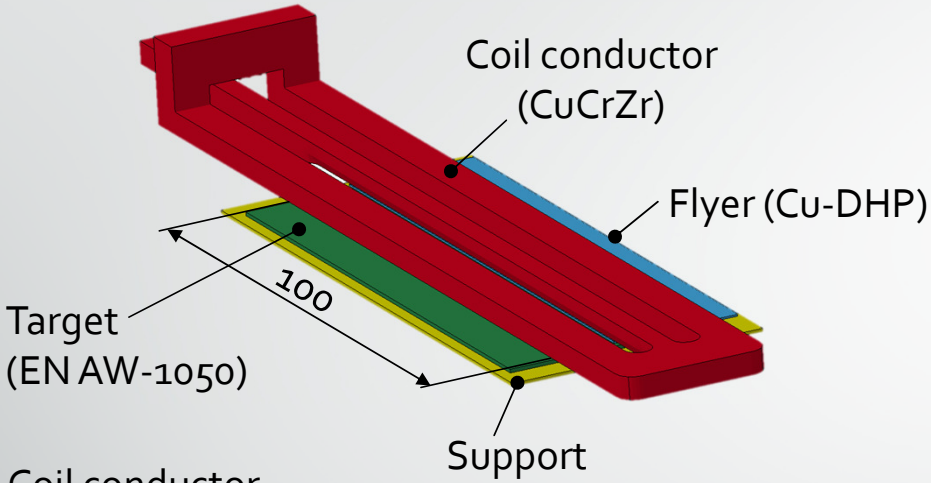
V109: 30kJ, 544kA, 22.2kHz, t_{flyer}=2, gap=3, x=-2

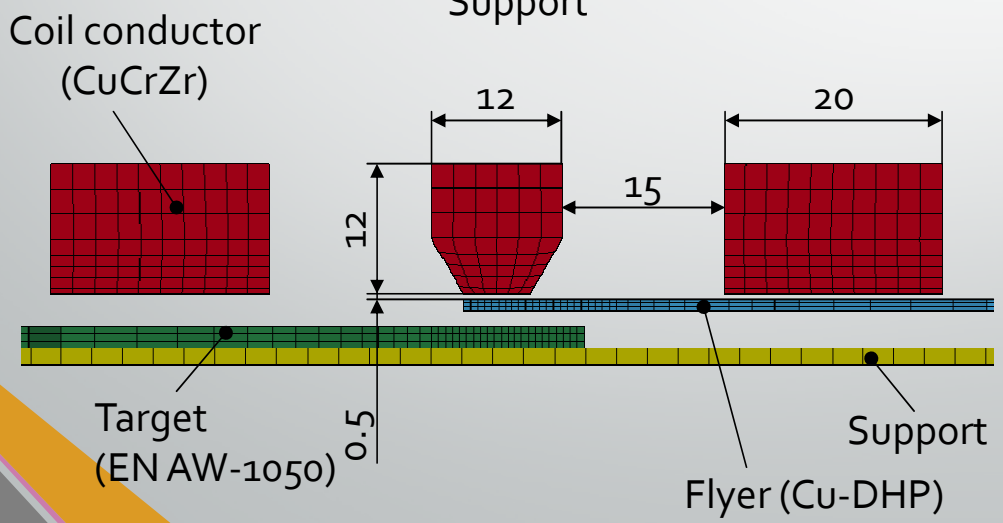
Corresponding macroscopic simulations

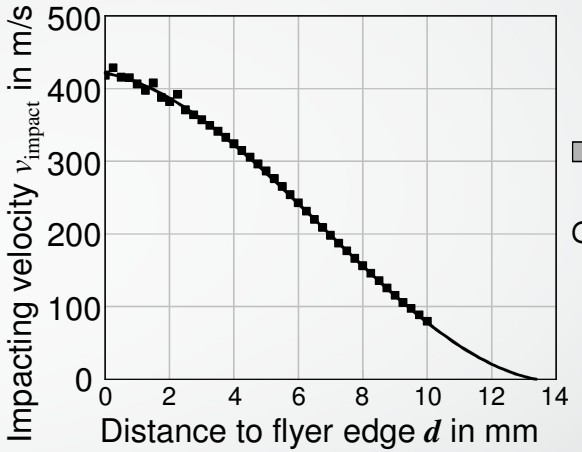


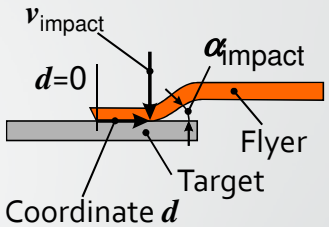
V109: 30kJ, 544kA, 22.2kHz, t_{flyer}=2, gap=3, x=-2

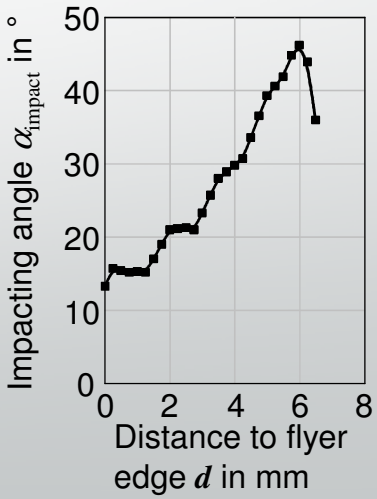
Numerical calculation of collision parameters







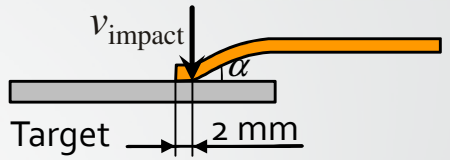


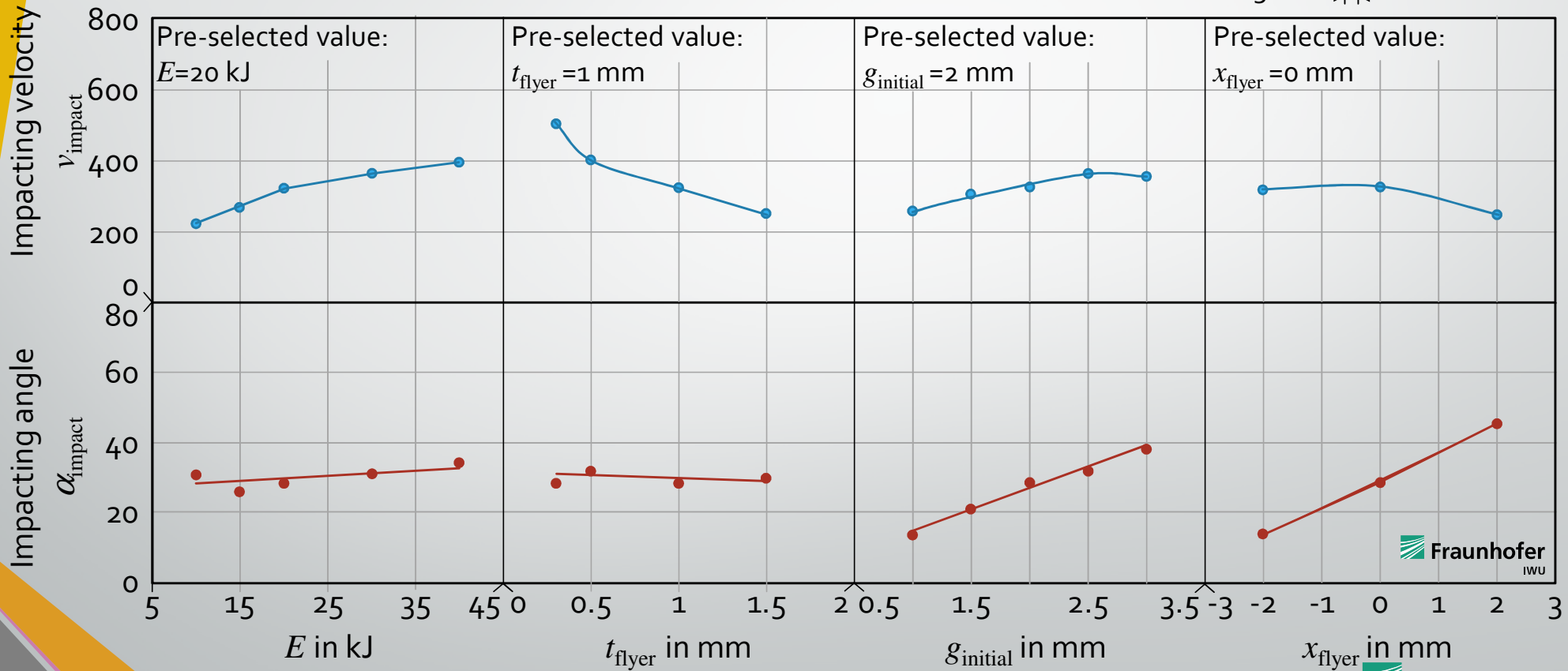


Process parameters
Capacitor charging energy: 30 kJ
Initial gap flyer / target: 3mm
Flyer
Material: Cu-DHP
Thickness: 1 mm
Edge position: -2 mm
Target
Material: EN AW-1050
Thickness: 2 mm
Edge position: 14 mm

Correlation of adjustable process parameters and collision parameters

Collision parameters at a distance of 2 mm from the flyer edge are considered because typically this area is welded if welding occurs at all.





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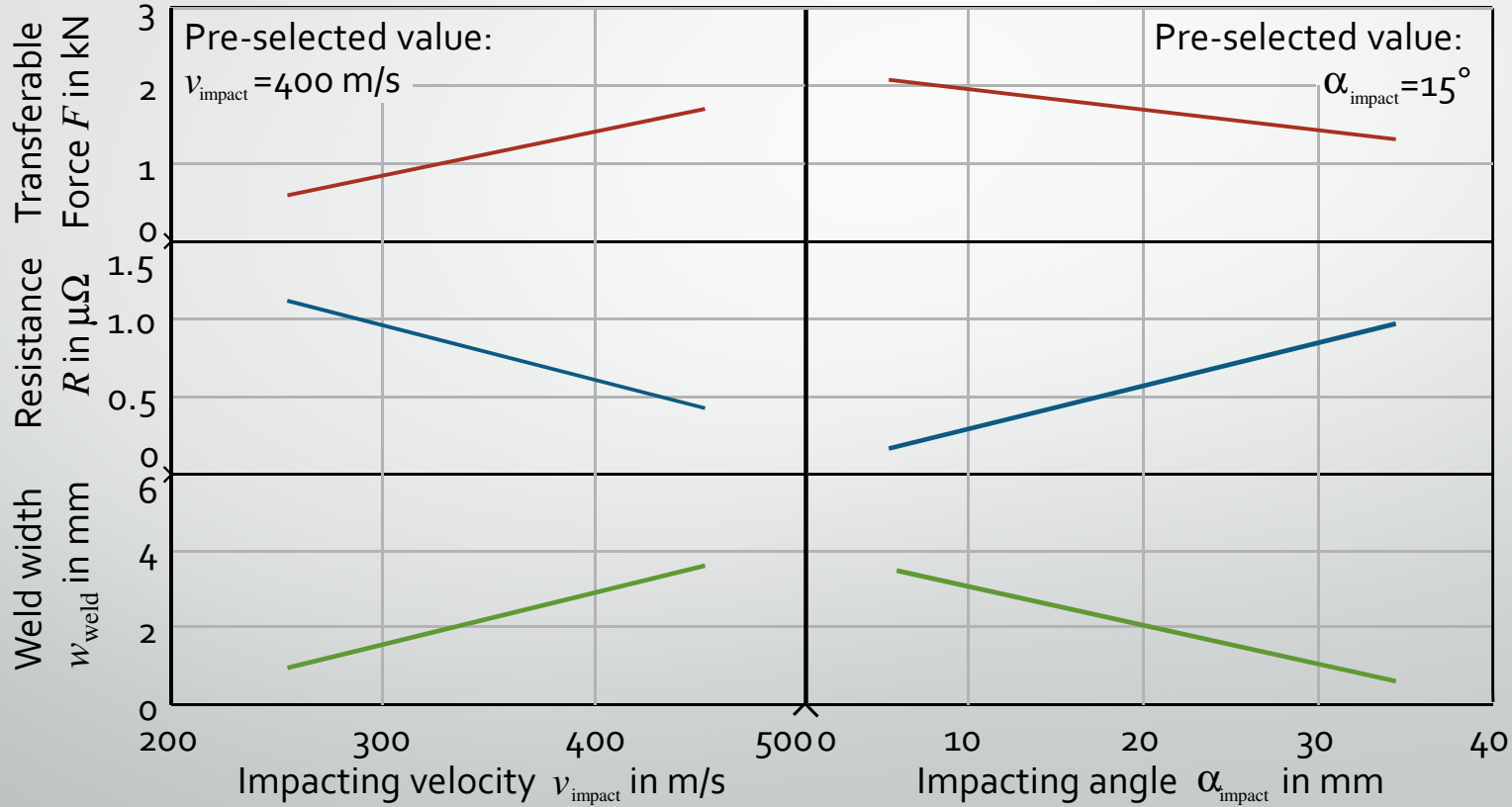
Correlation of collision parameters and joint quality

Maximum transferable force in a lap shear test is considered for mechanical joint characterisation



Summary

JOIN'EM
INDUSTRIAL TECHNOLOGIES FOR ADVANCED JOINING AND ASSEMBLY PROCESSES FOR MULTI-MATERIALS

- JOIN'EM aims at reducing the heavy use of copper to reduce cost and weight.
- Hybrid aluminium copper parts shall replace current full copper solutions.
- MPW is a promising technology for manufacturing copper aluminium joints.
- An experimental and numerical process analysis considering MPW of aluminium copper joints has shown that high quality joints require by trend
  - high impacting velocity (i.e. >250 m/s for welding of Cu-DHP and EN AW-1050) and
  - low impacting angle (i.e. 5°-20° for welding of Cu-DHP and EN AW-1050).
- The impacting velocity is higher if
  - high capacitor charging energy (and consequently higher force) is applied and
  - the flyer thickness (and consequently the flyer mass to be accelerated) is low.
- The impacting angle is lower if
  - the initial gap width between flyer and target is small and
  - the overlap of flyer and tool is relatively long.

Fraunhofer IWU

Acknowledgement

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