

JOIN'EM

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

Process analysis for magnetic pulse welding of aluminium-copper joints

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Agenda

- 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

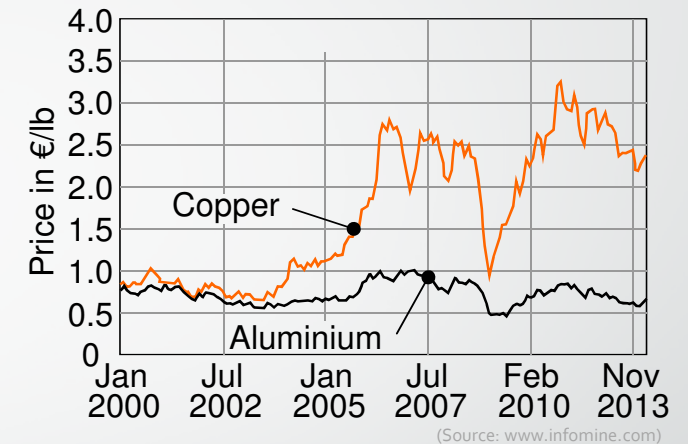
JOIN'EM – facts and figures

- Titel JOINing of copper to aluminium by ElectroMagnetic 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



JOIN'EM – overall aims

- 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



	Copper	Aluminium
Electrical conductivity	58 MS/m	36 MS/m
Thermal conductivity	401 W/mK	236 W/mK
Density	8.9 g/cm ³	2.7 g/cm ³
Price	4.478 €/ton*	1.550 €/ton*

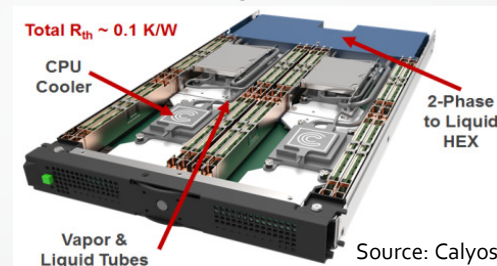
(Source: <http://www.boerse-online.de/rohstoffe>; 2016-11-04)

JOIN'EM – objectives

- 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



White goods



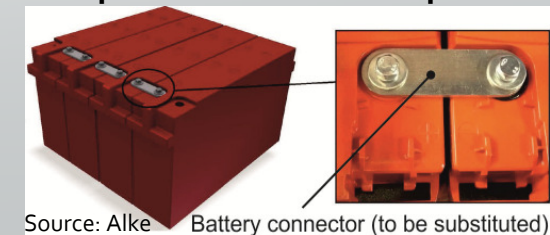
Battery systems



HVAC



Transport/automotive components



Setup and process parameters

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

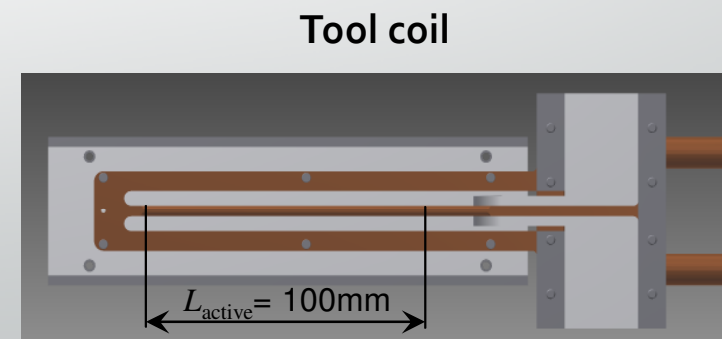
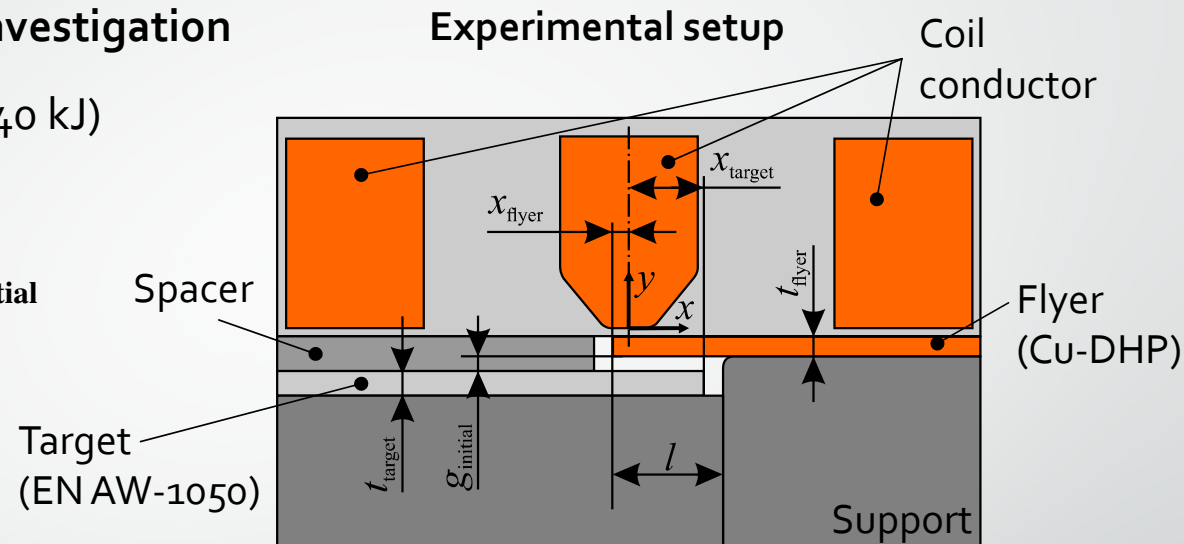
Capacitance C (300 μF)

Target thickness t_{target} (2 mm)

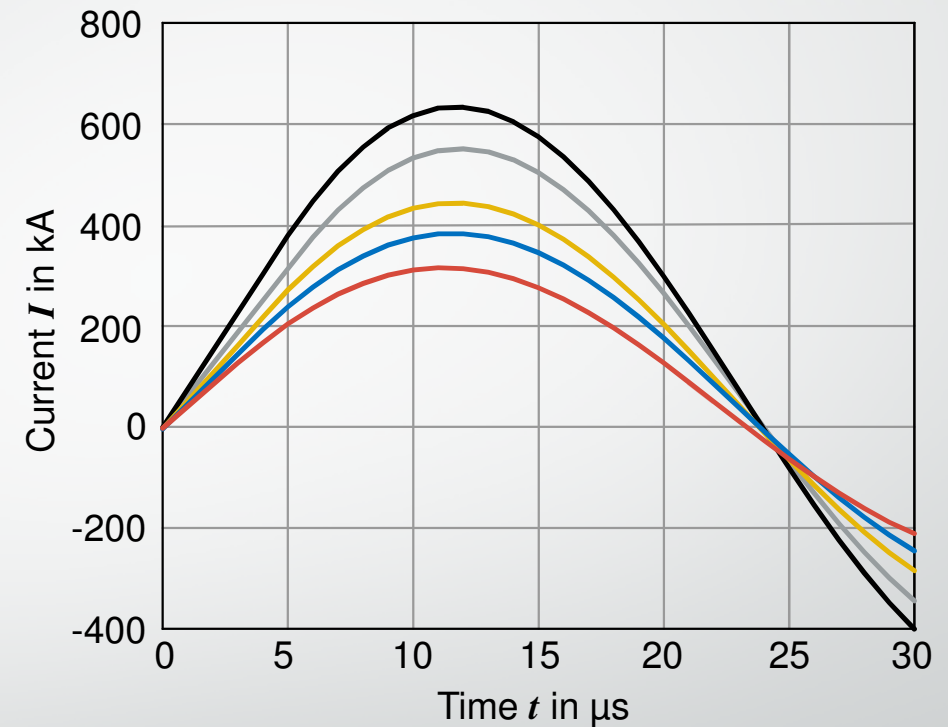
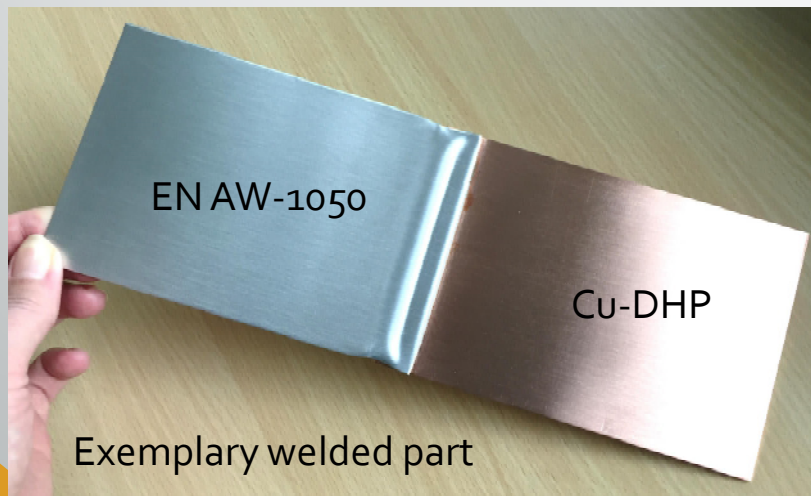
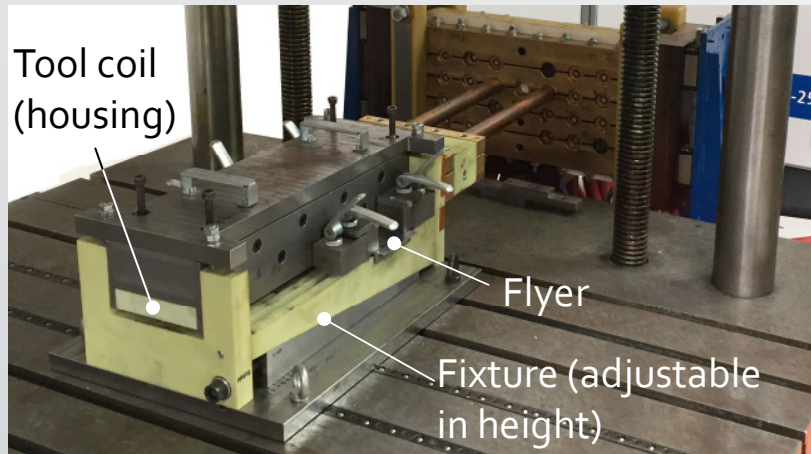
x-position of target edge x_{target} (14 mm)

Free length l (16 mm)

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



Welding experiments

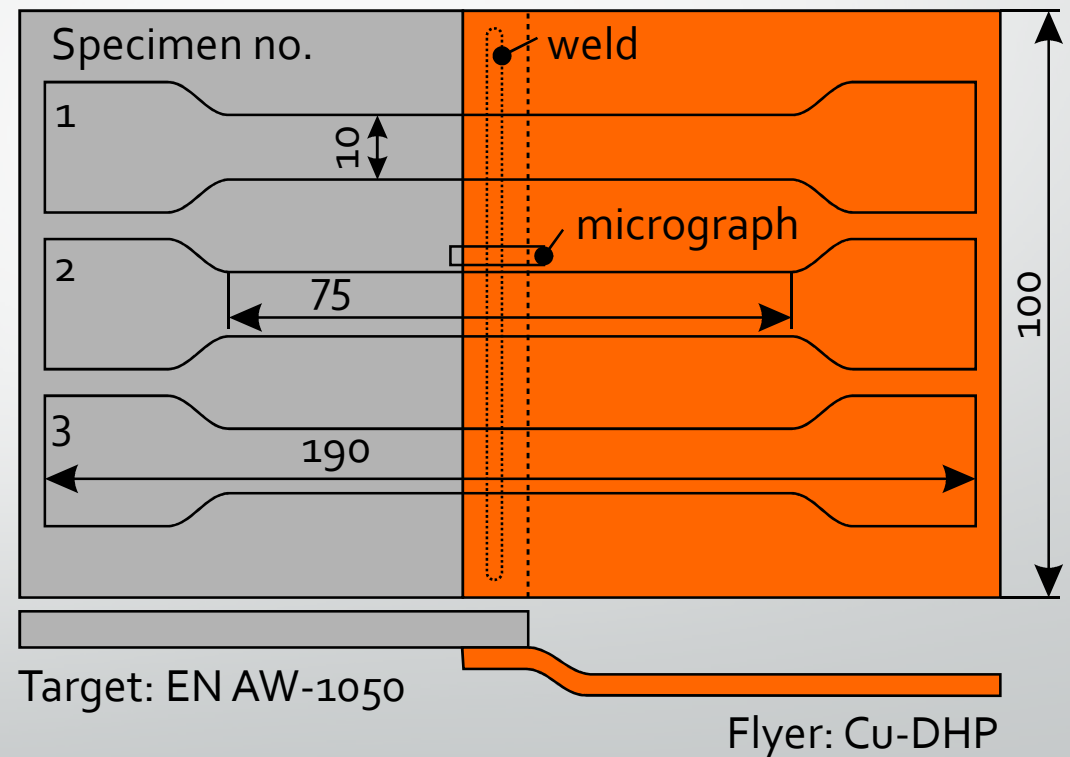


Capacitor charging energy
— 10 kJ — 15 kJ — 20 kJ
— 30 kJ — 40 kJ

Characterization of the joint

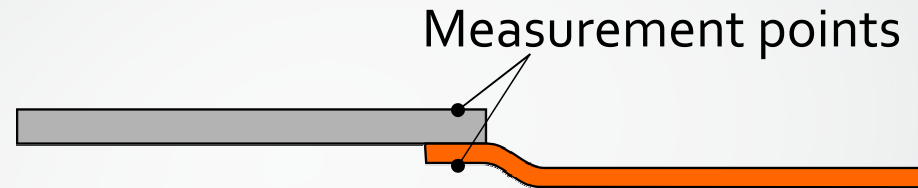
- Electrical resistance measurement
- Lap shear test
- Metallographic analysis

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.

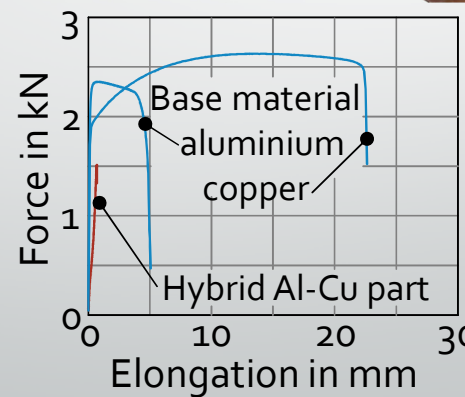
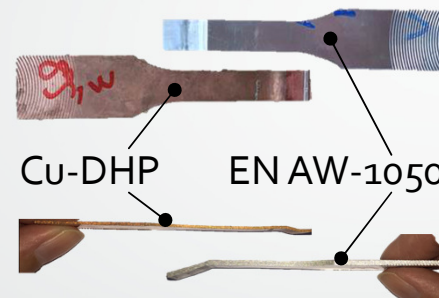
➔ Calculated resistance corresponds to resistance of the joint.

Characterization of the joint

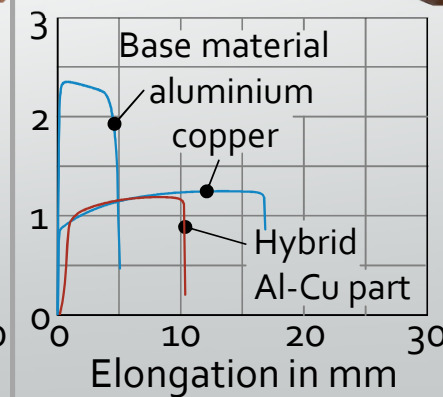
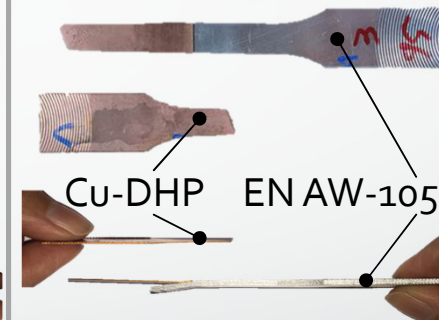
- Electrical resistance measurement
- Lap shear test
- Metallographic analysis

Failure cases

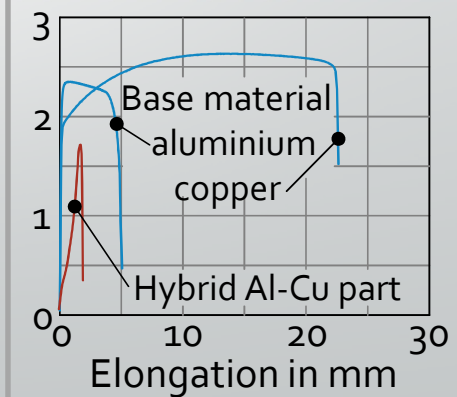
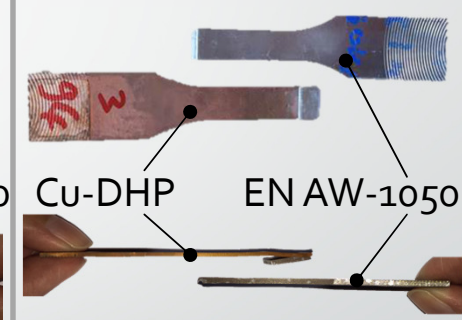
Failure in the joint
(occurs for all flyer thicknesses)



Failure in the copper
base material
(occurs for flyer thick-
nesses of 0.5 mm only)



Failure in the alumi-
nium base material
(occurs for flyer thick-
nesses ≥ 1 mm)



All cases: Welding of copper flyers to aluminium targets

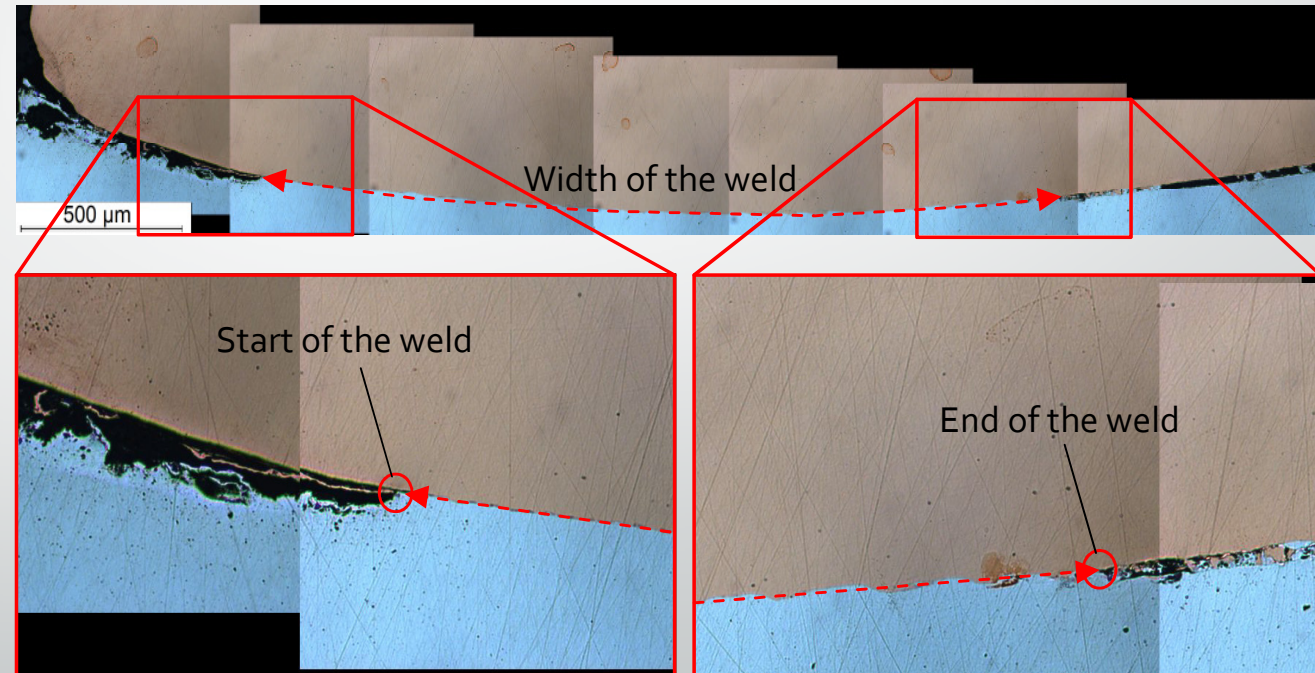
Characterization of the joint

Cu-DHP



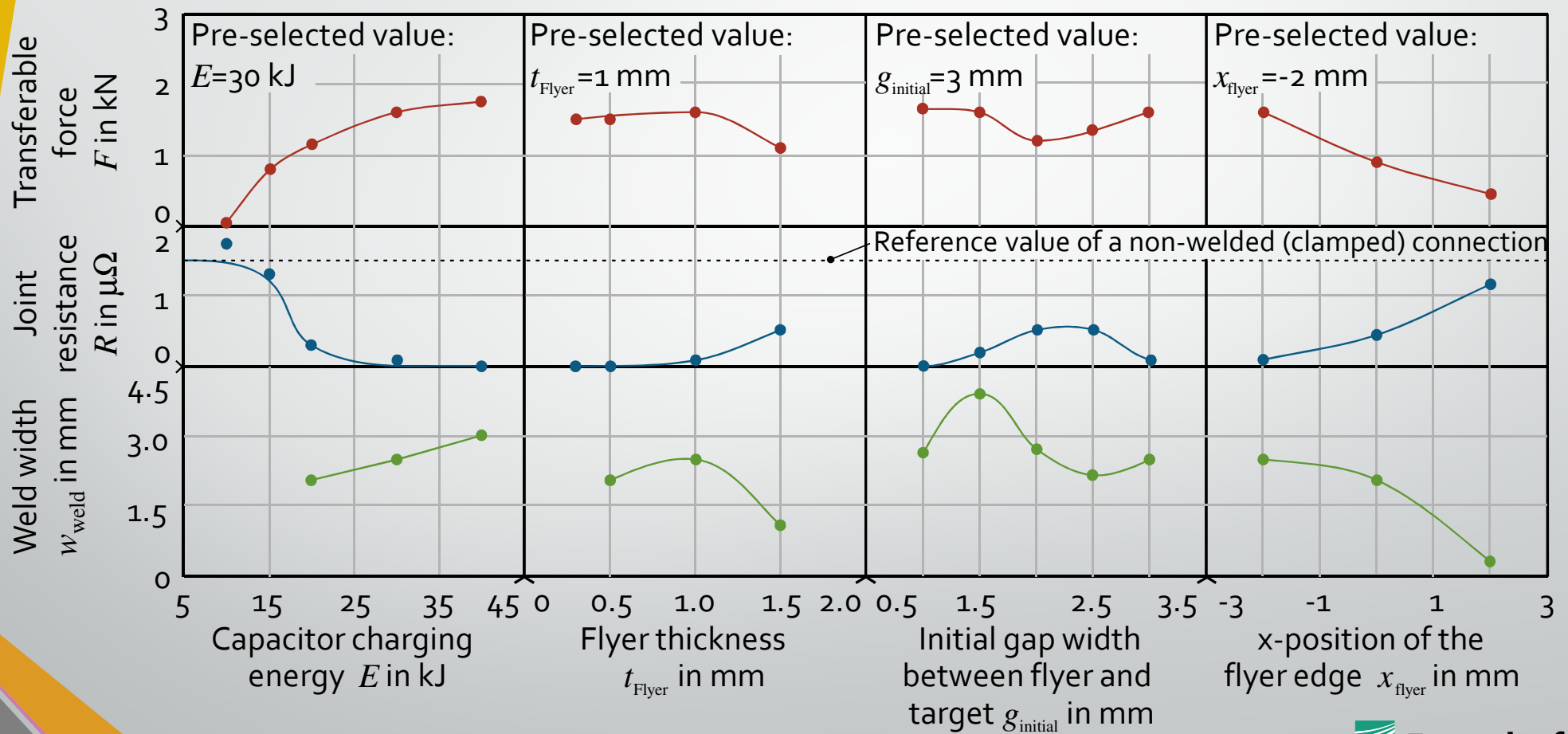
EN AW-1050

- Electrical resistance measurement
- Lap shear test
- Metallographic analysis

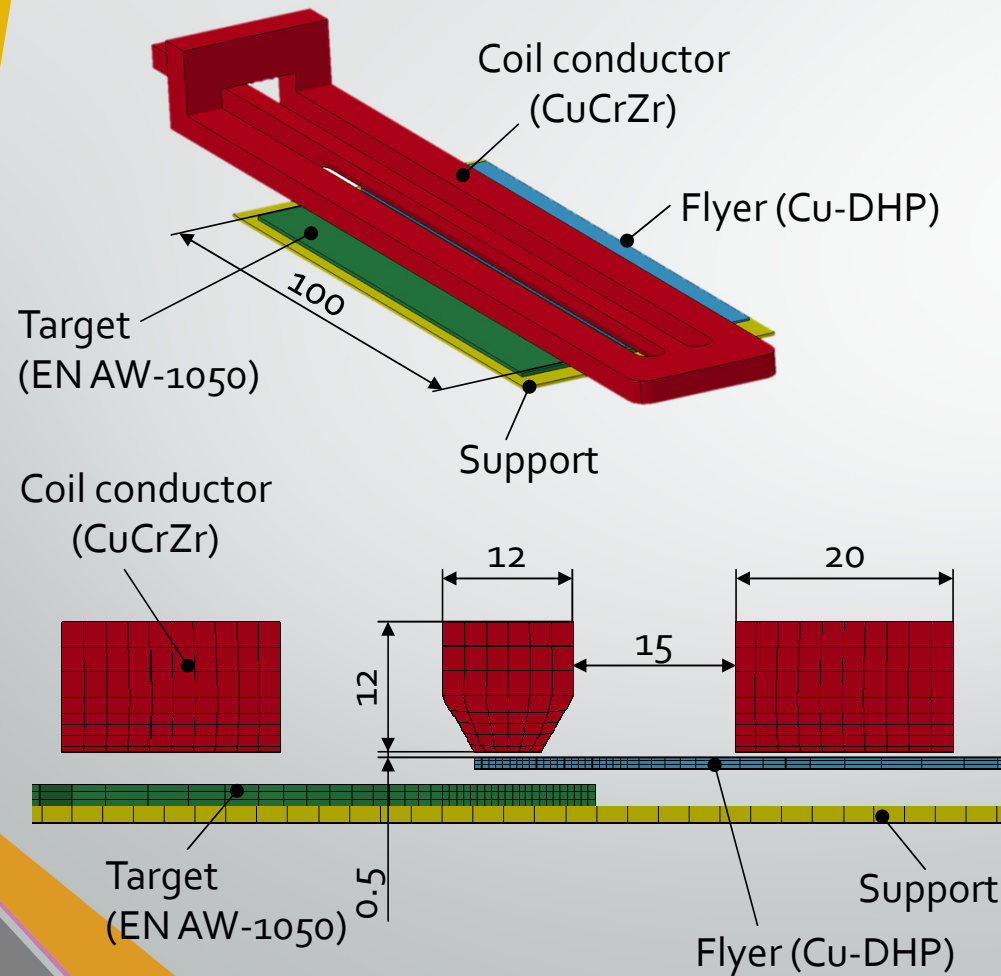


Correlation of adjustable process parameters and weld quality

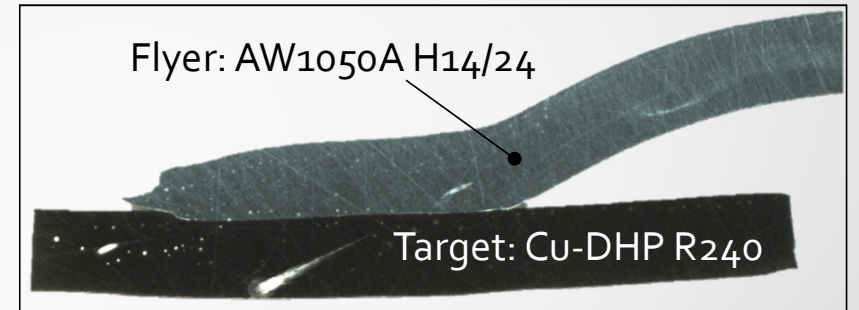
Maximum transferable force in a lap shear test is considered for mechanical joint characterisation



Numerical modelling

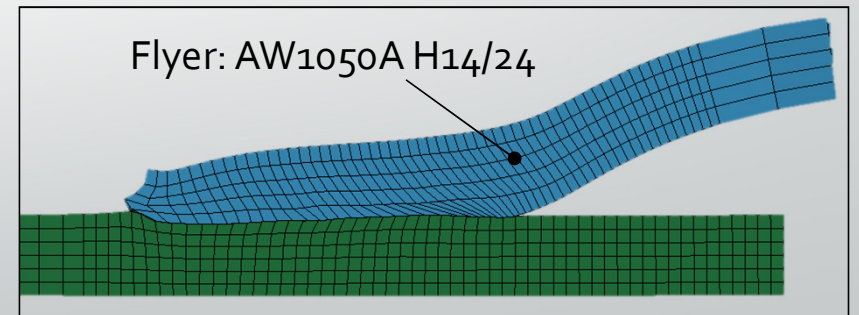


Experiment



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

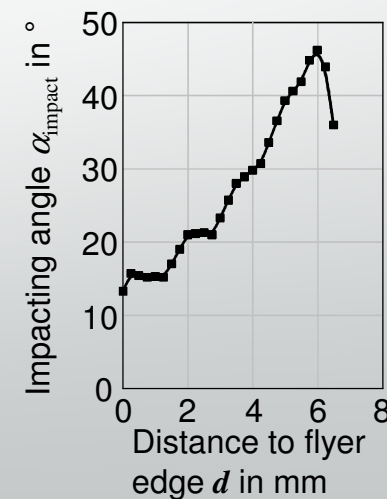
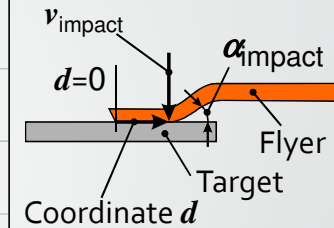
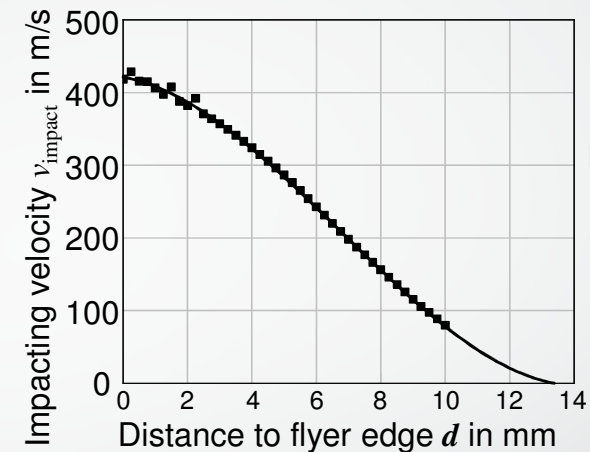
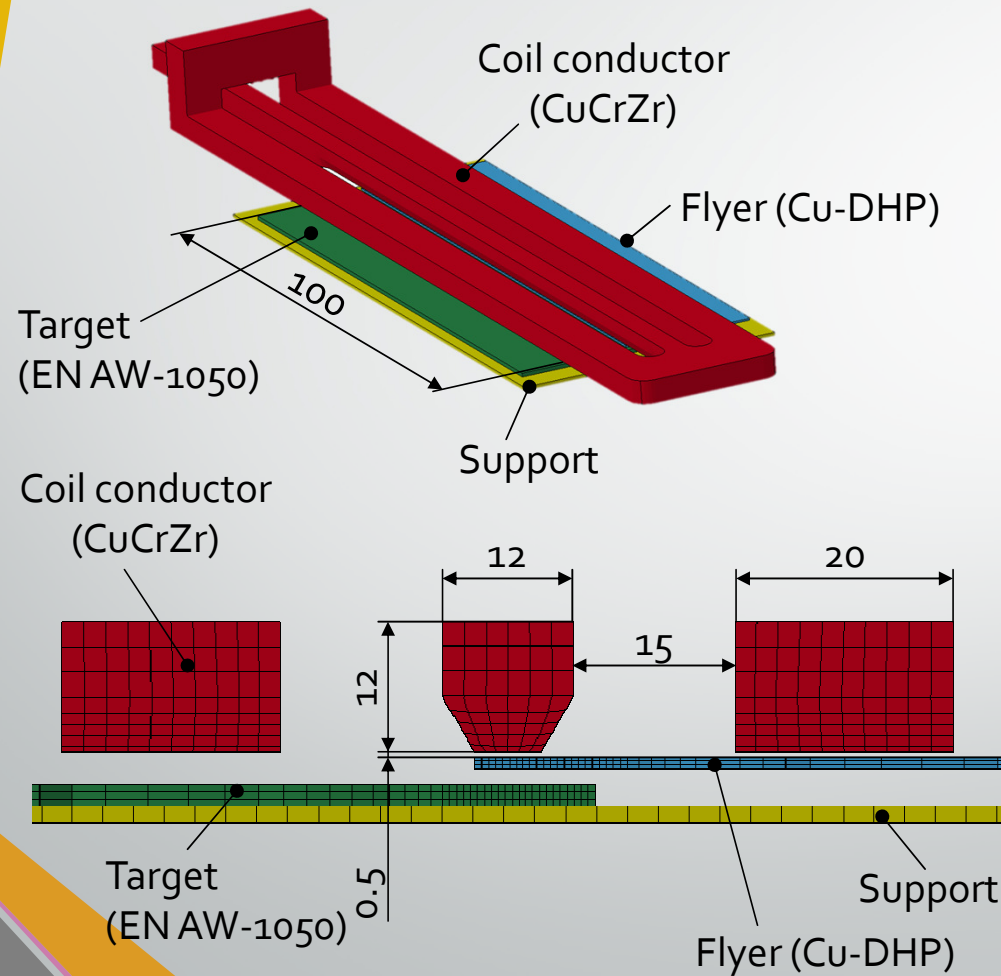
Corresponding macroscopic simulations



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

Numerical calculation of collision parameters **JOIN'EM**

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Process parameters

- Capacitor charging energy: 30 kJ
- Initial gap flyer / target: 3mm

Flyer

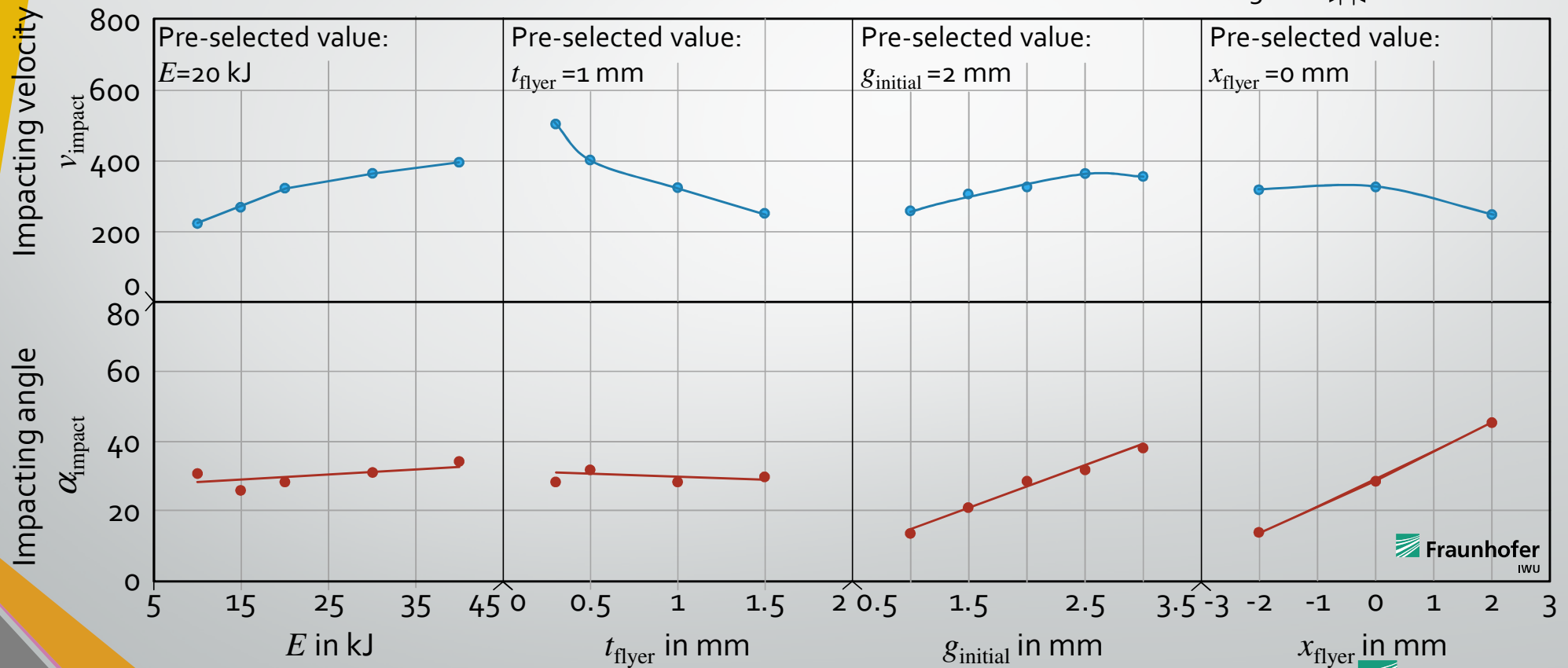
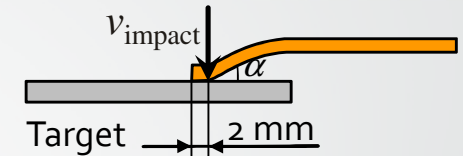
- Material: Cu-DHP
- Thickness: 1 mm
- Edge position: -2 mm

Target

- Material: EN AW-1050
- Thickness: 2 mm
- Edge position: 14 mm

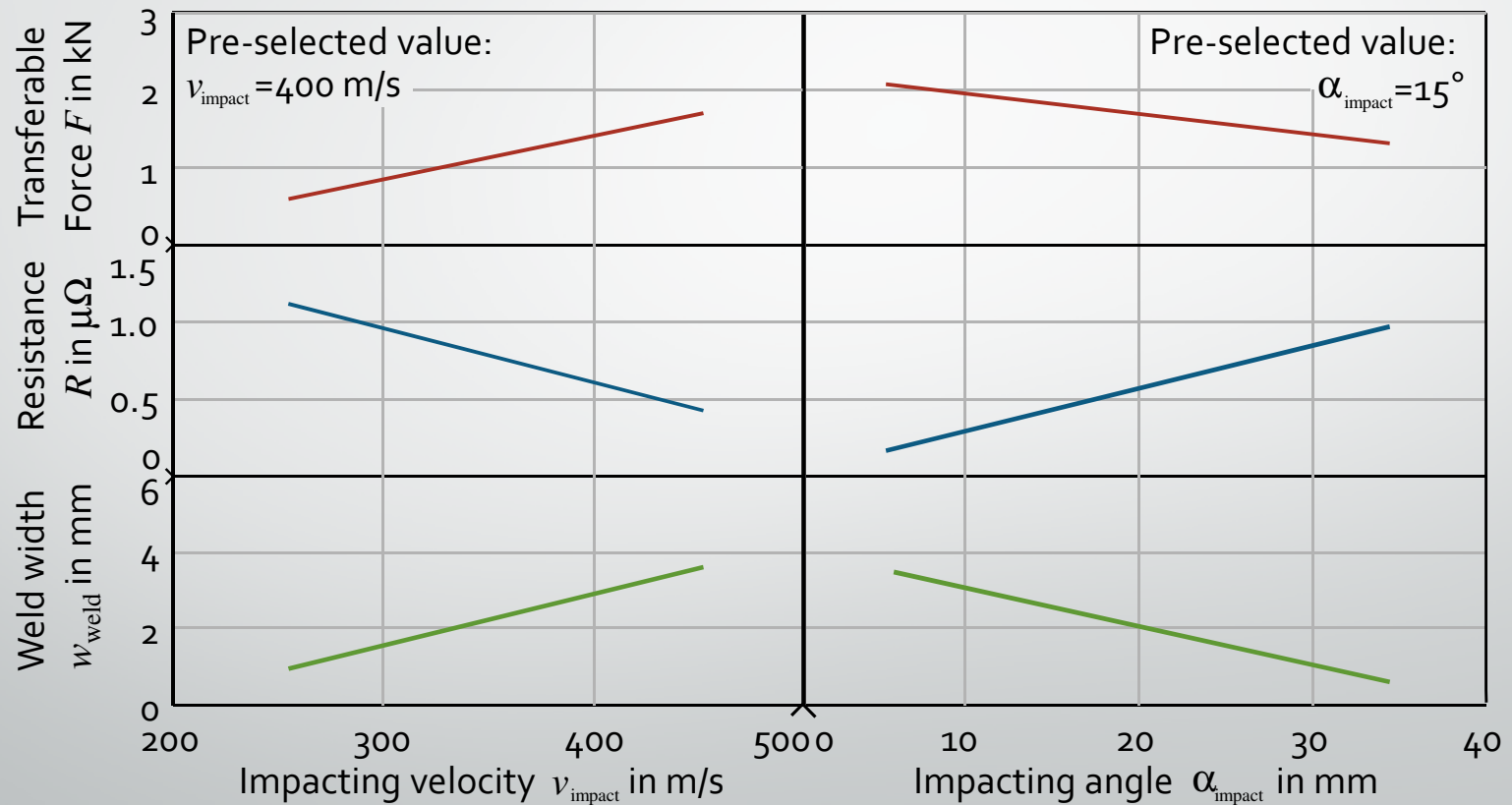
Correlation of adjustable process parameters and collision parameters

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.



Correlation of collision parameters and joint quality

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



Summary

- 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.

Acknowledgement

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