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Assessment of Gap and Charging Voltage Influence on Mechanical Behaviour of Joints Obtained by Magnetic Pulse Welding

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MOTIVATION

Current challenge :

Development of multi-material assembly for lightweight structures → MPW : joining solution

Optimization of the MPW → improvement of durability and reliability of dissimilar-material assemblies

Project MSIM :

Driving the MPW toward its optimal ability for an efficient welding of dissimilar-material assemblies

- Analysis of the interaction process parameters/joint quality
- Analysis of the effect of metal dissymetry on the joint quality
- Modeling and computational simulation of the MPW
- Feasibility study and development of tooling

present results : weld quality depending on the process parameters

Experimental approach :

- characterization and classification of the different joints encountered
- relation between weld quality and process parameters
- weldability study of Al/Al and Al/Cu assemblies

Welding conditions

Welding set-up

MPW 25-9 (25kJ,9kV) PULSAR

Pulse generator device :

- contains a bank capacitors of 690µF
- provides charging voltage up to 8.5kV
- provides discharge frequency of ~10kHz

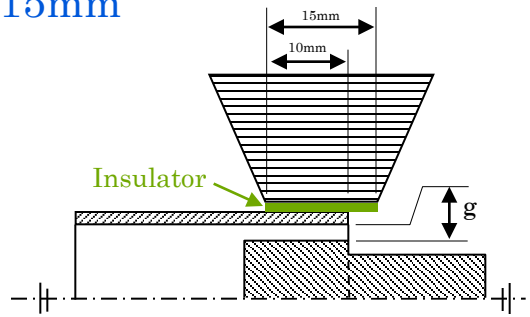
Working device :

- 3 turns coil + field shaper
- work zone : Ø=27mm and l=15mm

Welding of tubular assembly

- Al6060T6/Al6060T6
- Al6060T6/Cu

Parameters investigated :
U(kV) and g(mm)

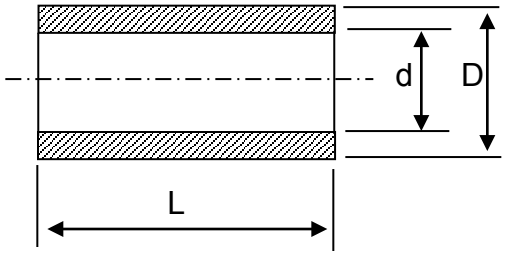


Usual material properties

	$\sigma_{él}(\Omega m)^{-1}$	Tf(°C)	$\rho(kg/m^3)$	E(GPa)	G(GPa)	Rm(MPa)	$Rp_{0.2}$(MPa)	Ar(%)	Hv
Al6060T6	$2.5\ 10^7$	650	$2.7\ 10^3$	70	26.6	290	240	10	80
Cu	$5.8\ 10^7$	1065	$8.9\ 10^3$	124	46.6	250	200	14	80

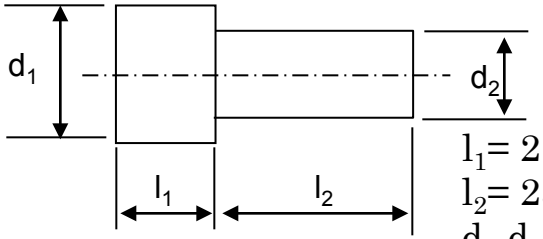
Specimen geometry and dimensions

Flyer :



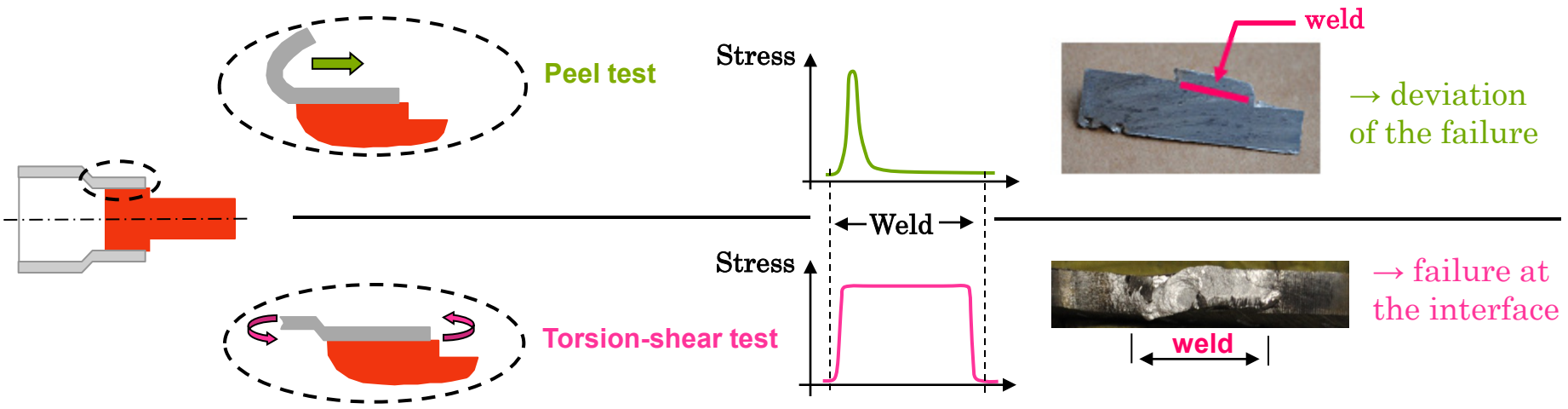
D=25mm
d=22mm
L= 50mm

Inner part :



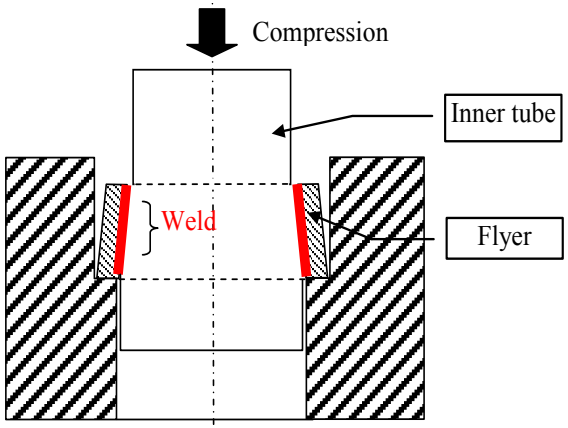
l_1= 21mm
l_2= 23mm
d_1,d_2 : variable

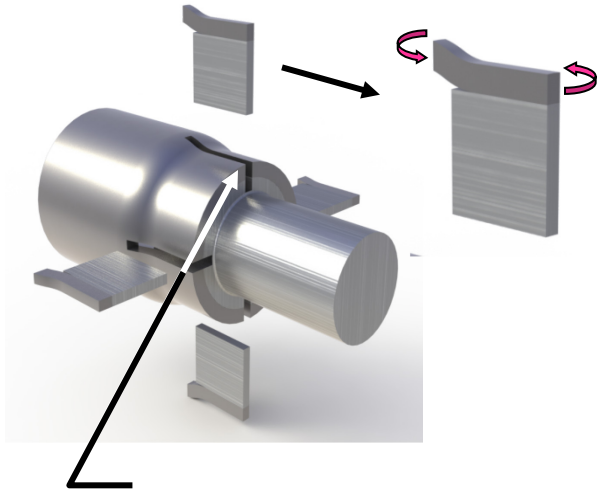
Characterization of the joint



→ dimensional characterization

Push-out test





Microstructure examination

→ mechanical characterization

→ structural characterization

Joint characteristics

Dimensional characterization

Unwelded interface

Beginning of bonding
(trace of residue)

Beginning of good welding
(thin weld)

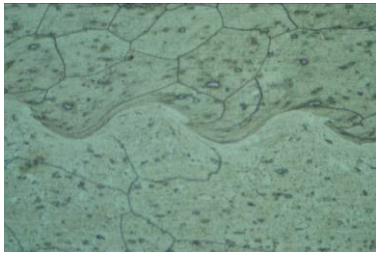
Large weld

Striation : circular path due to interfacial deformation → ductile and potentially permanent weld

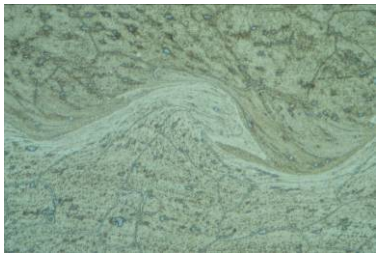
Structural characterization

Beginning of bonding

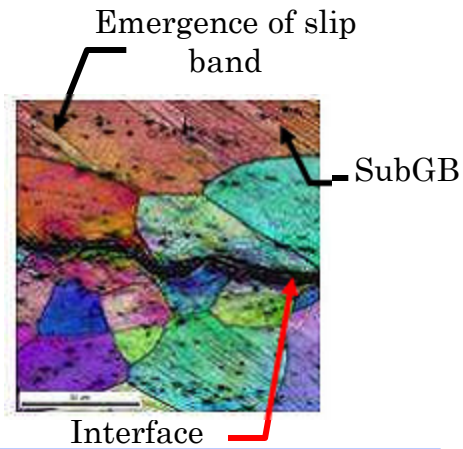
Beginning of good welding



Potentially permanent weld

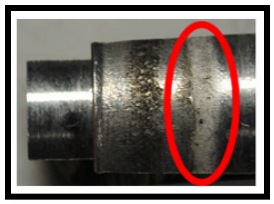


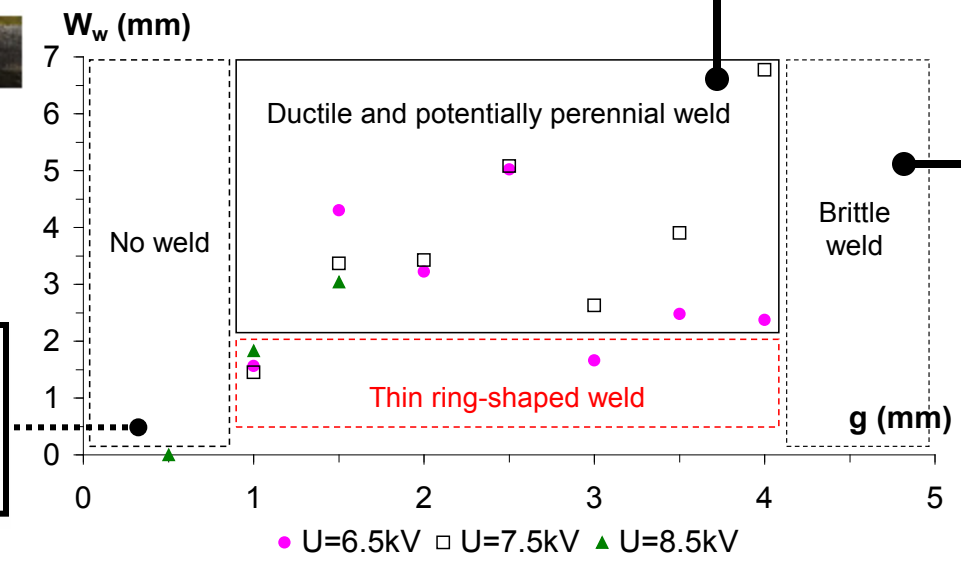
EBSD analysis

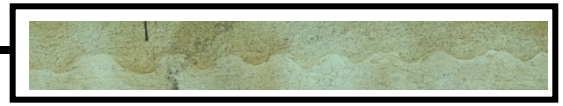


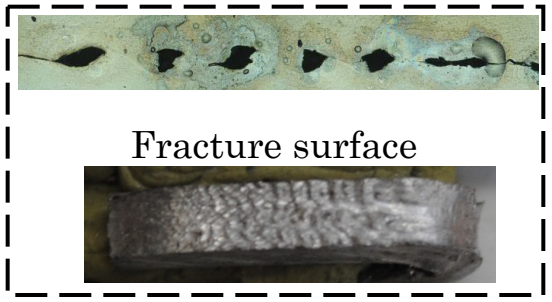
Welding characterization

Weld classification

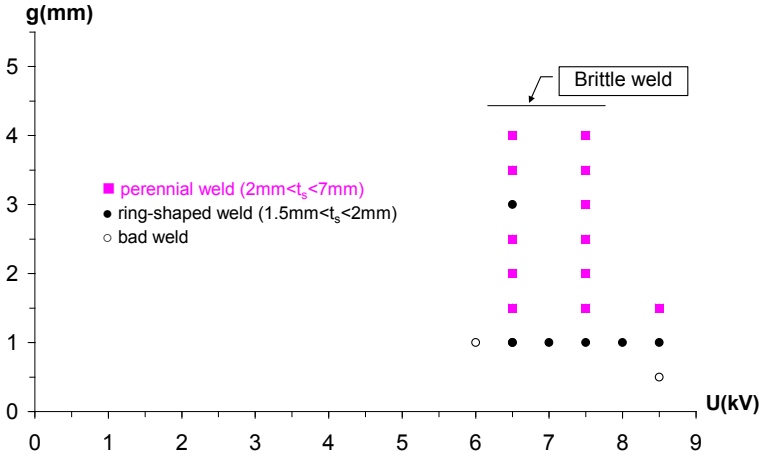




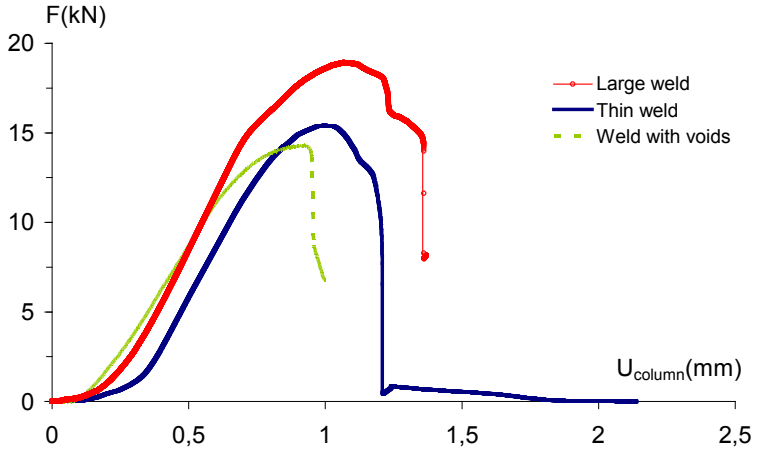




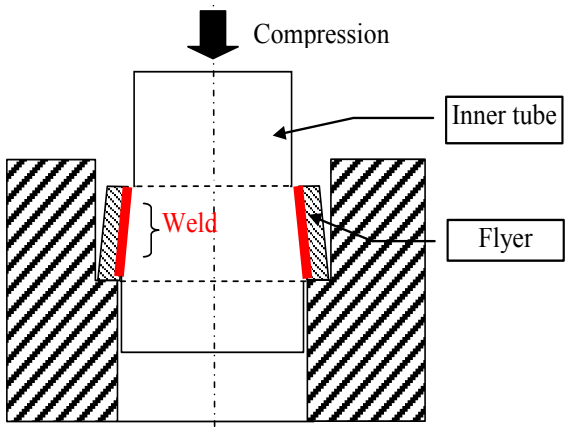
Welding range



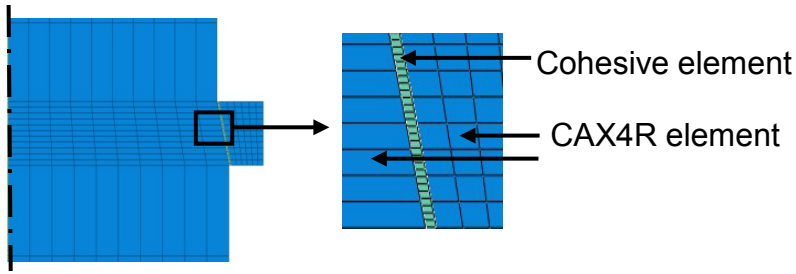
Mechanical behaviour



Welding characterization



FEM modeling of the push-out test



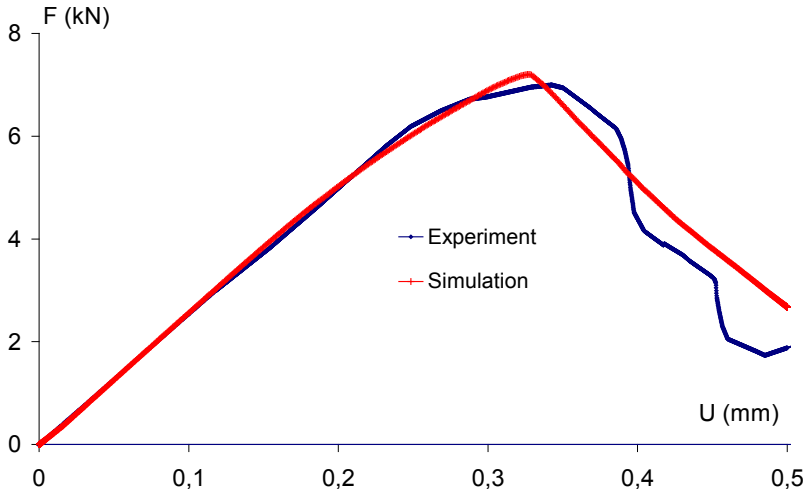
Constitutive modeling :

Flyer and the inner part behaviour :
J2 elastic-plastic model with isotropic work hardening

Interface behaviour :
linear traction separation model associated with
a progressive damage mode

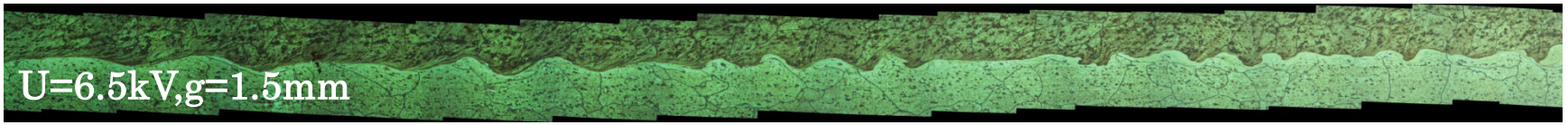
damage initiation :
criterion on nominal stress

damage evolution :
criterion on energy dissipated due to failure



Effect of metal dissymetry

Al/Al

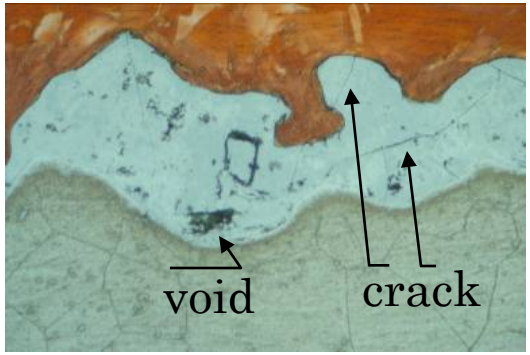


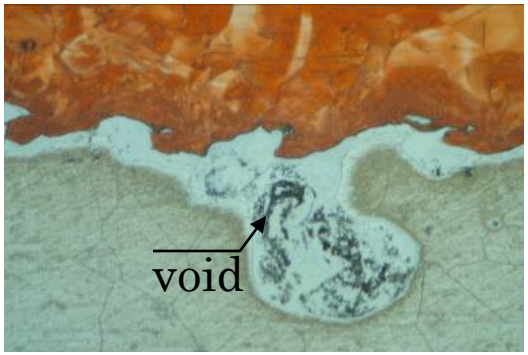
(etching: Weak's reagent during ~12s)

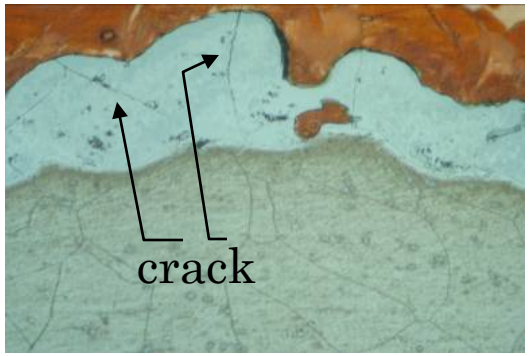
Al/Cu

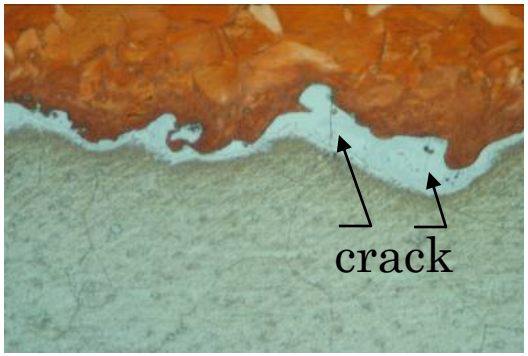
(etching : Klem's II reagent during ~3mn followed by Weak's reagent during ~12s)

→Intermetallic formation : hyperquenching (10^4 to 10^6K/s) of Al-Cu molten pockets







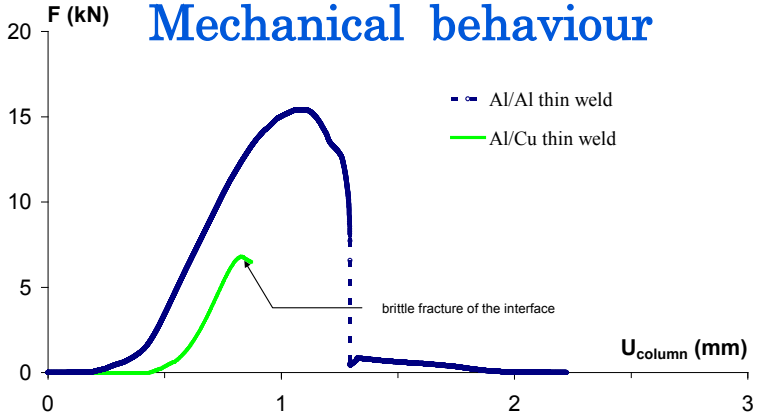


Intermetallic phase :

- amorphous phase
- with cracks and voids

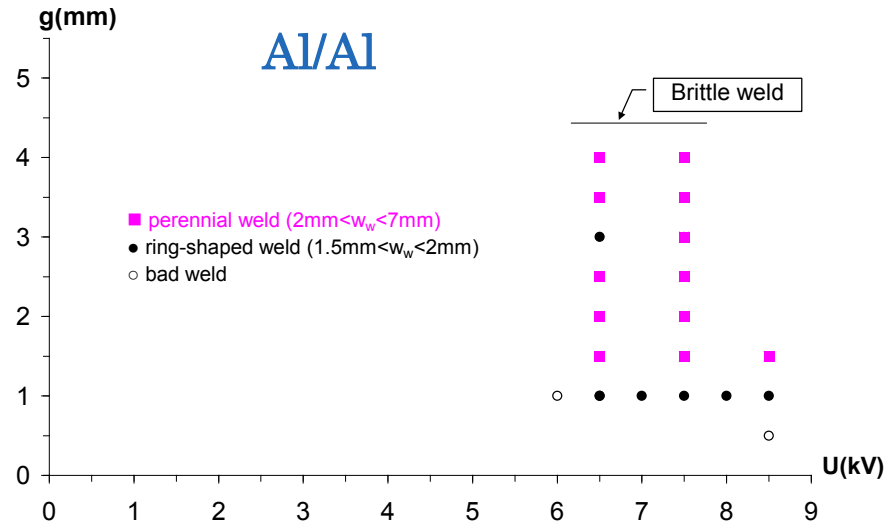
→ makes the joint brittle

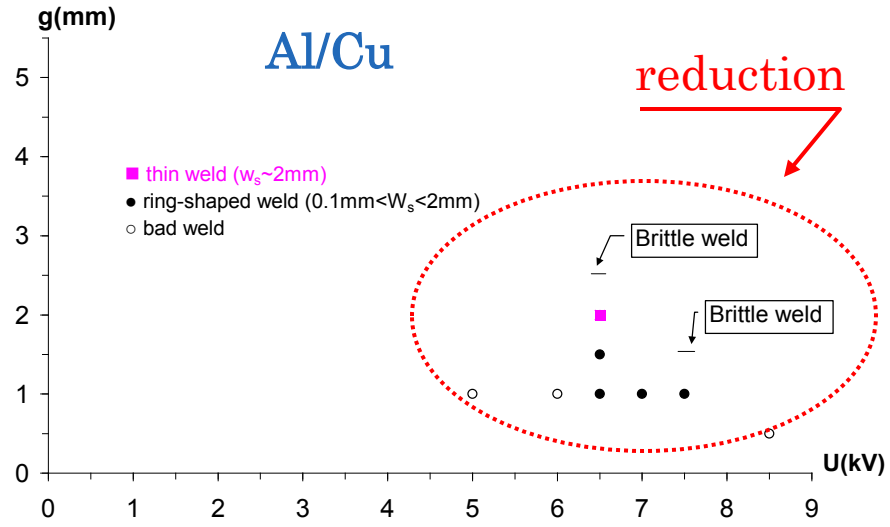
Mechanical behaviour



Effect of metal dissymetry

Welding range





Comparison of achieved good weld

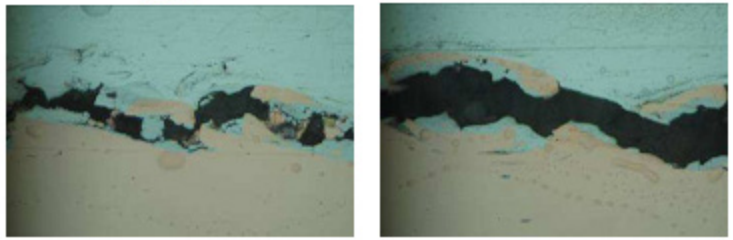
Al/Al

Large residue

Al/Cu

Short length residue

Illustration of Al/Cu weld above the upper limit (brittle weld)



(case with U=7.5kV, g=4mm)

Conclusions

- weldability study of aluminium AA6060T6 tubular assembly :

→ three weld cases :

  - a weld with a thin size (ring shape weld)
    → beginning of good welding (interface with wave formation)
  - a weld with a relatively large size
    → ductile and therefore potentially permanent
  - a defective weld (large size but with voids)
    → rather brittle

→ the gap increase improves the weld size – there is an optimum gap

- weldability study of AA6060T6/Cu tubular assembly :

→ combination of Al6060T6/Cu : detrimental to the interface integrity

  - effect of intermetallic phase formation
    → phase with cracks and voids
    → brittle and low resistant weld
  - possibility of achieving good weld

→ combination of Al6060T6/Cu : reduction of the weldability range

Assessment of Gap and Charging Voltage Influence on Mechanical Behaviour of Joints Obtained by Magnetic Pulse Welding

THANK YOU FOR YOUR ATTENTION

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