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THE OHIO STATE UNIVERSITY

IUL Institute of Forming Technology and Lightweight Construction

Welding and Forming of Sheet Metals by Using Magnetic Pulse Welding (MPW) Technique

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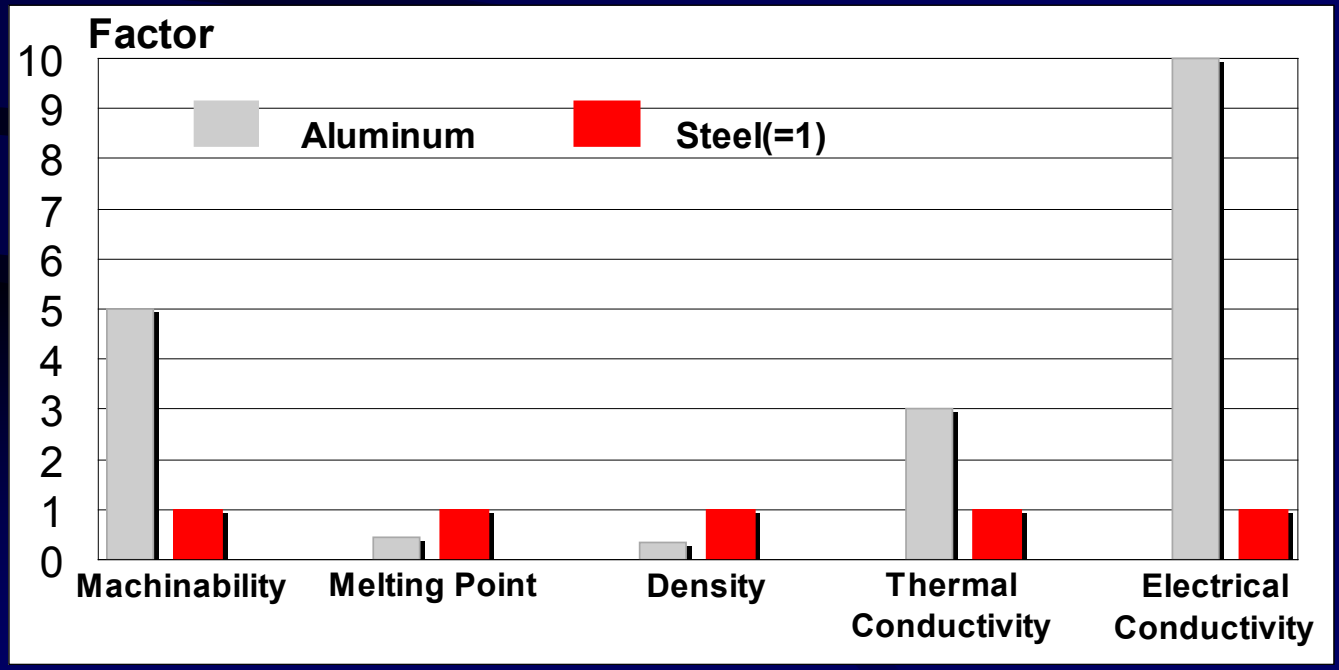
OUTLINE

1) Introduction
2) Principle of MPW
3) Experimental Setup
4) Experimental Results
5) Conclusions
6) Future Plan

INTRODUCTION

Hybrid structures of aluminium alloy and steel are suggested for reducing the weight of automobiles to improve fuel efficiency and control air pollution. Therefore, joining steel and aluminium alloy in different shapes is receiving attention.



Comparison of Aluminium and Steel

INTRODUCTION

History:

Magnetic Pulse Welding process was developed in the late 1960s and early 1970s for nuclear energy applications. Russian scientists at the Kurchatov Institute of Nuclear Physics invented a technique for pulsed magnetic welding of end closures of nuclear fuel rods.

INTRODUCTION

Magnetic Pulse Welding Benefits and Advantages

- ✓ Use for several dissimilar metals joints combination
- ✓ Eliminates localized annealing
- ✓ Heat-free solid-state welding process
- ✓ Less Joint weight
- ✓ No filler material is needed
- ✓ Joint interface is stronger than the weakest material

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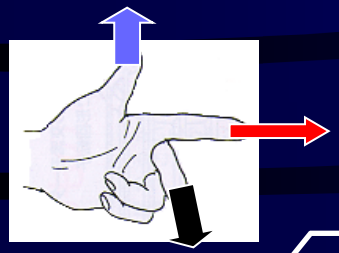
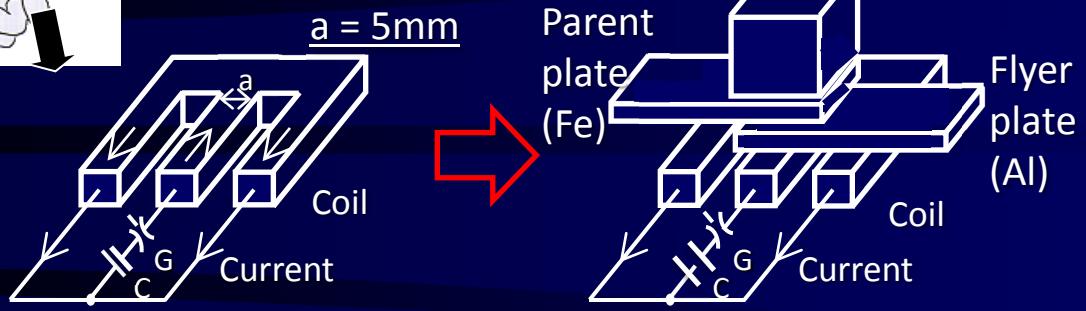
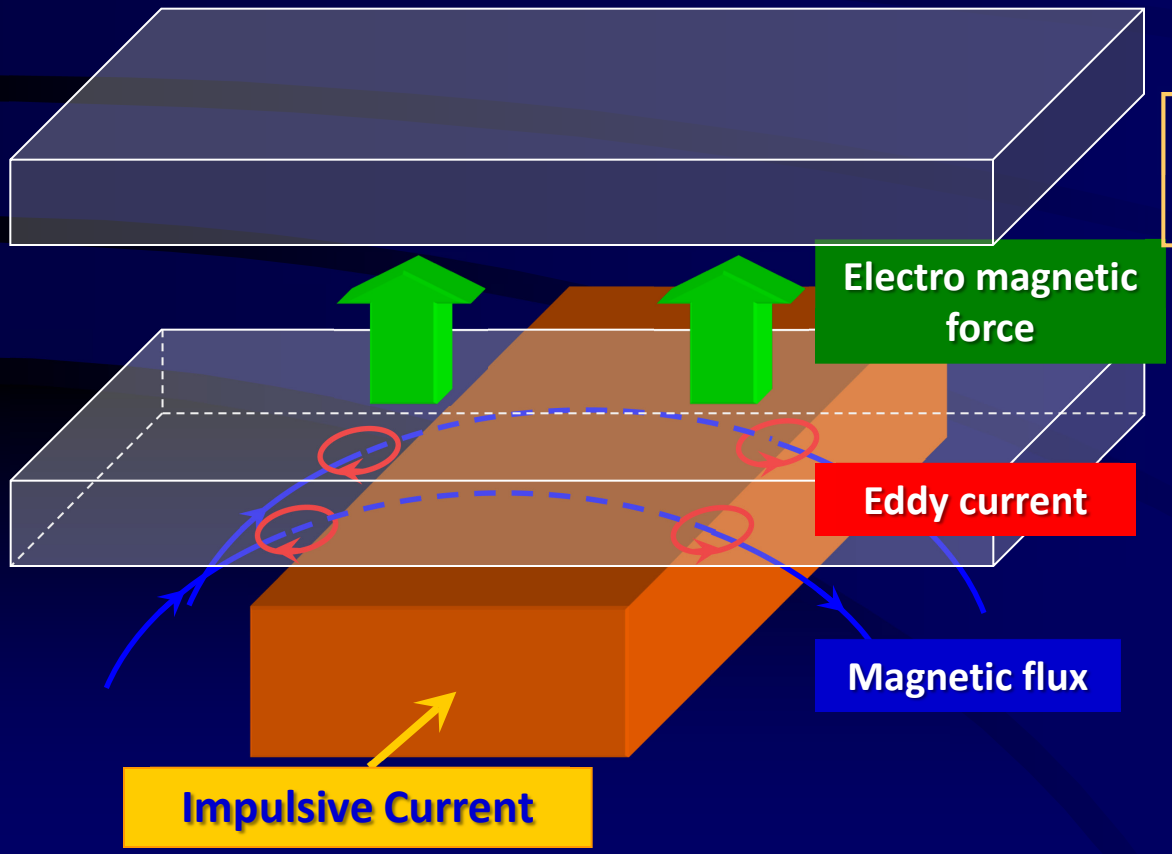
PRINCIPLES OF MPW







High electric current is applied to the coil

Magnetic flux occurs

Eddy current is generated in the Al plate.

Electromagnetic force causes the Al plate fly.

The Al plate crashes into the Fe plate, and they are jointed

PRINCIPLE OF MPW

The eddy current ***i*** and the magnetic pressure ***p*** are given as following:

i = Eddy current

B = Magnetic Field

P = Magnetic Pressure

κ= Electrical conductivity

μ= Magnetic permeability

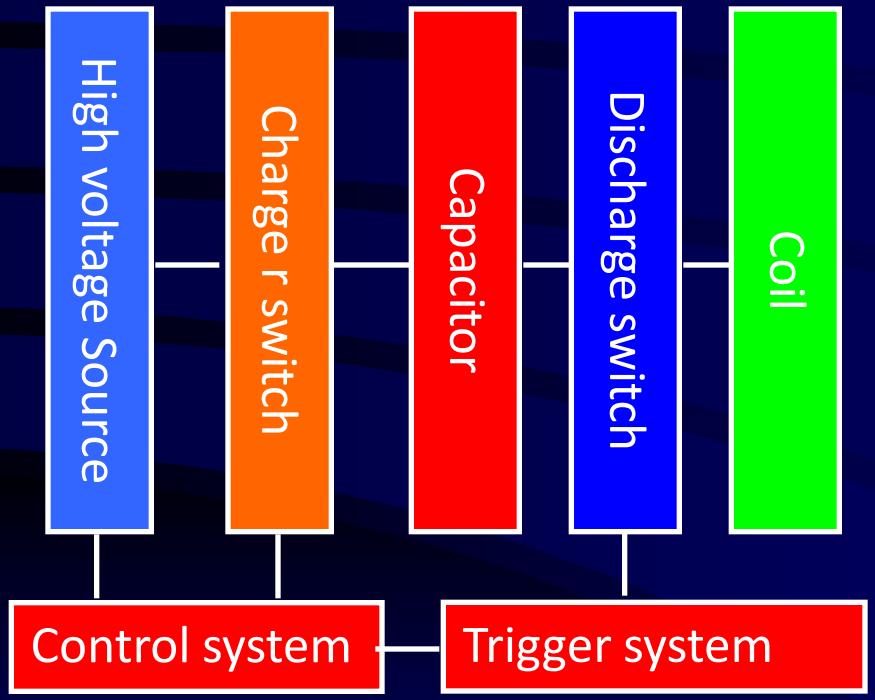
τ= Thickness

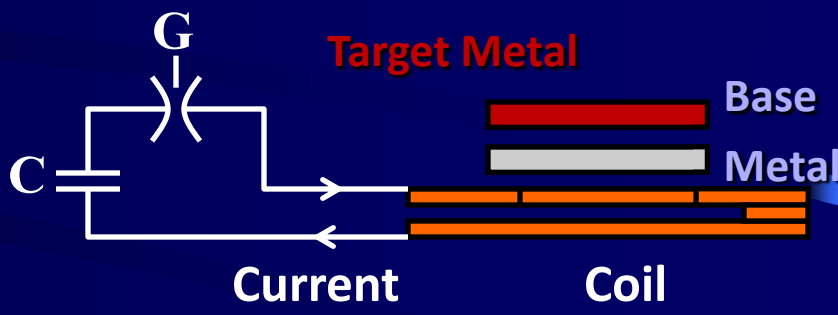
ω= Angular frequency

$$\nabla \times i = -\kappa\left(\frac{\partial B}{\partial t}\right)$$

$$\begin{cases} P(pressure) = \left(\dfrac{B^2}{2\mu}\right)\left[1 - \exp\left(\dfrac{-2\tau}{\delta}\right)\right] \\ \delta(skin-depth) = \sqrt{2/\omega\kappa\mu} \end{cases}$$

MPW Device Description





G: Gap Switch

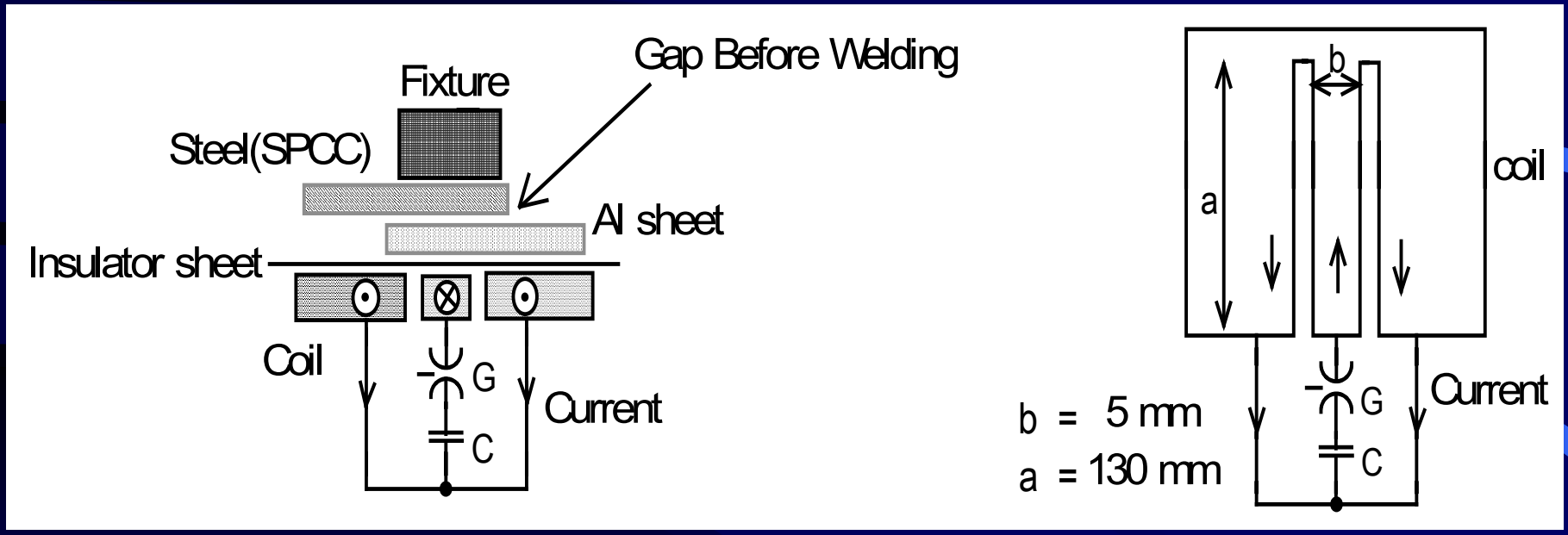
C: Capacitor Bank = 12-200µF

Charging Voltage= 2-5kV

Total Inductance = 30nH

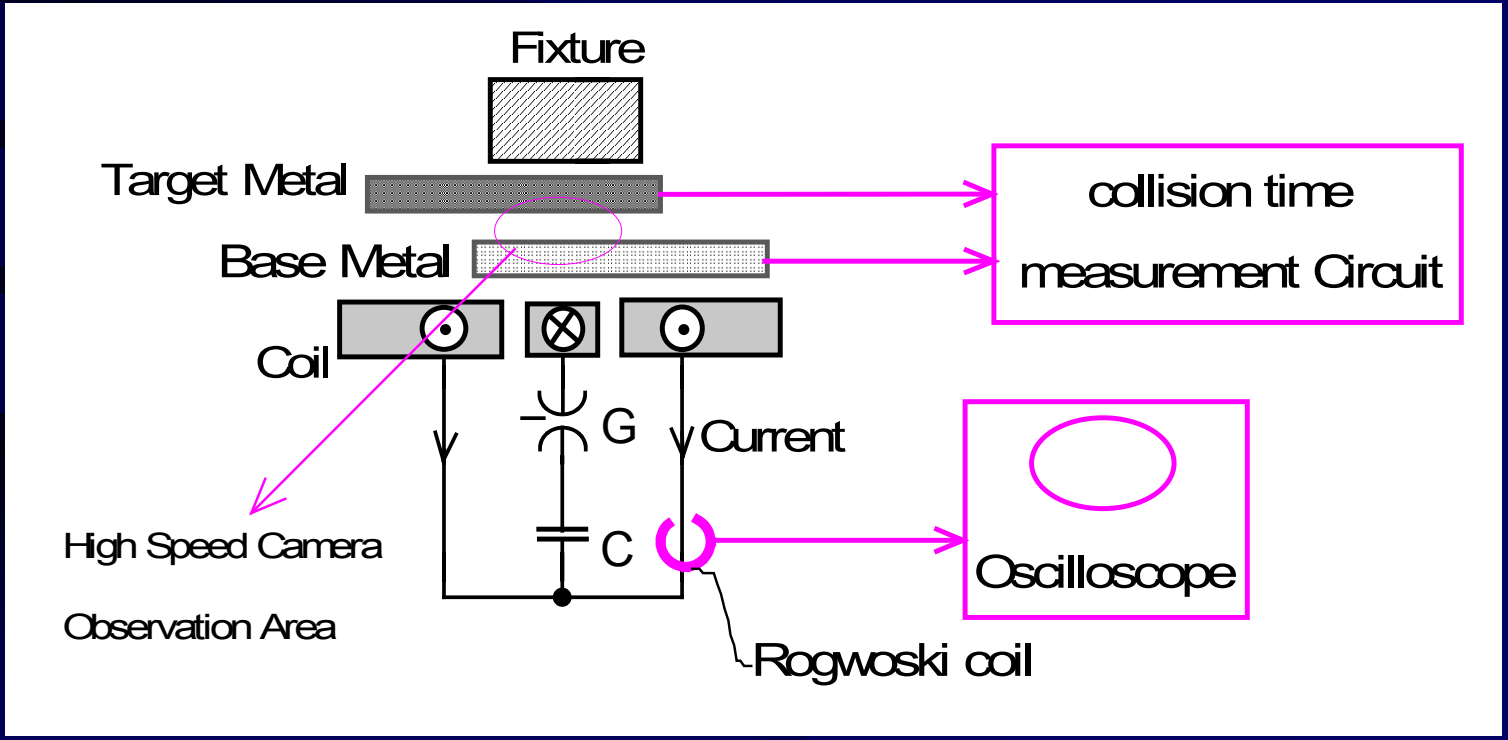
Discharge Energy= 0.8-4kJ

Experimental Setup



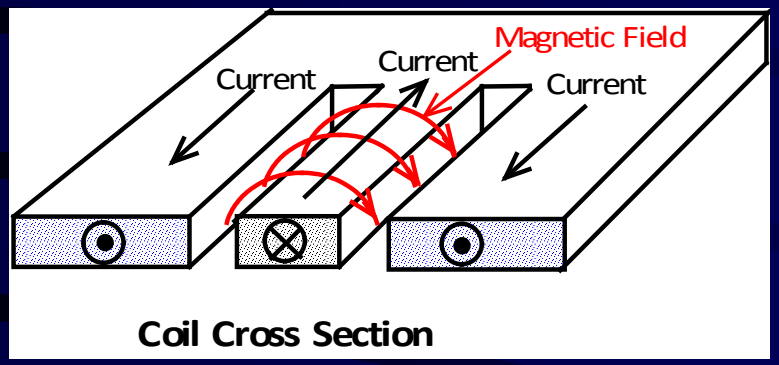
MPW Device Description

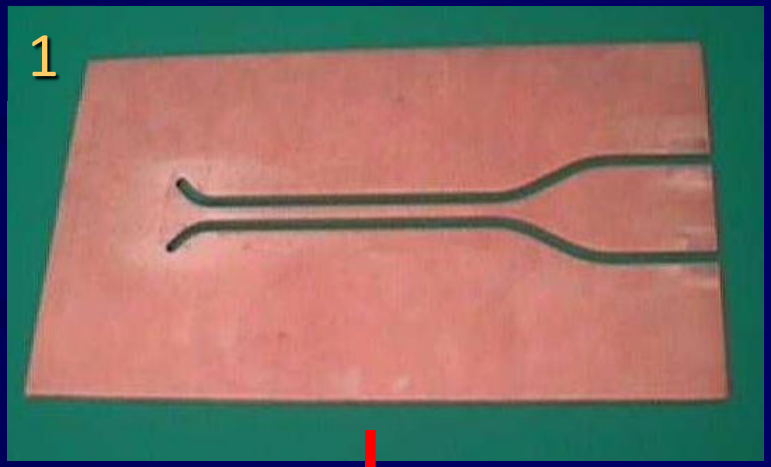
Diagnostics setup

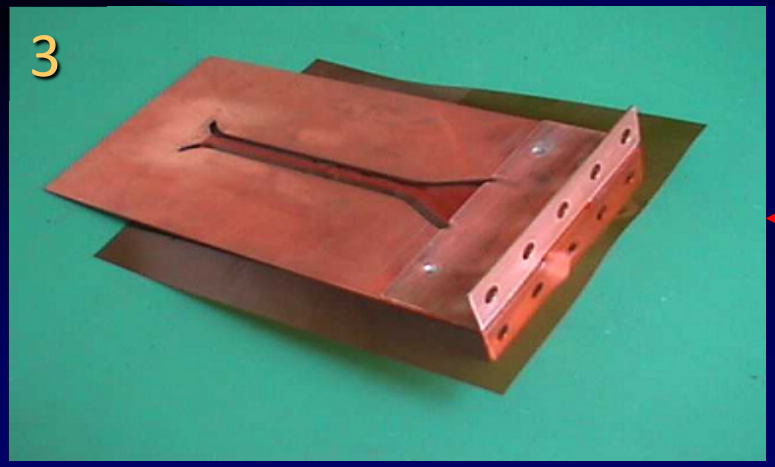


MPW Device Description

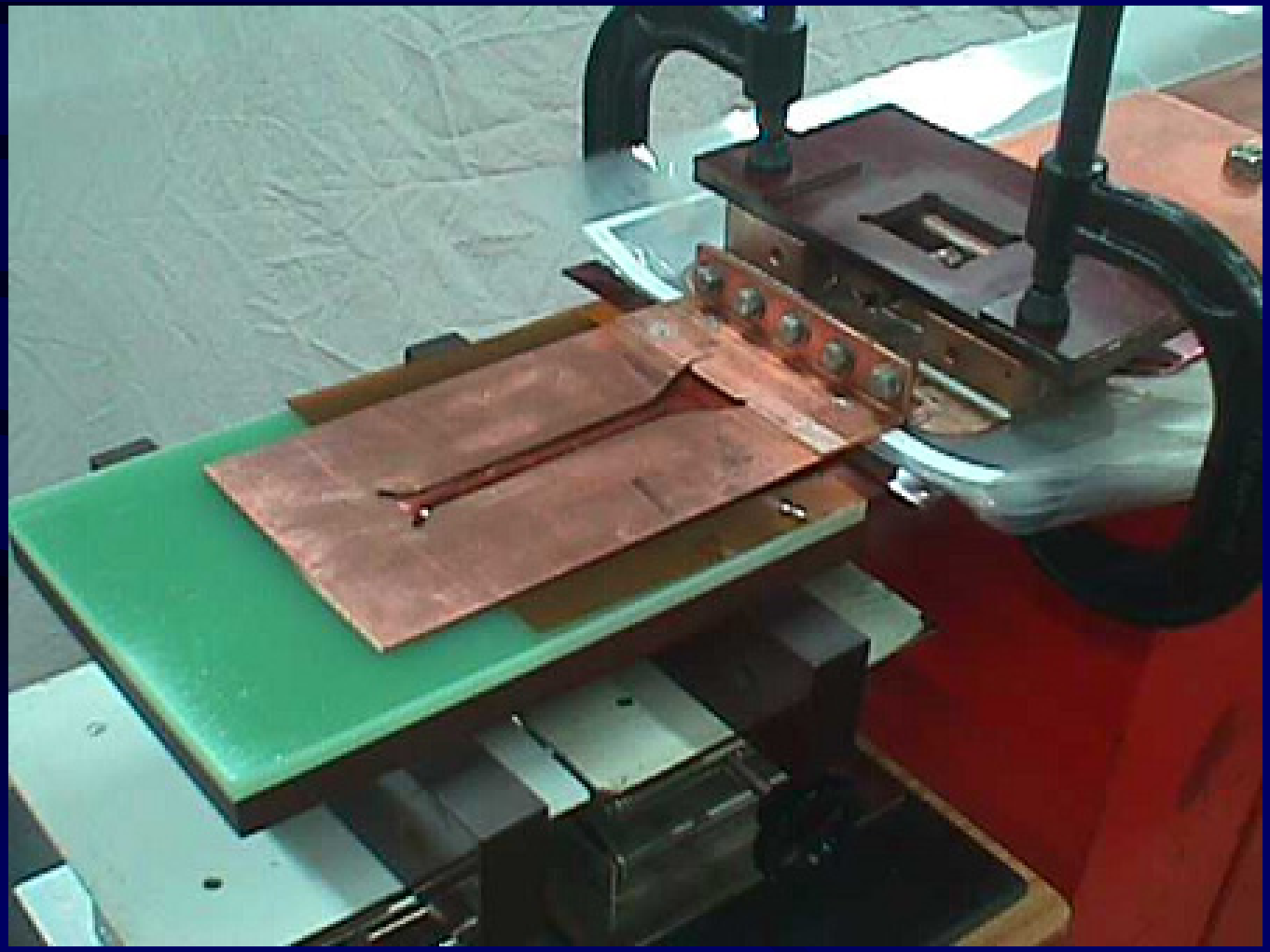
Flat Coil Perpetration







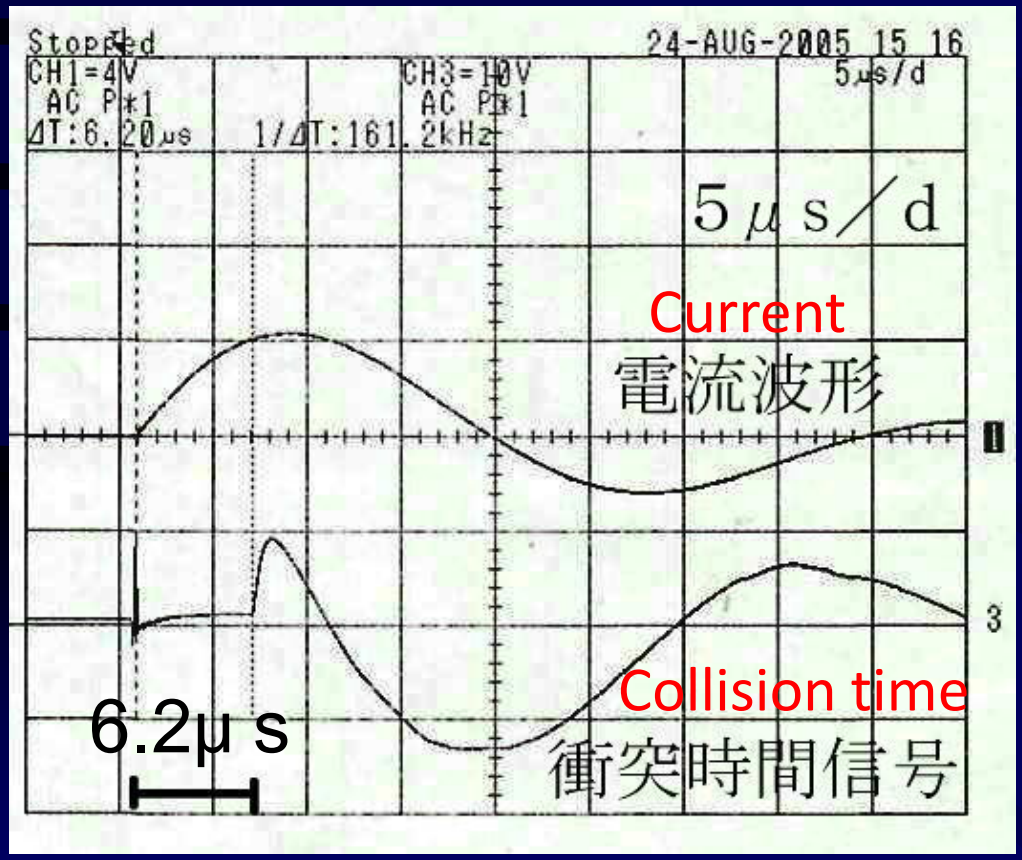
MPW Device Description



MPW Device Description

MPW Process

Typical Discharge current and collision time



Maximum Current:
160kA

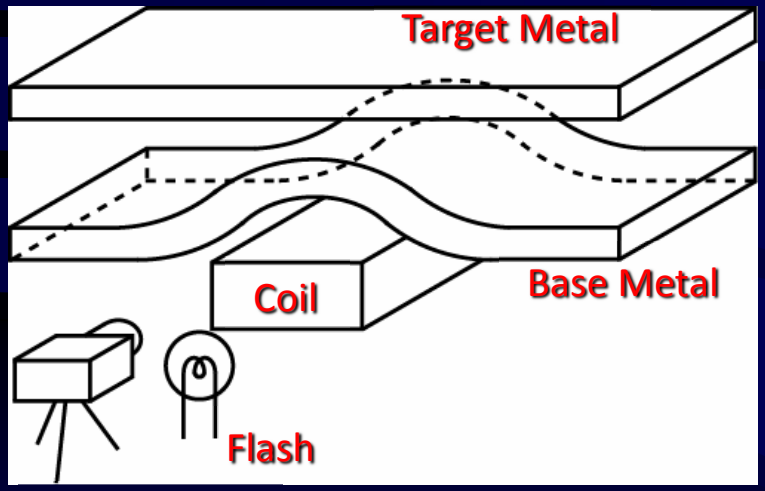
Bank Energy:
2.5kJ

Base and Target Metal Collision Time:
6.2mS

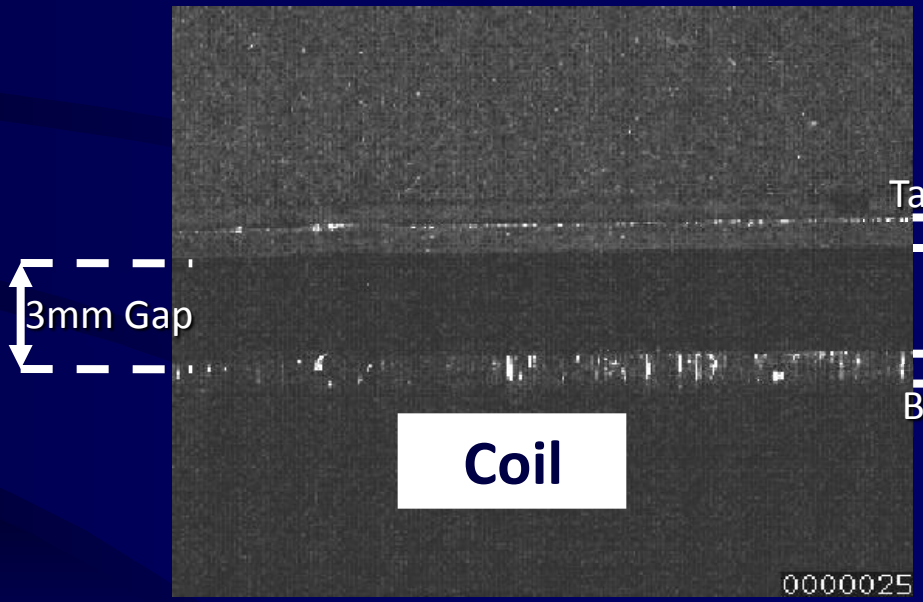
Speed of Base Metal just before collision:
480m/s

MPW Process

Observation of Base and target Metal Collisions time by a High Speed Camera



High Speed Camera



Configuration Before Welding

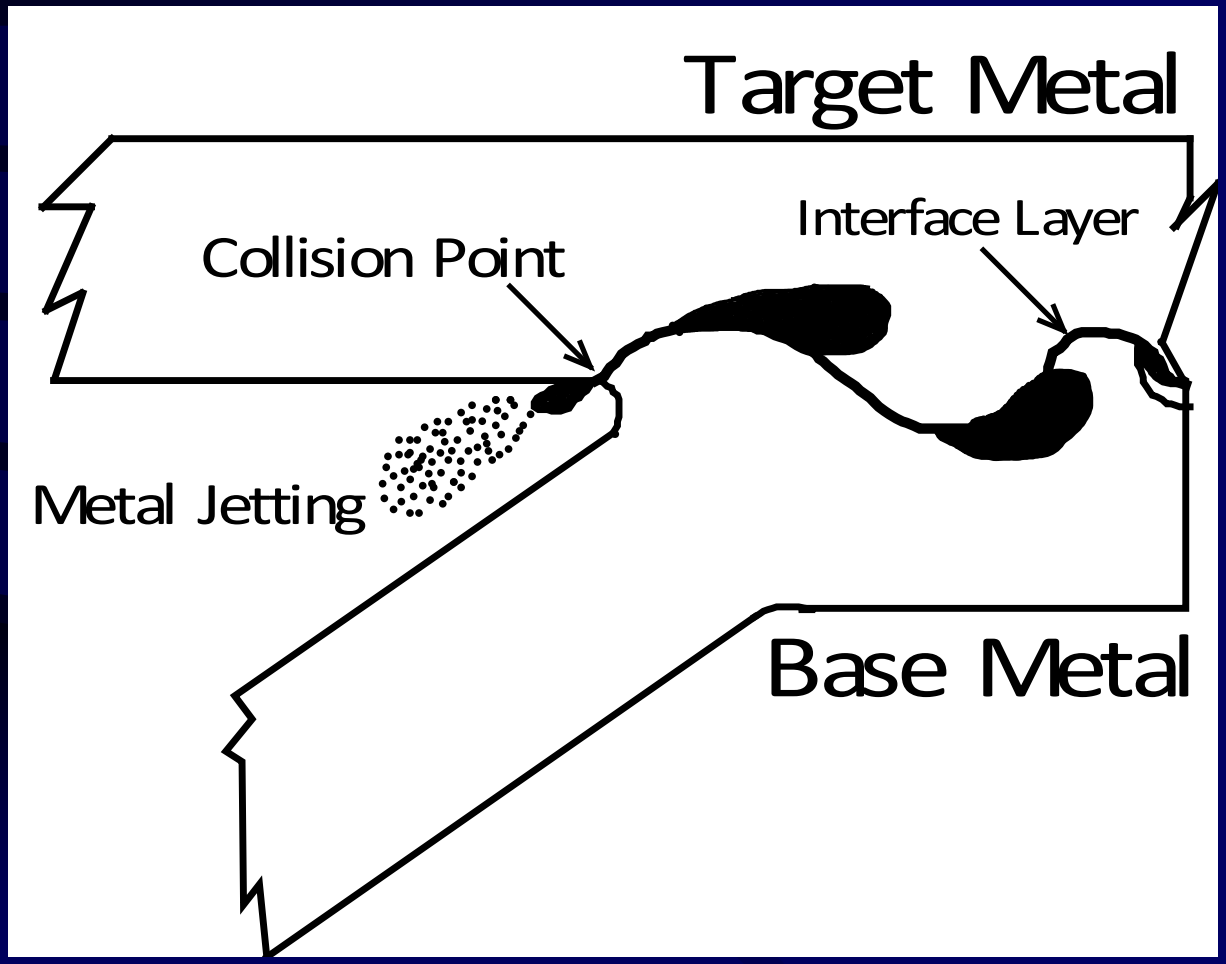
MPW Process

Observation of Base and target Metal Collisions time by a High Speed Camera

The Average Velocity of Base Metal Just before collision:

200-500m/s

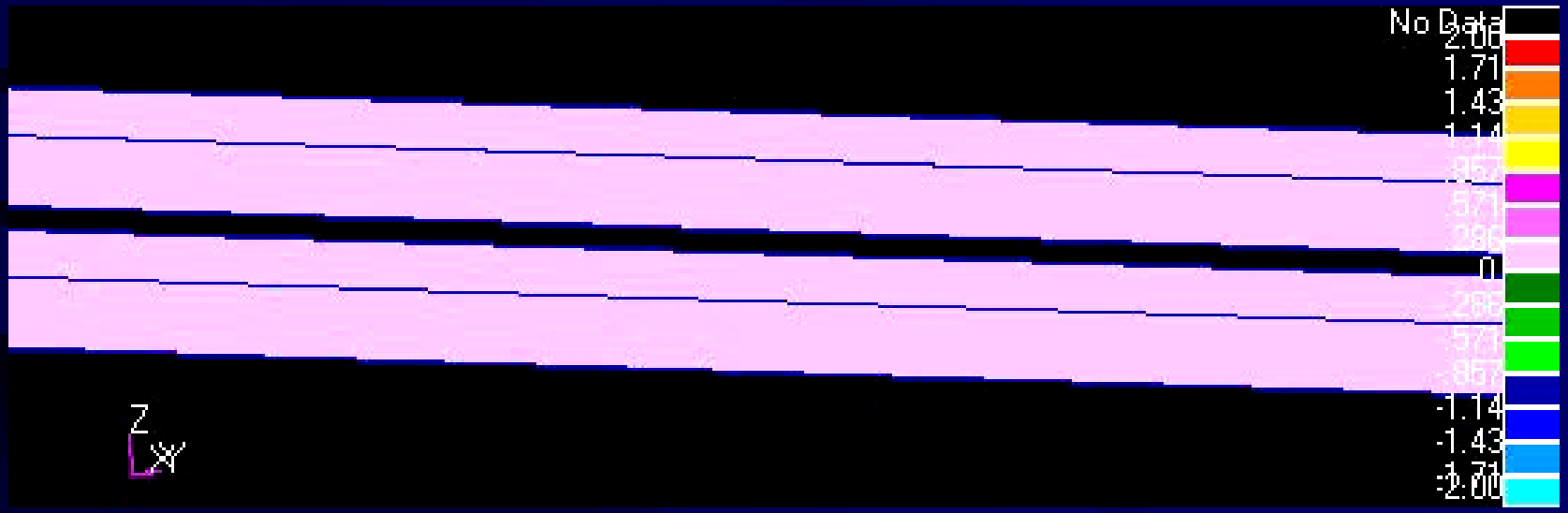
MPW Process



The Impact Region Produced By MPW

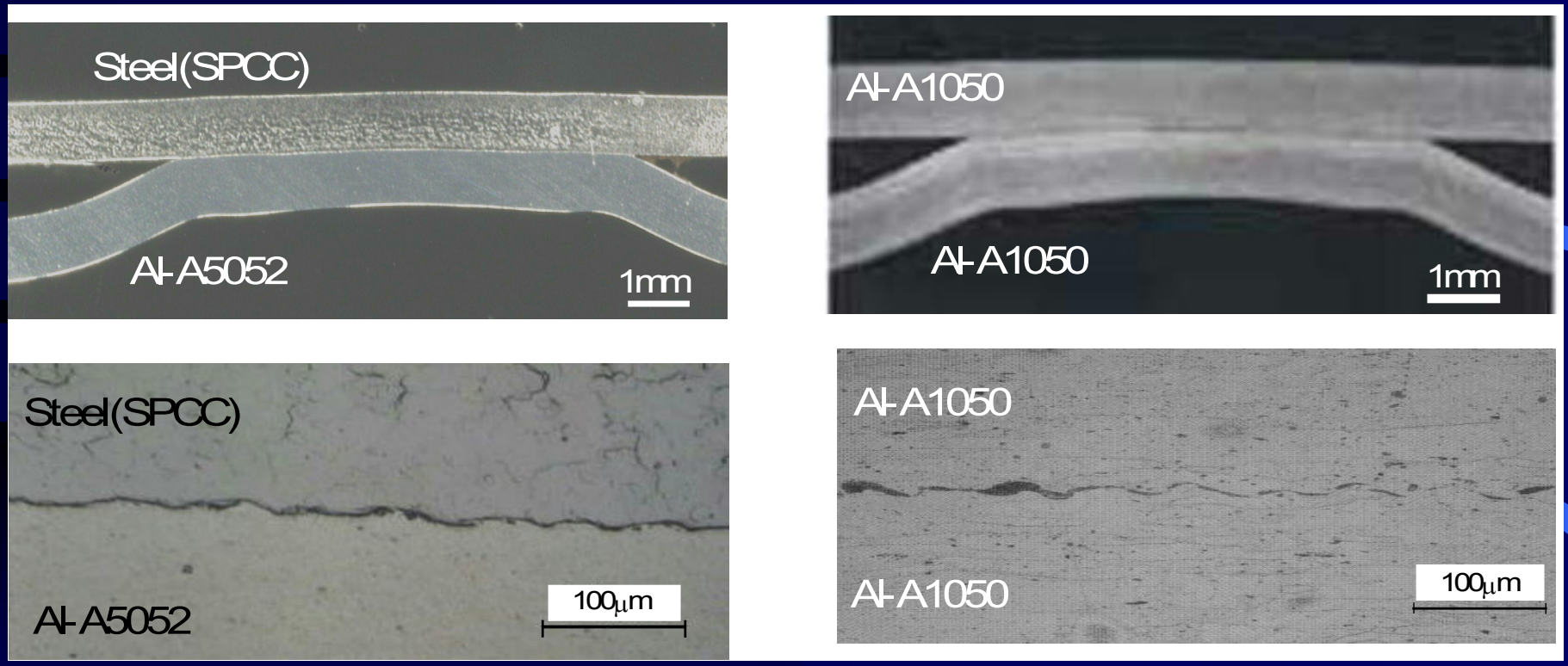
MPW Process

Simulation of Magnetic Pressure



Experimental Results

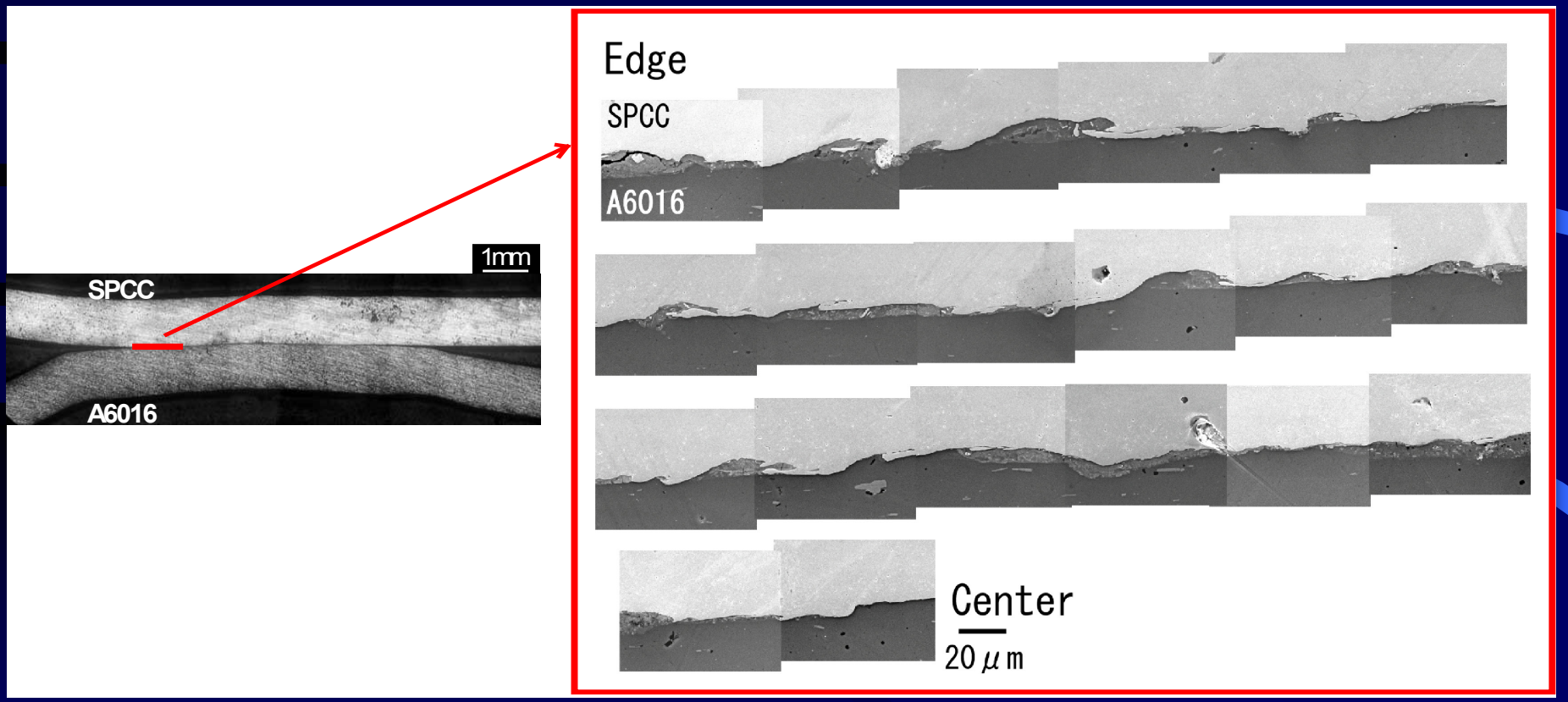
Weld Geometry



Typical macrostructure of joined interface zone for A1050/A1050 and A5052/SPCC

Experimental Results

Weld Geometry

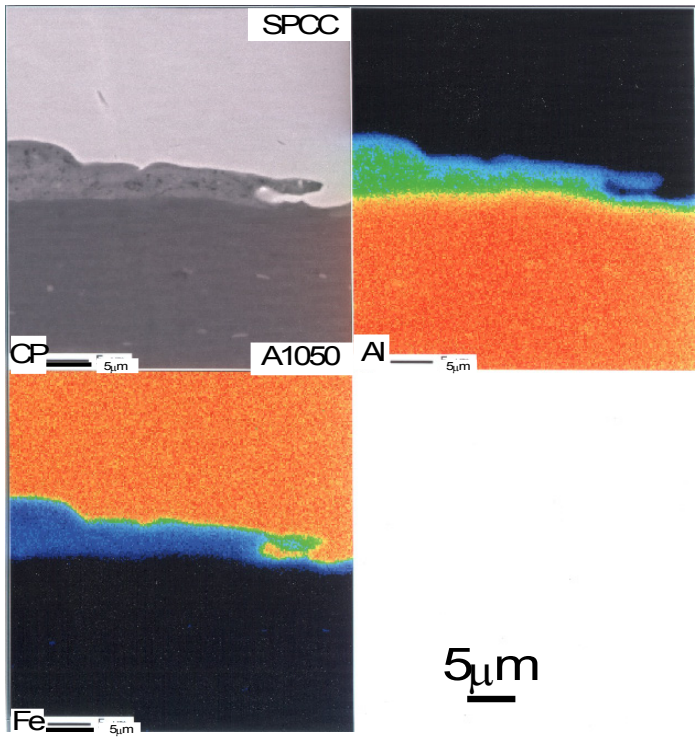


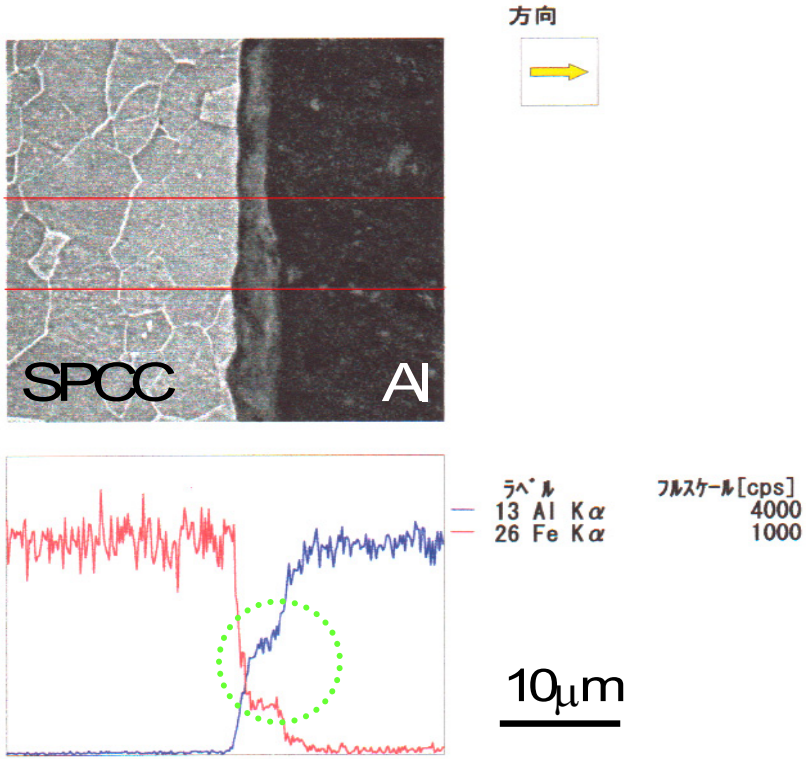
SEM image of joined interface for A6016/SPCC sample

Experimental Results

Electron Probe Micro-Analysis (**EPMA**)

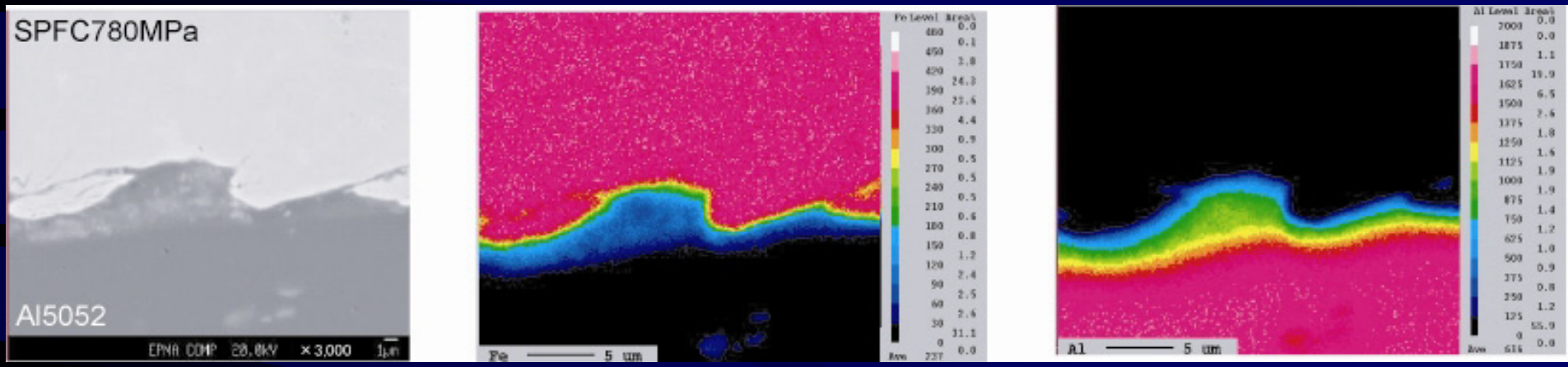
A1050/SPCC





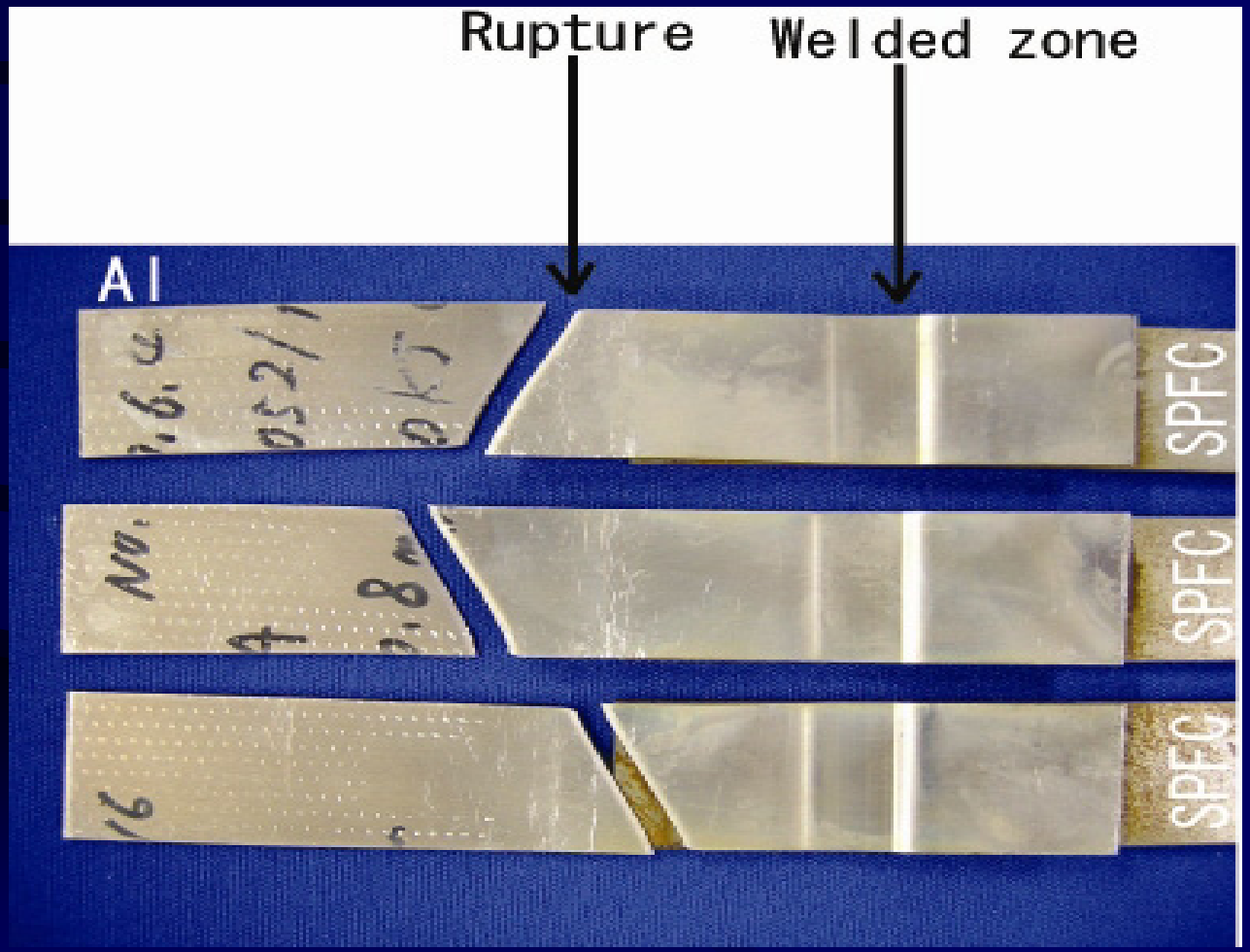
Experimental Results

Electron Probe Micro-Analysis (EPMA)



SEM image and EPMA result for *Al*, *Fe* distribution for A5052/SPFC780 sample

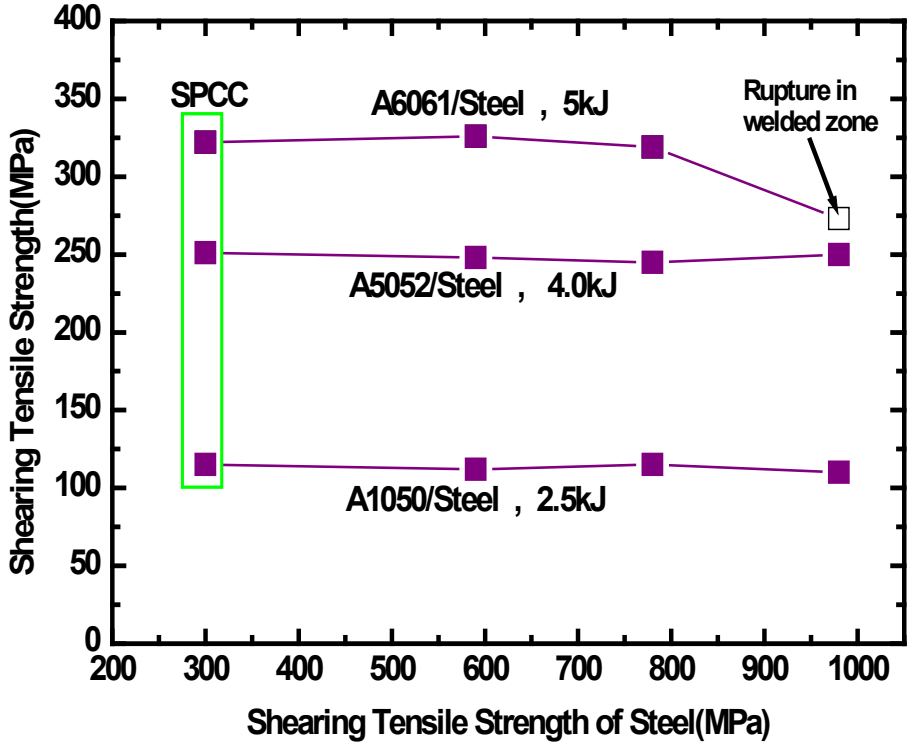
Experimental Results



Typical rupture of *Al* alloy in the tensile shearing strength test of *Al/SPFC* joints.

Experimental Results

Tensile Shear Test

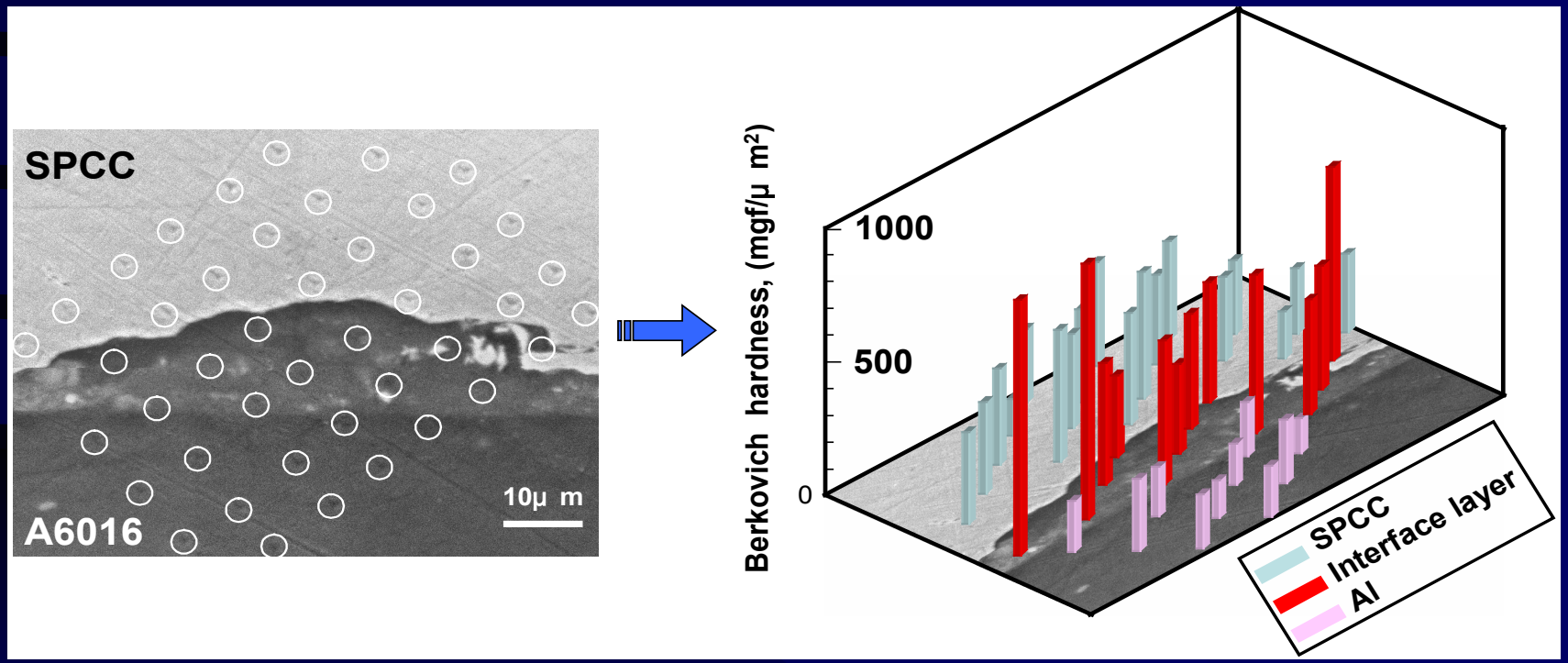


Distribution of tensile shearing strength for No.3 divided piece of welded sample with several different bank energy.

■ **rupture on Base metal (Al)** □ **rupture on welded area**

Experimental Results

Micro-Hardness Profile



Micro-Hardness profile of interface layer for A6016/SPCC

Conclusions

We can conclude that the solid-state weld quality achievable for most aluminium alloys and High strength Steel combination by using MPW method.

Conclusions

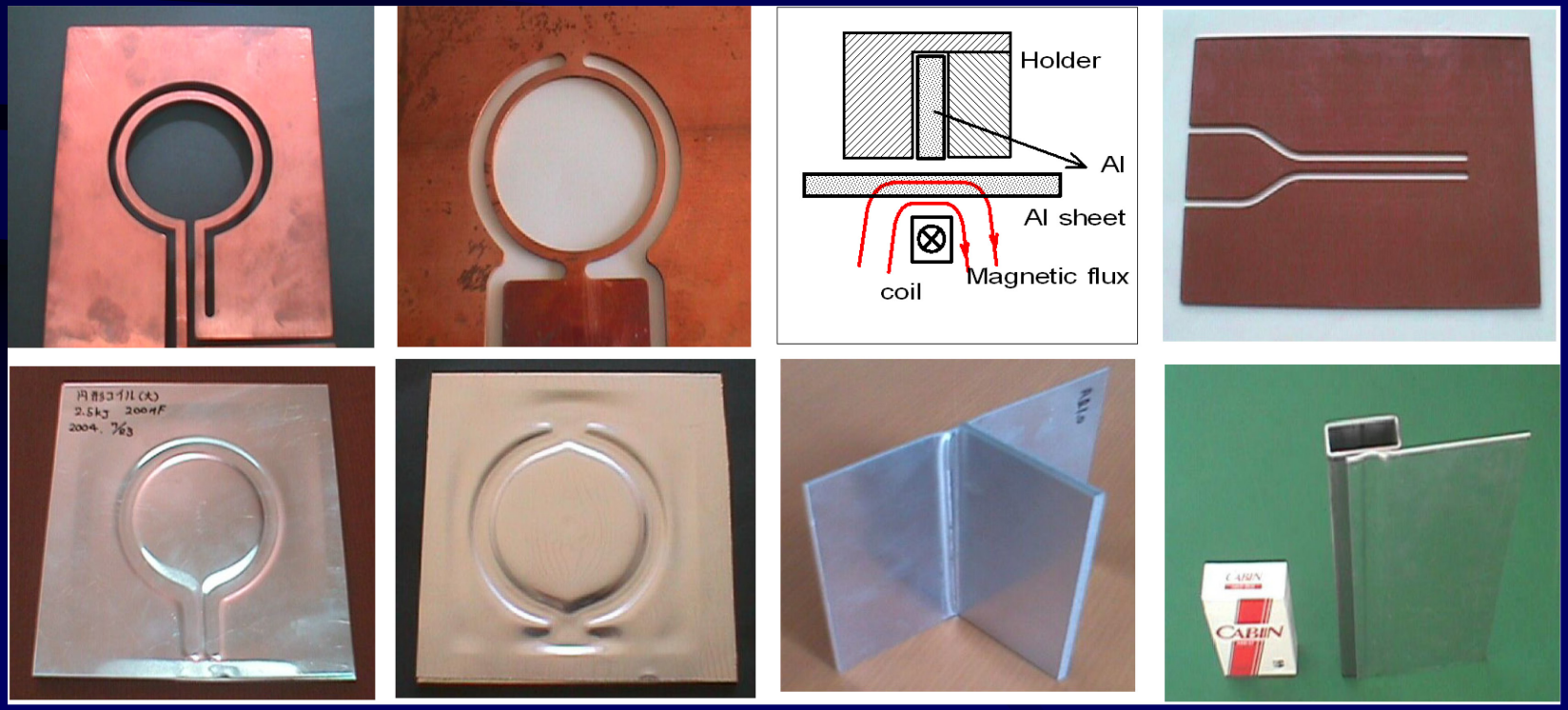
Our experimental results show that the weld joint is always stronger than the weaker metal and in all tested combination a discontinuous or continuous pocket-type, wavy transition layer was formed without any significant heat-affected zone (HAZ).

Conclusions

The Observation of the interface layer shows that the intermetallic phase develop in small pockets at the wave crests but their thickness is relatively small and these zones are insignificant in terms of the total bonded surface.

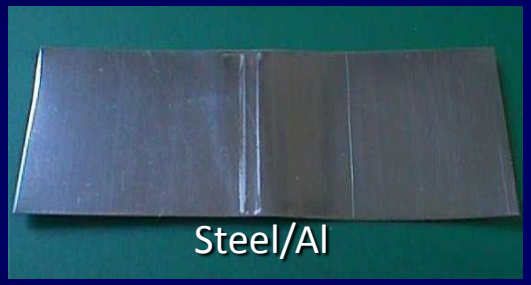
Conclusions

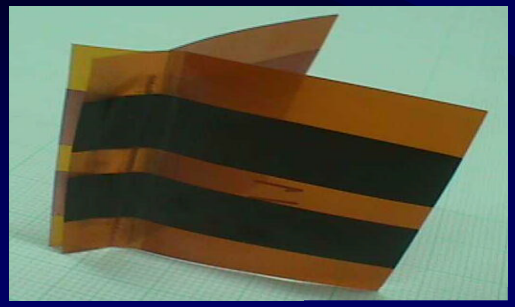
The capability of our MPW method has been also examined for several other types of metals joints, such as T-joint, circular joint, long sheet work-pieces joints (up to 500mm) successfully.

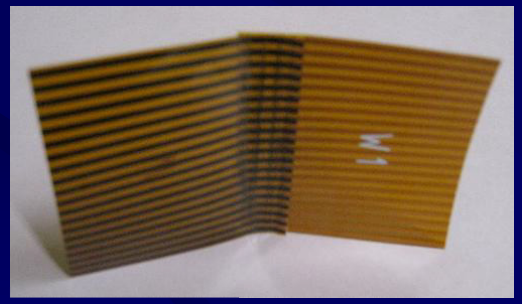


Experimental Results (WELDING)

Thin metal and Foil joints using MPW







Flexible printed connection

Experimental Results (WELDING)

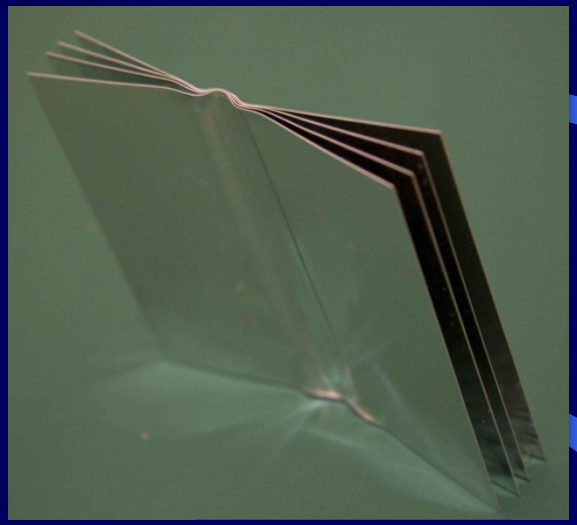
Various type of welded samples using MPW method

Al/Al

Cu/Al

Multi Spots Welding

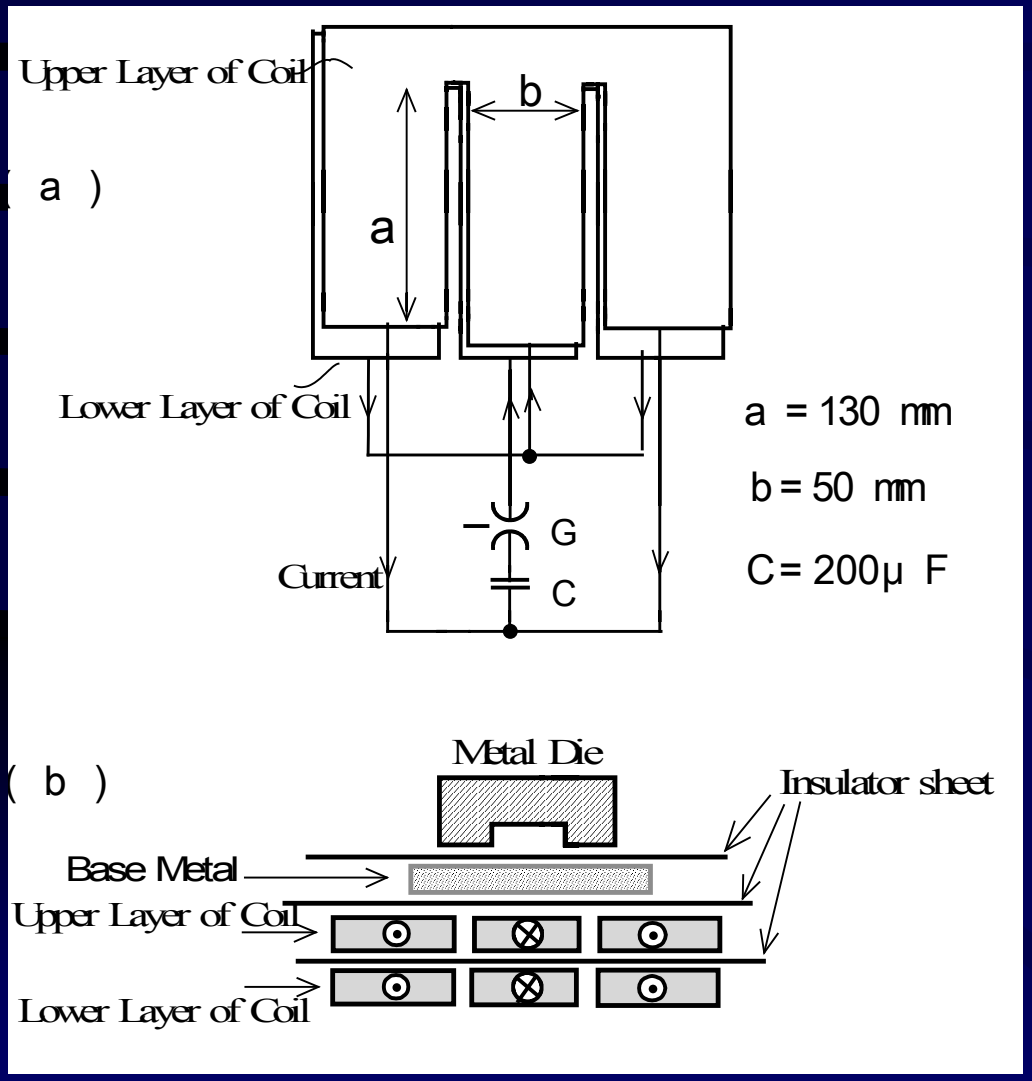
Al/Al

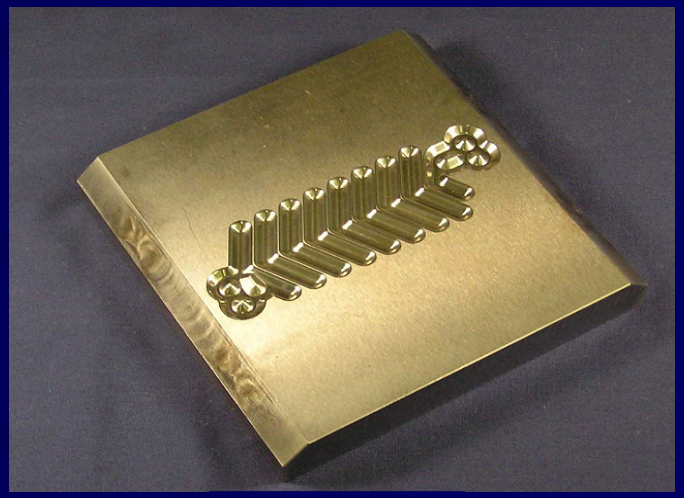


Al/Al/Al/Al

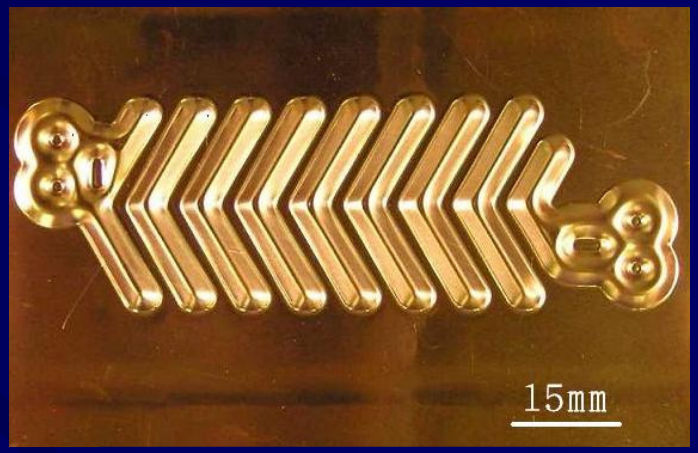
Multi Layers Welding

Experimental Results (FORMING)



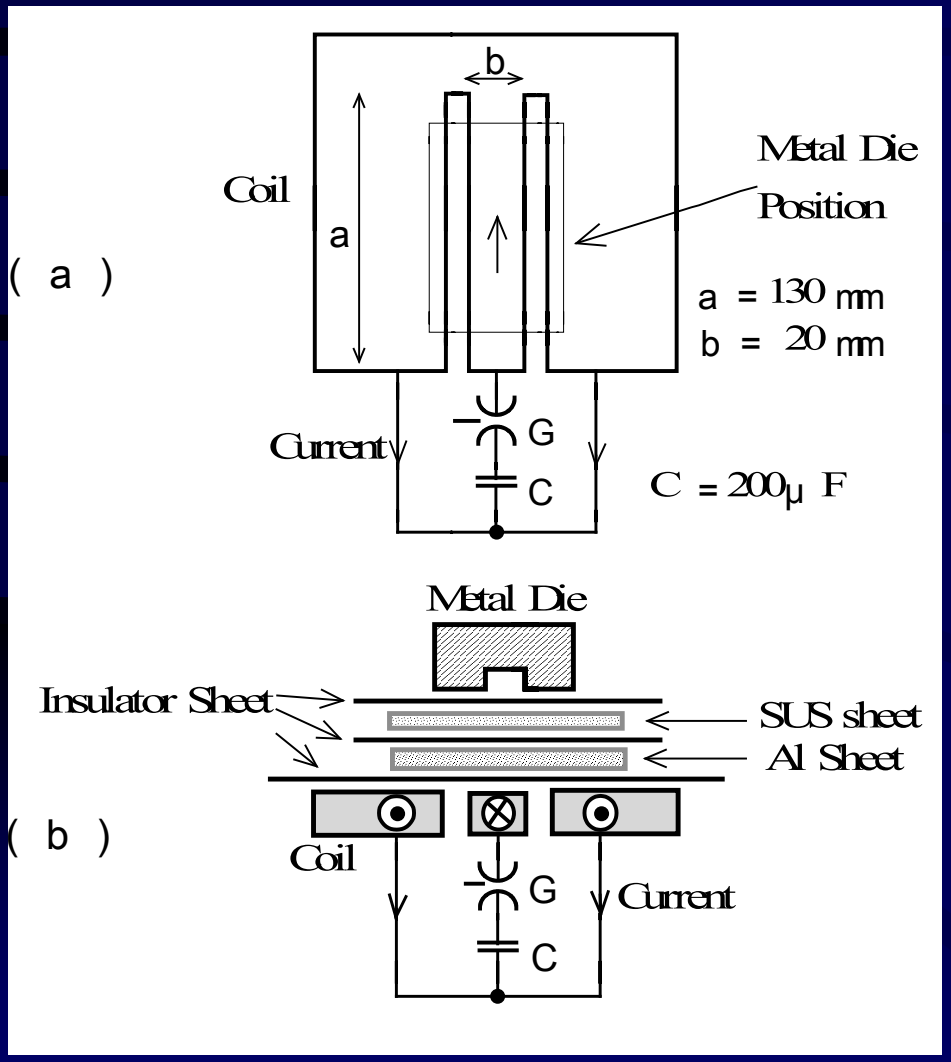


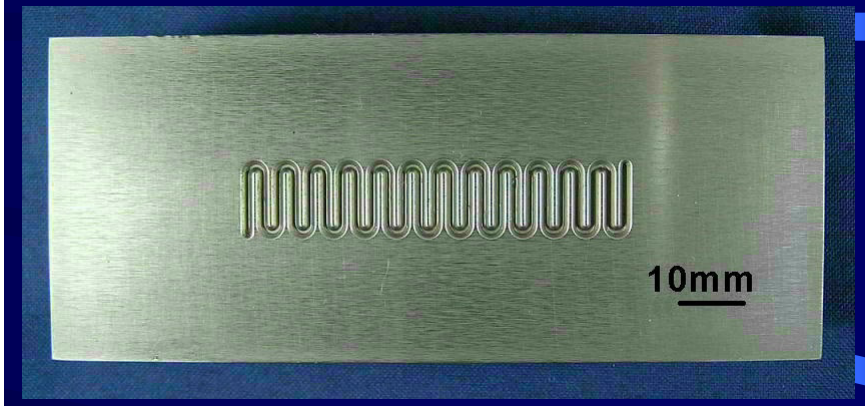
Metal Die



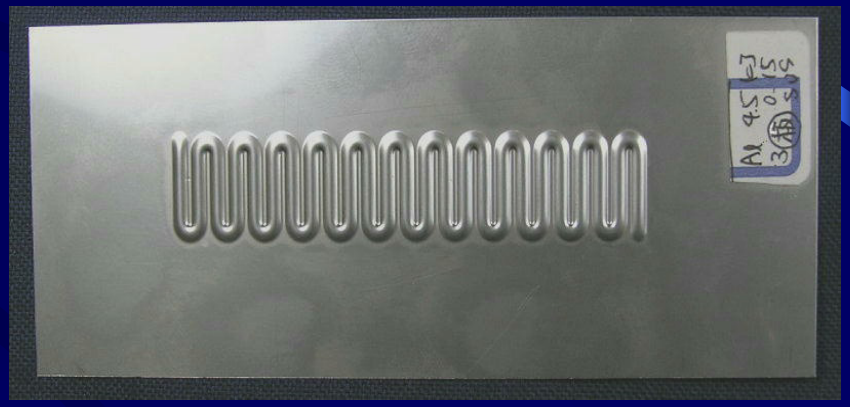
Formed Copper Sheet

Experimental Results (FORMING)





Metal Die



Formed SUS Sheet

Future Plan

Now we are working on application of MPW for Super Alloy joints and also the design of the compact commercial MPW system for Industrial application.

Thank you for your attention

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