The Ultrasonic Weld Mechanism State of the technology

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Overview

Welding Engineering Program

- Objectives
- Introduction
- Considered weld mechanisms
- Current model for joint formation
- Common practices and main issues today
- Recent research results
- Summary

Objectives

Welding Engineering Program

- Collect and summarize the available literature on Ultrasonic Metal Welding (USMW).
- Review key developments over 50+ years.
- Identify the most recent theories on the mechanism of USMW.
- Identify areas where further research is needed.

Introduction

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- USMW was discovered 1949 (by accident)
- Extensive ‘50’s-’60’s research in the US
- Research started in USSR and East Germany in ’50’s
- In Japan work started in early ’70’s
- Current research continues in Germany, Japan and the US

Basic USMW Systems

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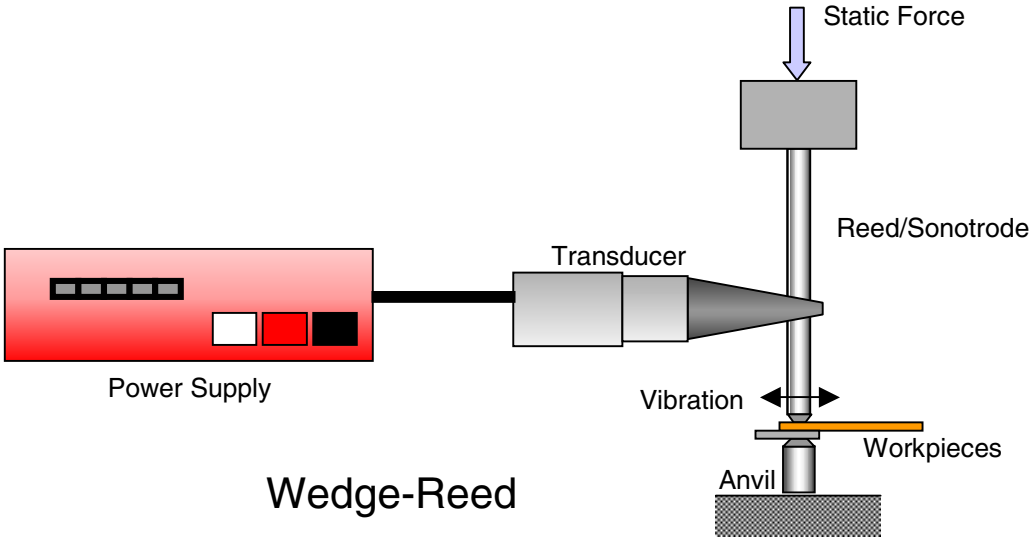
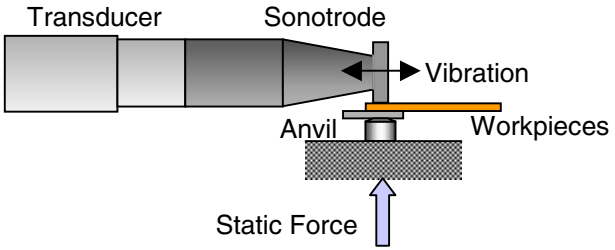
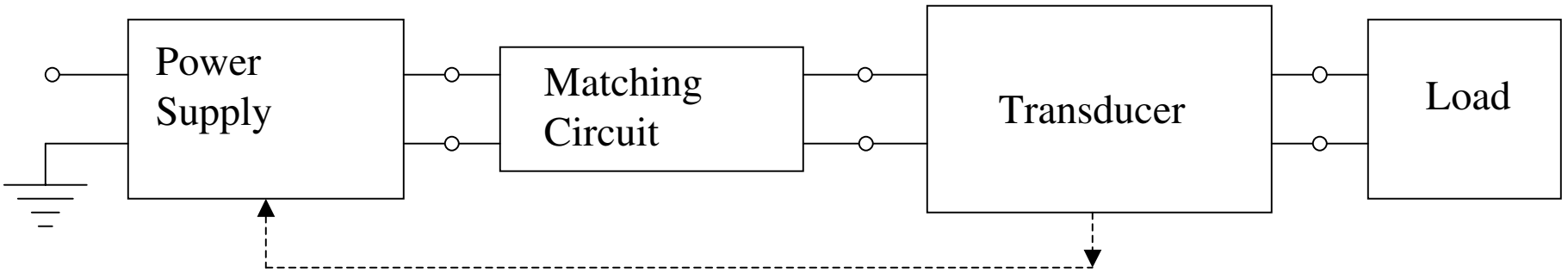


Wedge-Reed



Lateral-Drive



USMW and Related Processes

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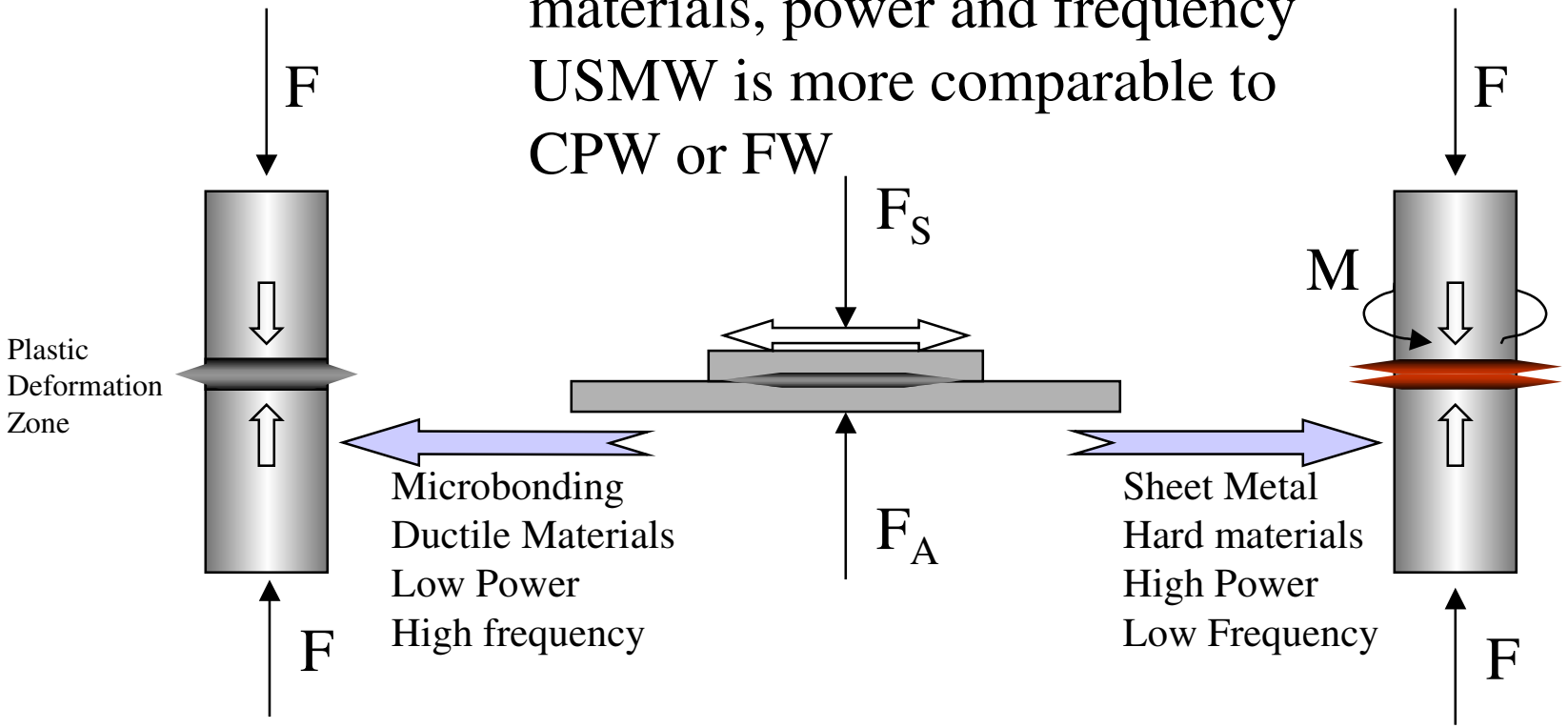
Cold Pressure Welding (CPW)

Depending on the Application materials, power and frequency USMW is more comparable to CPW or FW

Friction Welding (FW)



Welding Parameter Interaction

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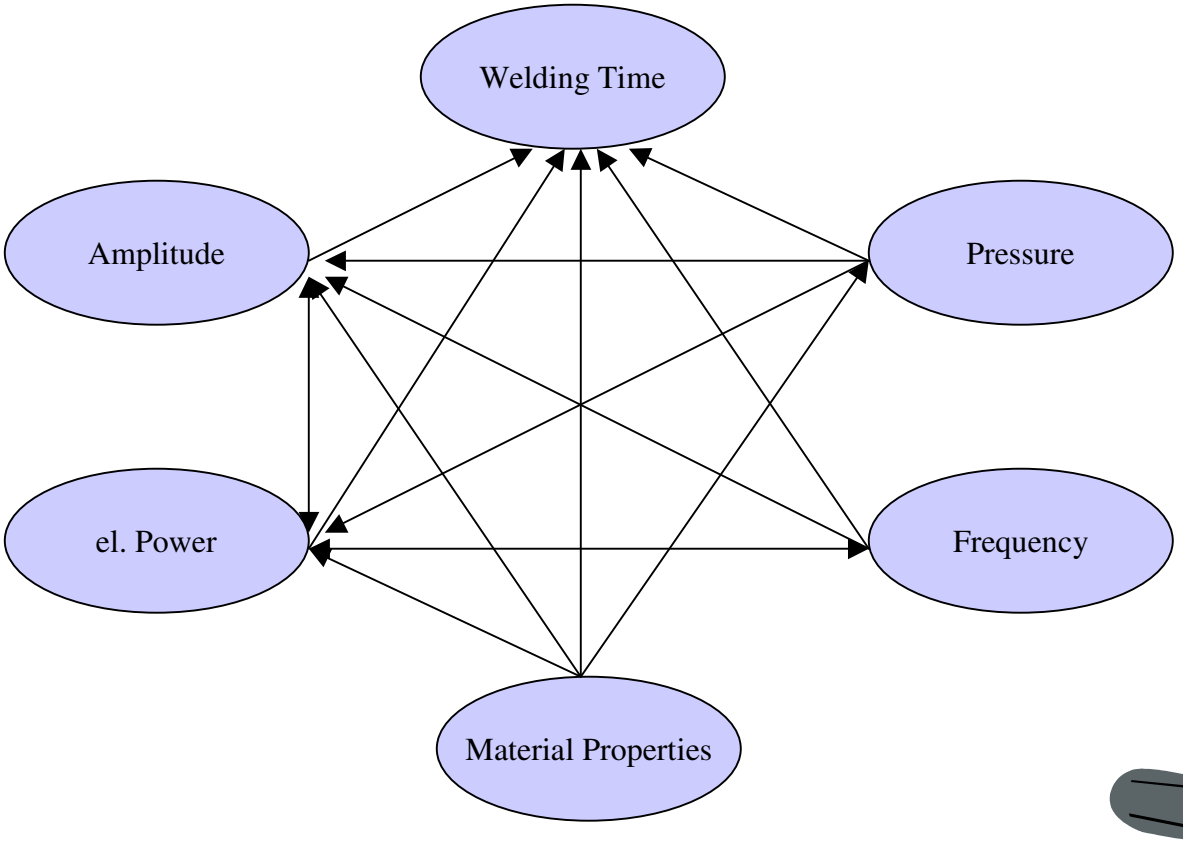

Bonding Mechanisms

- **Fusion-Melting has been considered possible at the interface. Interface microstructure has been associated with melting and rapid solidification. But USMW now considered a solid state process.**
- **Recrystallization- Observed in ultrasonically welded joints but a gross reorientation of grains or the microstructure is generally not possible.**

Bonding Mechanisms (cont'd)

- **Diffusion- Has been observed, especially along gain boundaries, but generally bulk diffusion does not take place.**
- **Plastic deformation with metallic adhesion- Observed in all USMW interfaces. The material mixing and subsequent metallic adhesion is considered the most important bonding mechanism. All other processes are possible, but are not necessary.**

Evolution of the Weld

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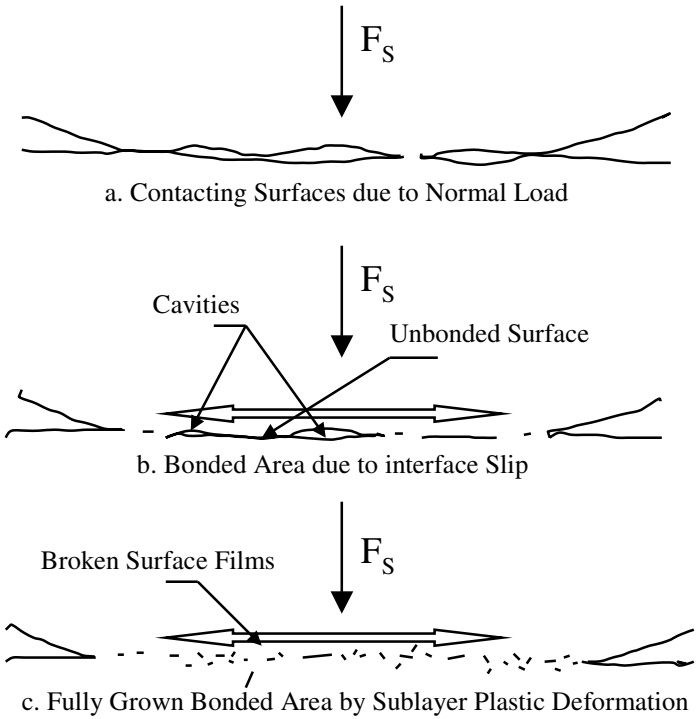

- Normal load presses the surface asperities into contact
- Slip deforms the asperities and adjusts the surfaces
- Sublayer deformation causes Oxides to dissipate and intense material mixing

Typical USMW Joint Interface

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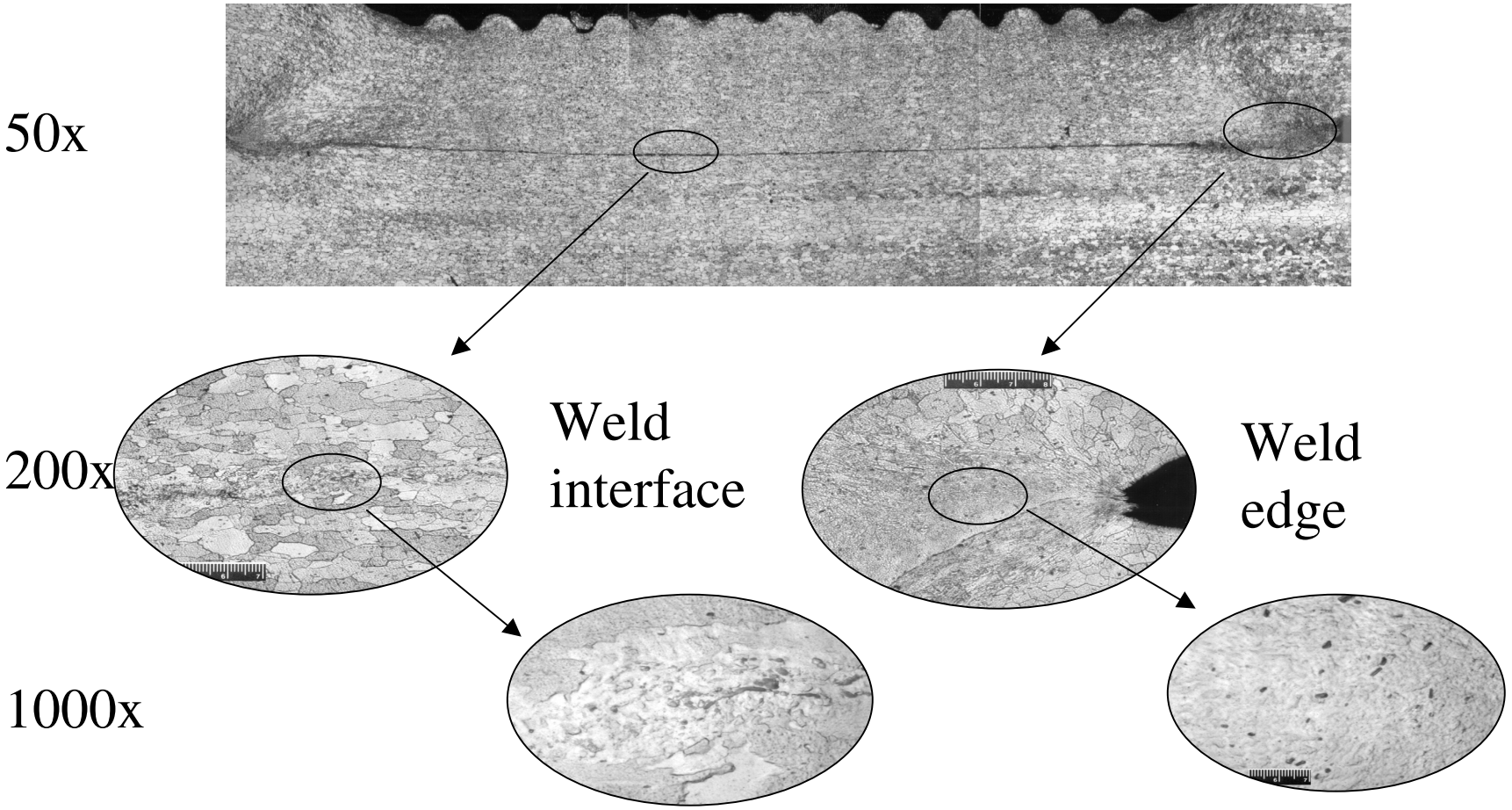

Sequence of Joint Formation

- 1st Stage: Metals are forced into close contact, asperities deform, contaminations start to dissipate.
- 2nd Stage: Metallic adhesion bonds and active centers form, (topo-)chemical reactions start
- 3rd Stage: Interface grain structure destroyed, residual stresses and active centers relax, atoms change their functional locations- leading to microscopic recrystallization and diffusion.

Model (cont'd)

- The three stages take place simultaneously or within a very short time difference.
- The last stage is responsible for the formation of a strong joint, because exchange effects occur between the metallic substances. This stage relies on elevated temperatures.
- If metals are welded that have no solubility, the joint strength relies only on inter atomic interaction.

Weldability Guidelines

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Weldability class/weldability	Lattice structure	Metals	Hardness/ HV
1/very good	cfs	Al,Au,Ag, Cu,Ni,Pd,Pt	300..1000
2/good	cfc cbc	Th α-Fe,Nb,Ta,V	1000..2000 300..1000
3/feasible	cfc cbc hex	Mn Mo,Zr Mg,Ti,Zn, Sb	2000..3000 1000..2000 300..1000
4/unlikely, not possible	cfc cbc hex	Ir,Rh,(Pb) Cr,W Be,Cd,Co, Si	>3000 >2000 >1000

- **Based on the model of weldability, classes can be formed based on deformability.**
- **Only classes 1 and 2 are suitable for USMW, metals in class 3 have low fracture loads.**
- **If different materials are to be welded the difference in hardness should not exceed 1000 HV.**

Common Practices and Issues

- Lateral Drive system with rigid anvil, amplitude controlled sonotrode and energy controlled weld process – widely used.
- If aluminum sheet metal is welded, good weld strength often is accompanied by "tip sticking."
- Welding parameters change as surface conditions change. However control systems do not account for changing conditions- leading to a variable process.

Recent Experiments-Background

- USMW process still not fully understood.
- The Wedge Reed design has provided strong joint strength with low sonotrode sticking.
- Correlate the sequence of events (initial, welding, extrusion stage) to vibration conditions.
- If surface conditions are not well controlled, weld process is also unreliable.

Experimental Setup

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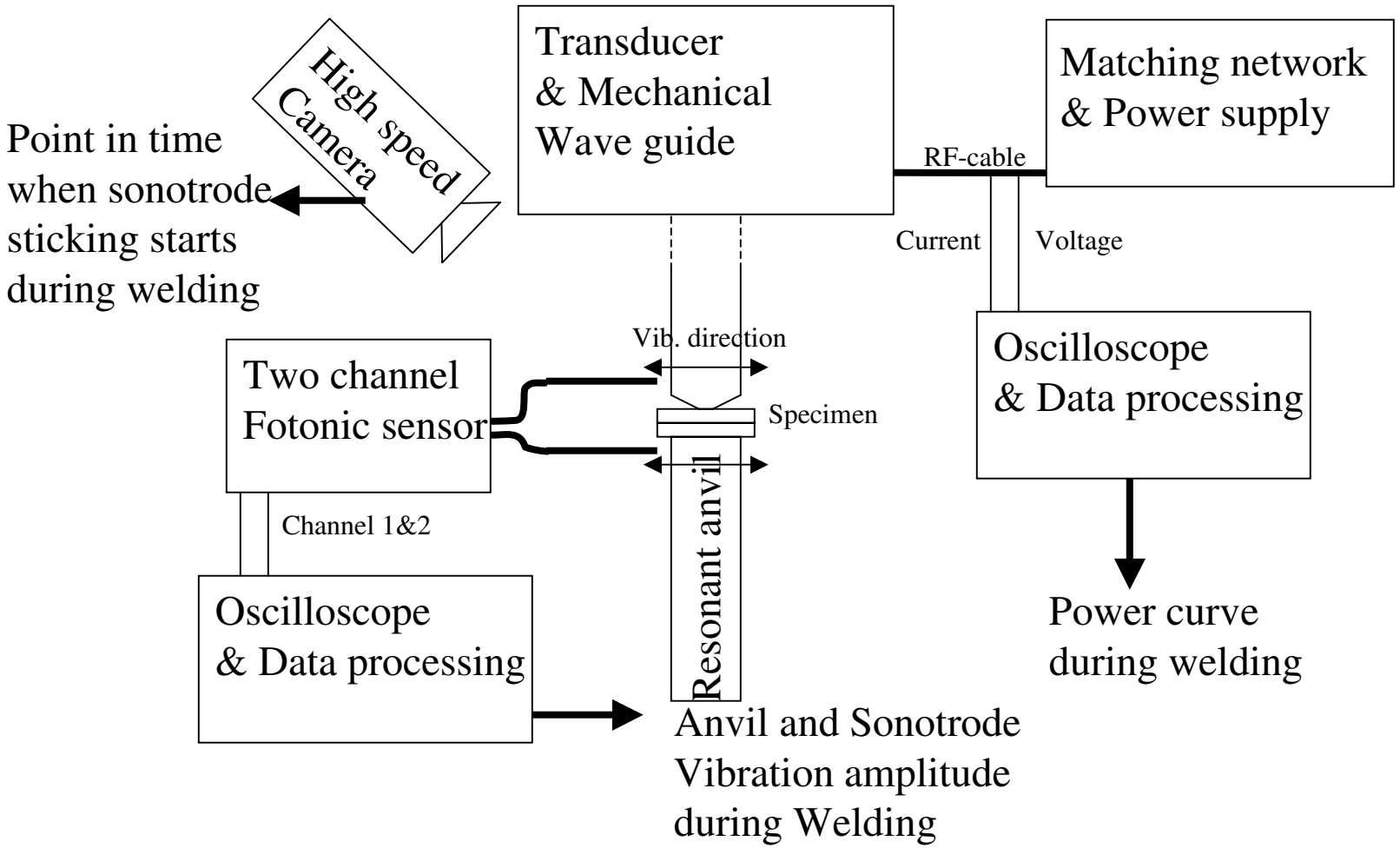

Results

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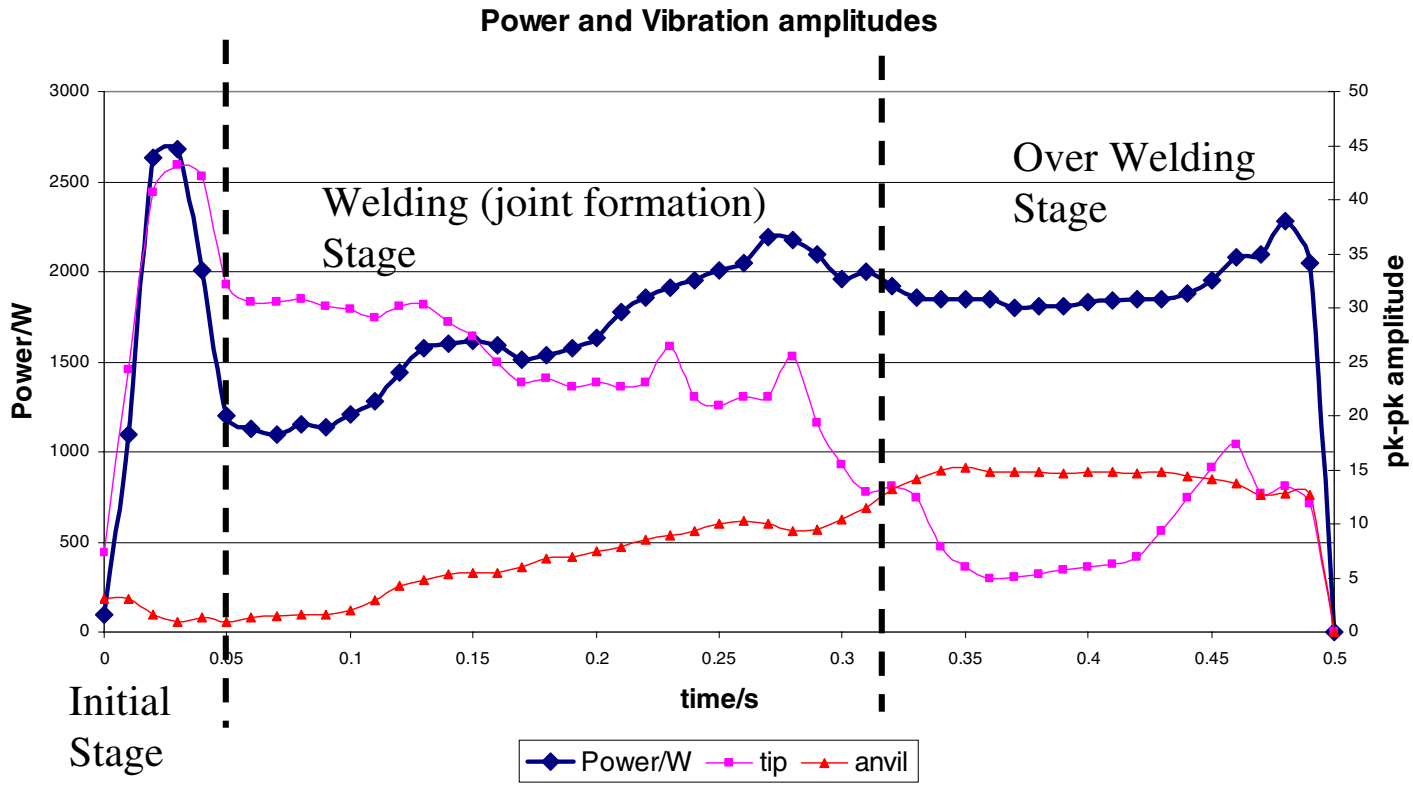

Summary

- Research on USMW has been conducted for 50+ years.
- USMW is commonly used for electrical connections, tube and package sealing and wire bonding.
- Models for basic parameter interactions and weld mechanism have been developed.
- For aluminum sheet metal welding, large scale applications remain a challenge.