Joining of Dissimilar materials

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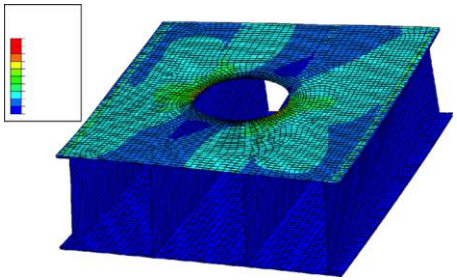
SINTEF Raufoss manufacturing

Outline

1. Introduction to Dissimilar Material Joining
2. Hybrid Structures
3. Review of Joining Processes / Technologies
4. Joint Characterization / Testing
5. Process and Performance Modeling
6. Process Selection
7. Future Research Challenges

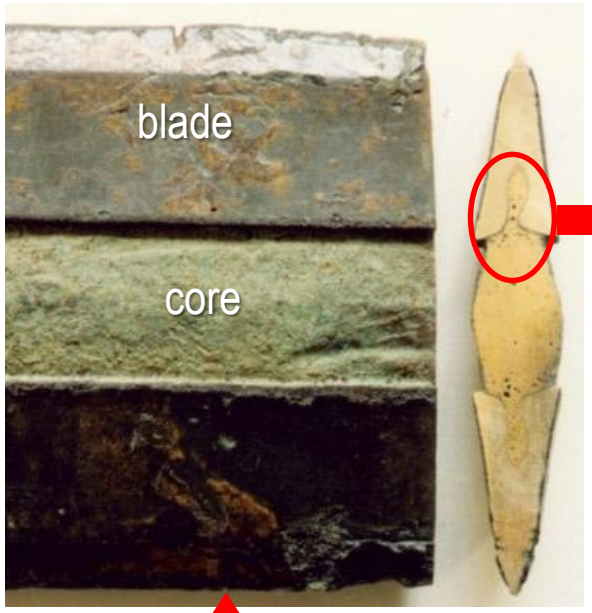
Definitions for Joining of dissimilar materials

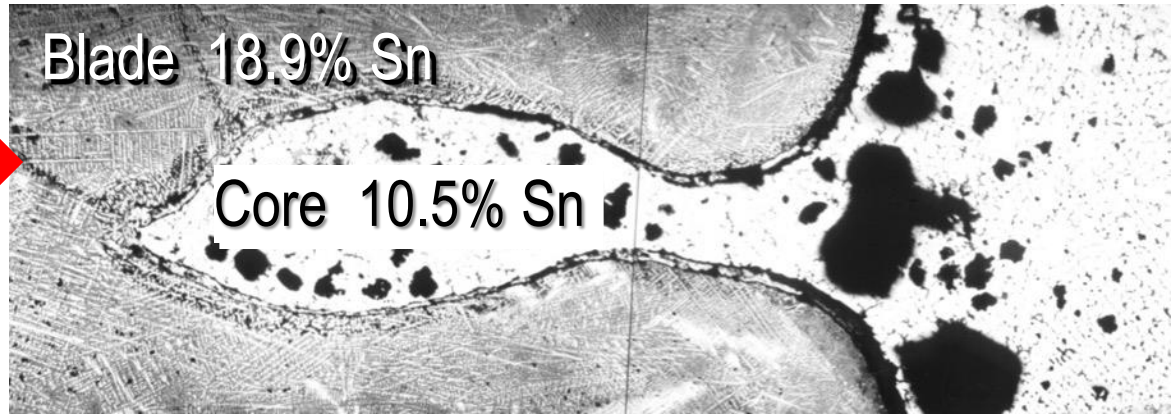
- **Joining:** Creating a bond of some from between materials or components to achieve a specific physical performance
  - Mechanical
  - Chemical
  - Thermal fusion
  - Solid state
  - Combination/hybrid



- **Dissimilar materials**: Materials difficult to join because of their different chemical compositions and/or physical properties
- **Hybrid structures:** Two or more components of dissimilar materials joined together to achieve a specific physical performance

Mixed Material Joining:
Bronze Age Bimetallic Swords





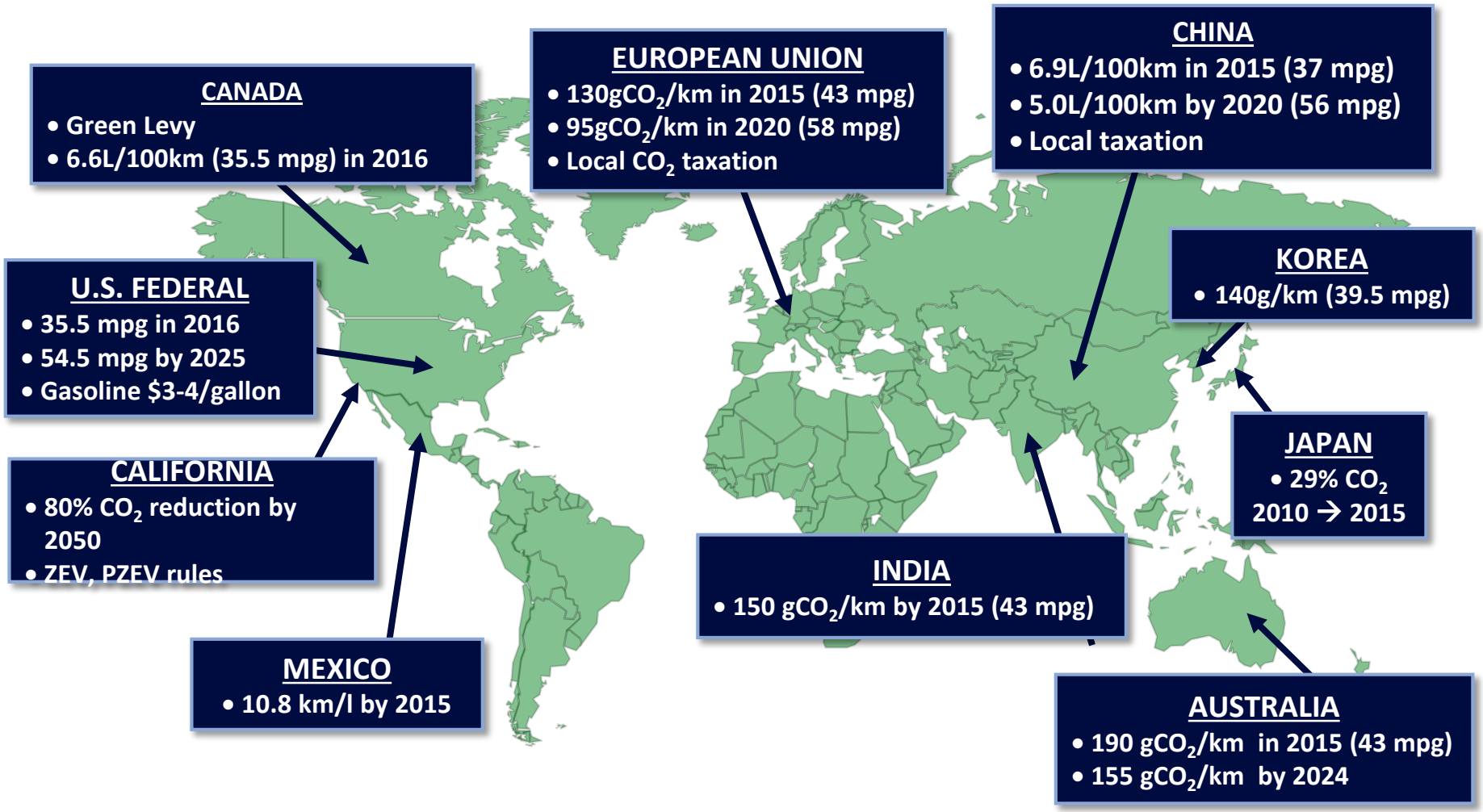
H. Lian, "The Chinese Traditional Casting Techniques", 69th World Foundry Congress, Hangzhou, China, Oct. 16-20, 2010

Hybrid structures

- Lightweight and high performance structures
- Integrating an increased number of functions in each part
- Different properties of different materials are jointly utilised to achieve the product performance needed
- Materials will interact with each other in new ways
- Need the ability to simultaneously optimize material choice, geometry, production processes

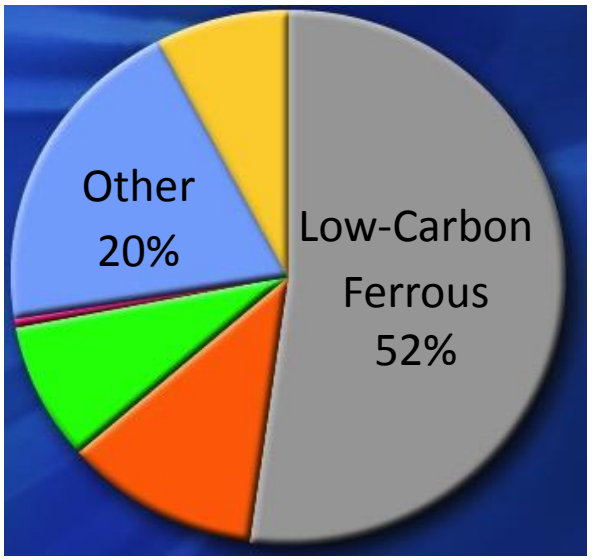
Boeing 787 Dreamliner
50% composite,
20% aluminium,
15% titanium, 10% steel
5% other

Regulatory Requirements



Personal Transportation Driving Mixed Material Product Solutions

Polymer/Composite 8%

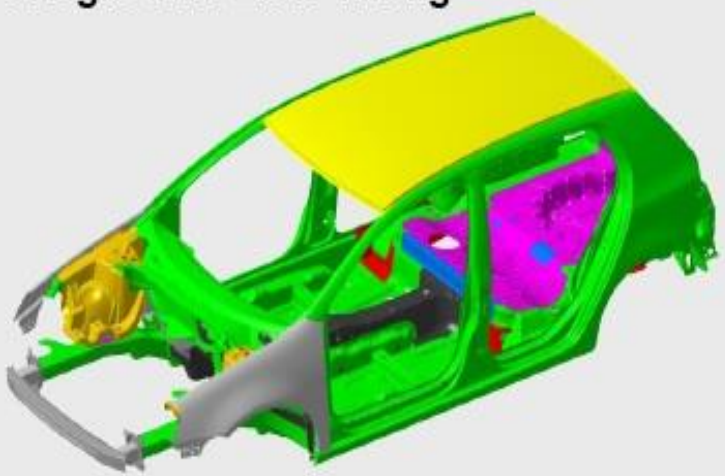


Magnesium 1%

Aluminum 8%

High Strength Steels 11%

Weight SLC BIW: 180 kg



Materials

- Aluminium sheet
- Aluminium die-casting
- Aluminium extrusion
- Steel
- Hot-formed steel
- Magnesium sheet
- Magnesium die-casting
- Fiberglas thermoplastic

Weight distribution

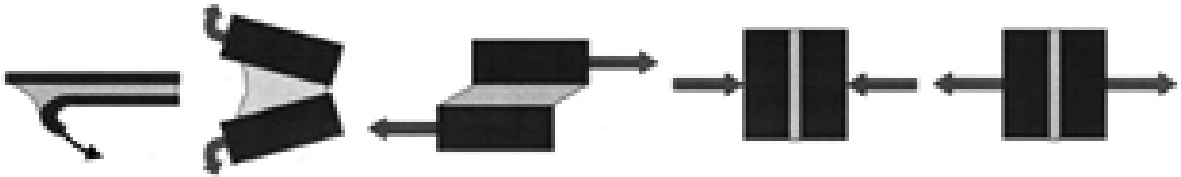
Aluminium	96 kg	(53%)
Steel	66 kg	(36%)
Magnesium	11 kg	(7%)
Plastic	7 kg	(4%)

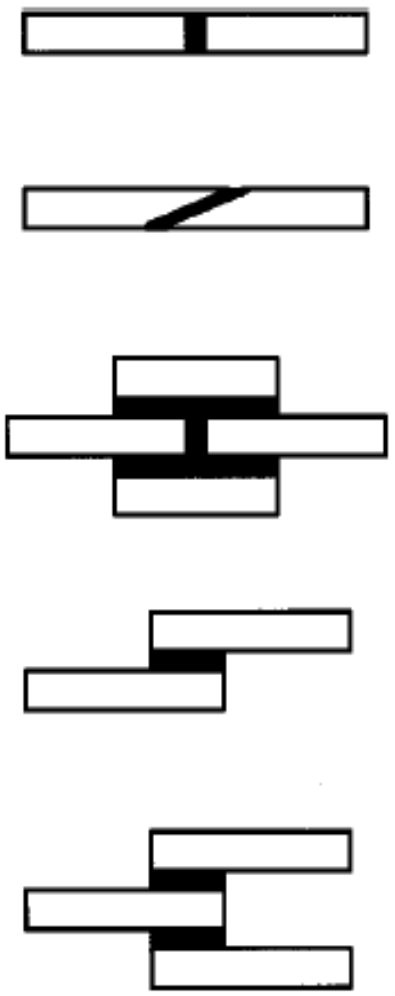
EU Project SuperLight Car

Source: Berger L, Lesemann M, Sahr C (2009) 7th European LS-DYNA Conference

Adhesive joining

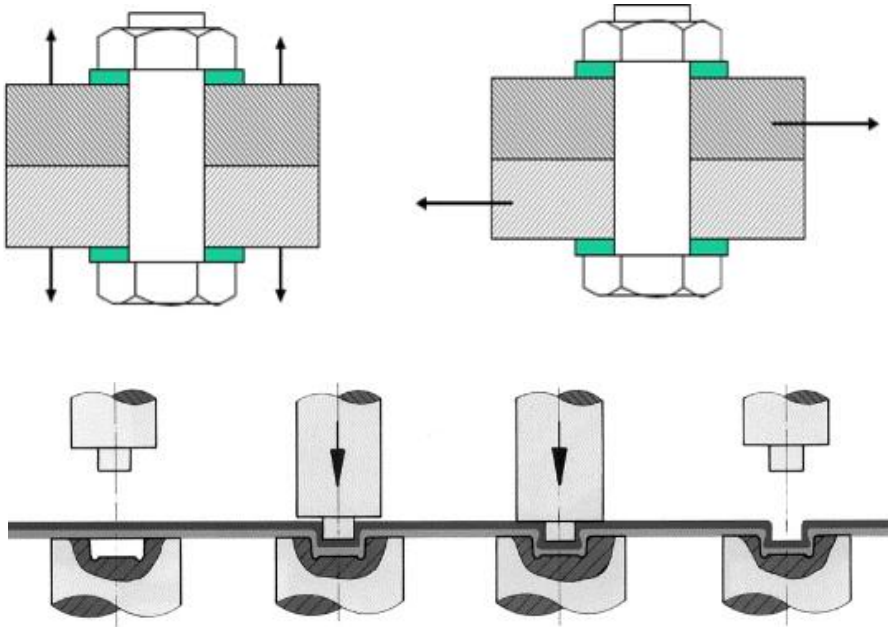
- Difficult to disassemble
- Surface preparation requirements
- Time needed for polymerization
- Limited thermal resistance
- Bond attenuation/degradation from atmospheric and chemical agents
- Joint design



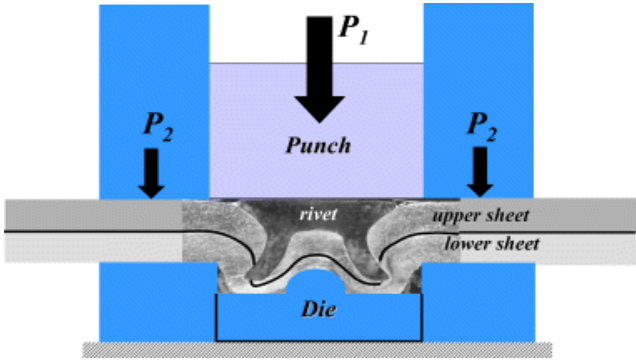


Mechanical Fastening

- Screw joints
- FlowDrill Screws
- Clinching
- Friction Stir Blind Riveting
- Self-Piercing Riveting
- Sewing
- Plastic deformation



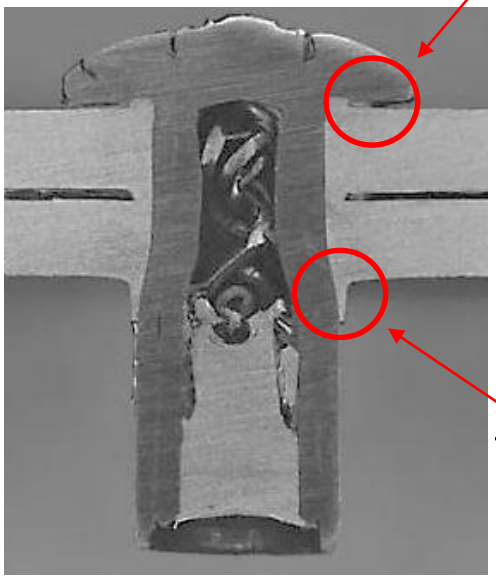
- Pro: Simple, no fusion, easy disassembly, automation,….
- Against: Stresses/fatigue, long-term capabilities, added mass, corrosion, …



Examples, Mechanical Fastening

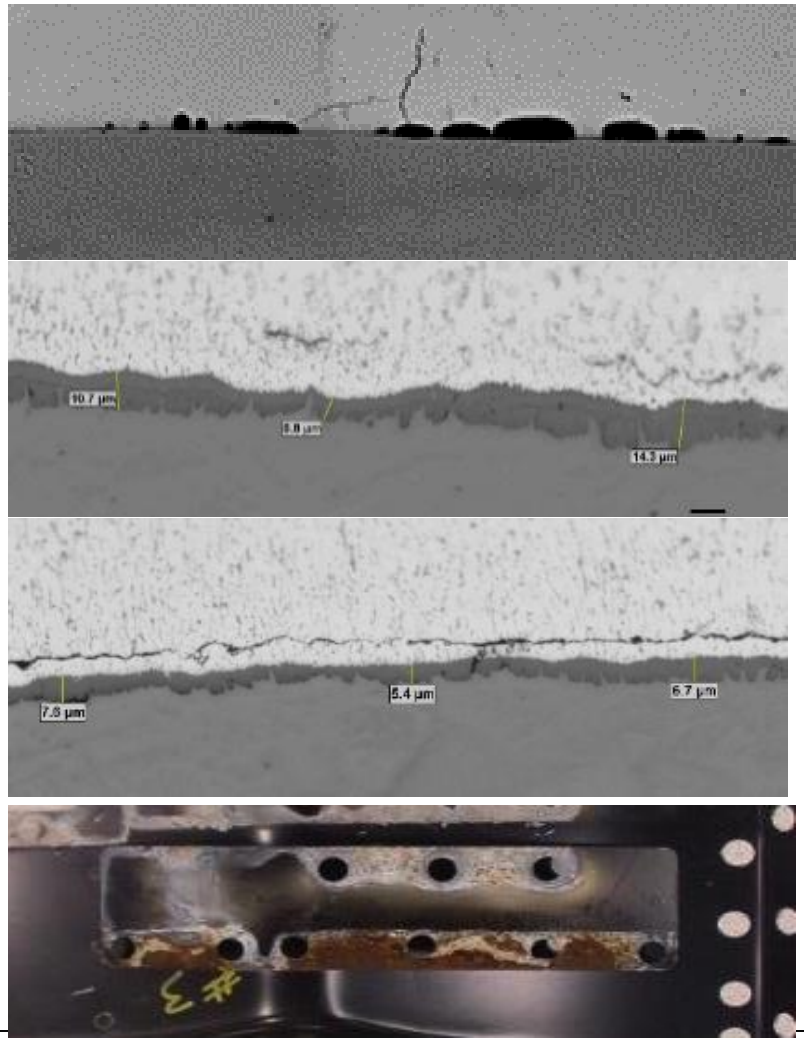
Flow Drill Screws

Friction Stir Blind Rivet



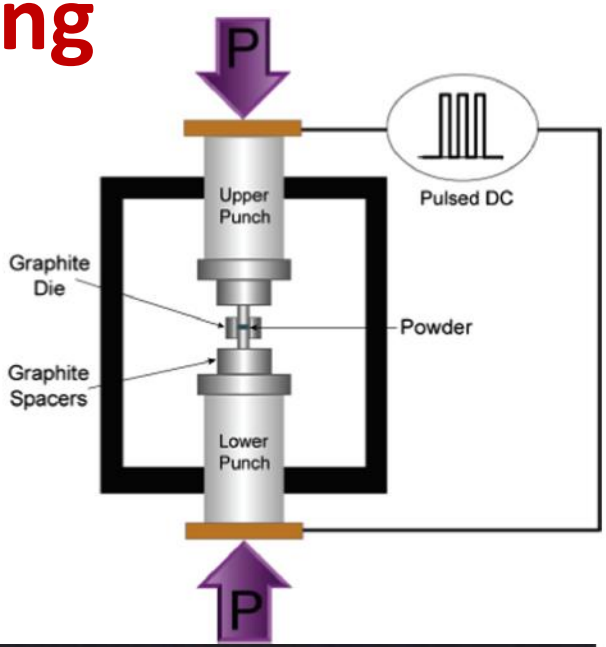
Multimaterial Fusion Welding Challenges

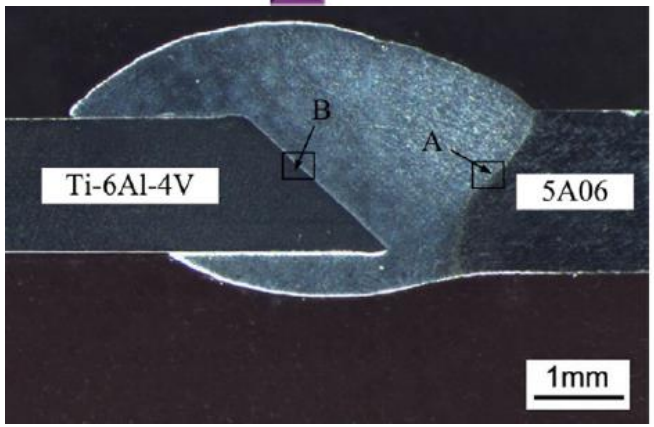
- Porosity
- Intermetallic Formation
- Pre-existing Oxide Layers
- Galvanic corrotion
- Dissassembly



Examples: Thermal fusion joining

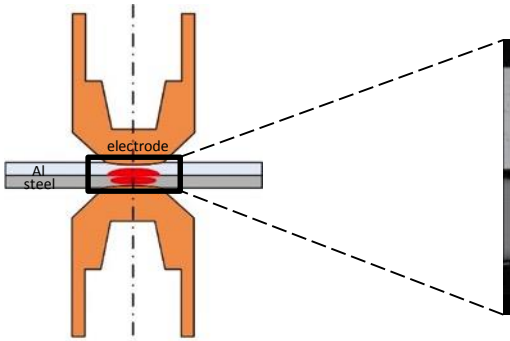
- **Spark Plasma Sintering/ Pulsed Electric Current Sintering:** Sintering of high-end materials such as tungsten carbide and ceramics
- **High Energy Beam Welding:** Laser, electron-beam: Conduction mode (sheets) or Keyhole mode (deeper penetration)
- **Brazing and soldering:** Well-known technology used to join ceramics to metals, dissimilar incompatible metals, complicated geometry
- **Resistance Spot Welding (RSW)**
- **Arc Welding**

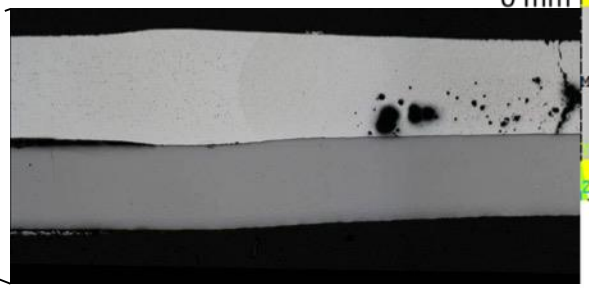


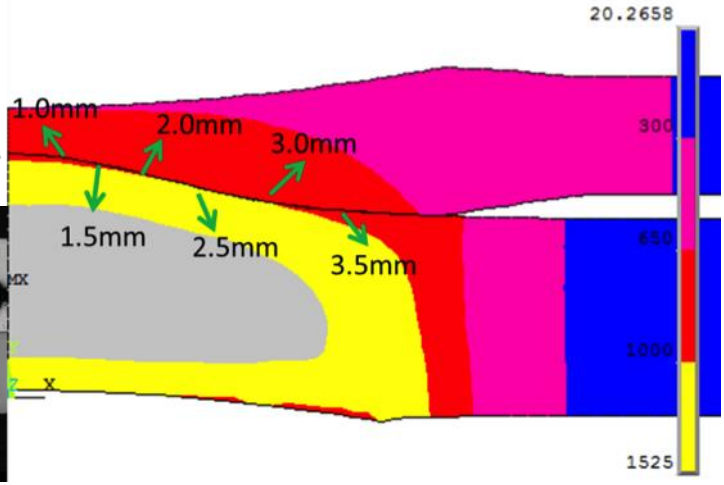


Chuvildeev, et al., 2014,

Al-Steel RSW





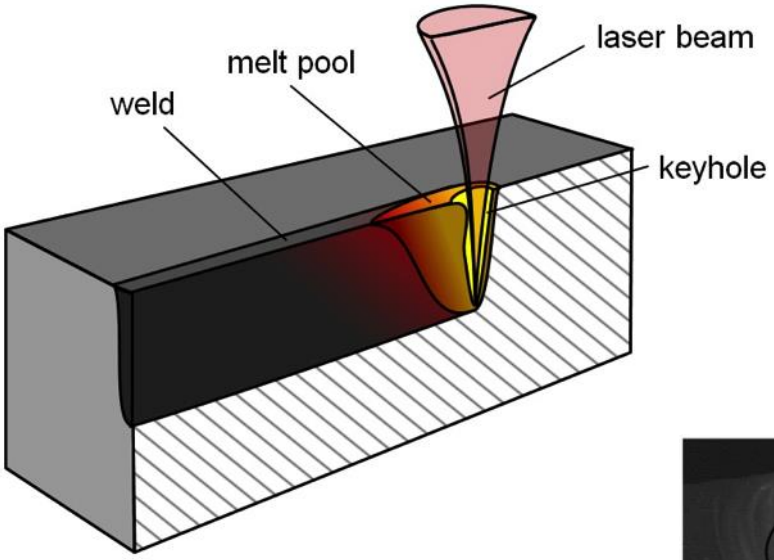


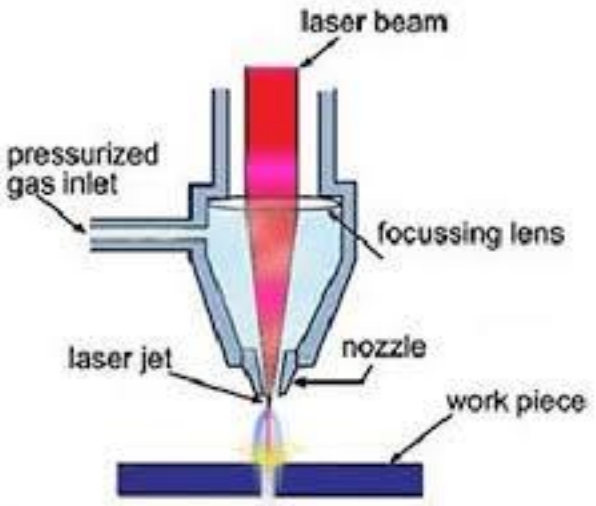
	Melting point (°C)	Thermal conductivity (W/(m.K))	Electrical resistivity (10^{-6}Ω.cm)	Density (Kg/cm³)	Thermal expansion rate (10^{-6}m/(m.K))
Al alloys	660	205-250	2.82	2700	22.2
Steels	1425 - 1540	47-54	14.3	7870	13.0

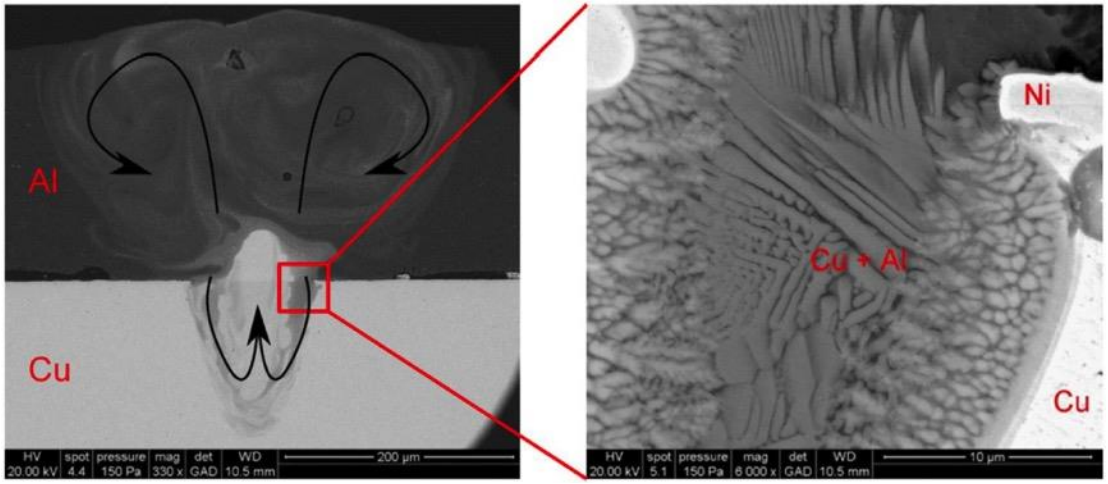
- Heat imbalance
- Formation of brittle intermetallic compound at Al-steel interface
- Cracking and porosity in Al
- Al expulsion/thinning

Important to know temperature field in the process!

Laser Welding





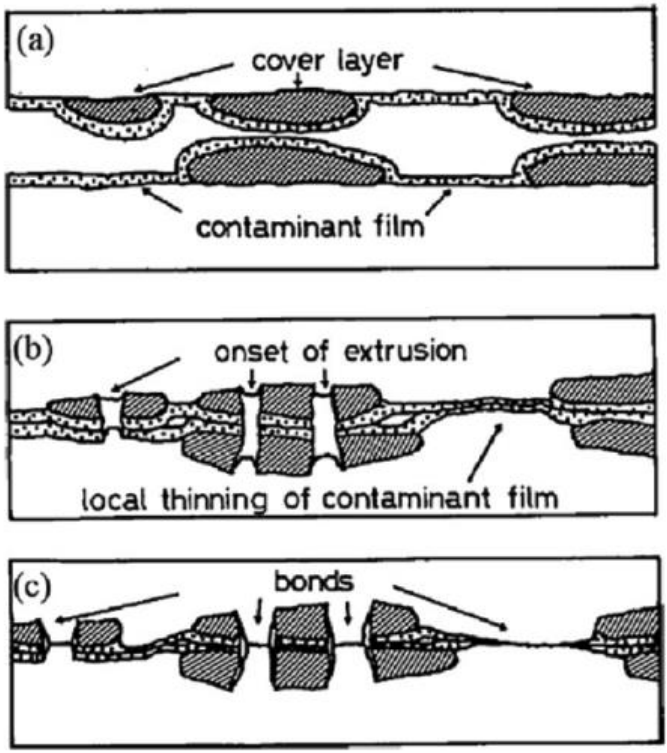


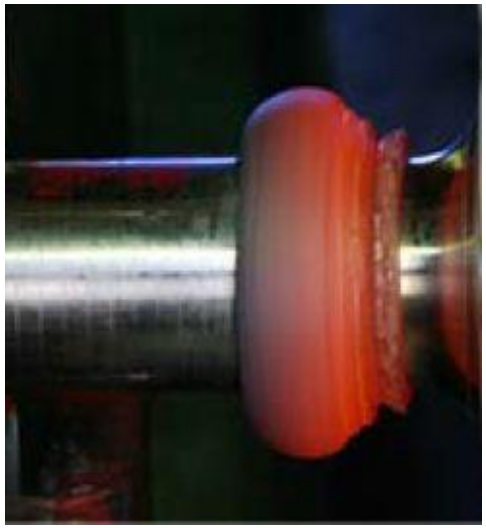
T. Solchenbach , et al.

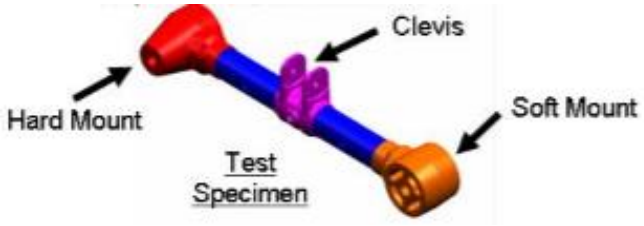
European Automotive Laser Applications 2013: 14th European Expert Conference, Bad Nauheim, Germany, February 19-20, 2013

Solid state joining processes

- Friction welding
- Cold Welding
- Friction Stir Welding
- Ultrasonic welding

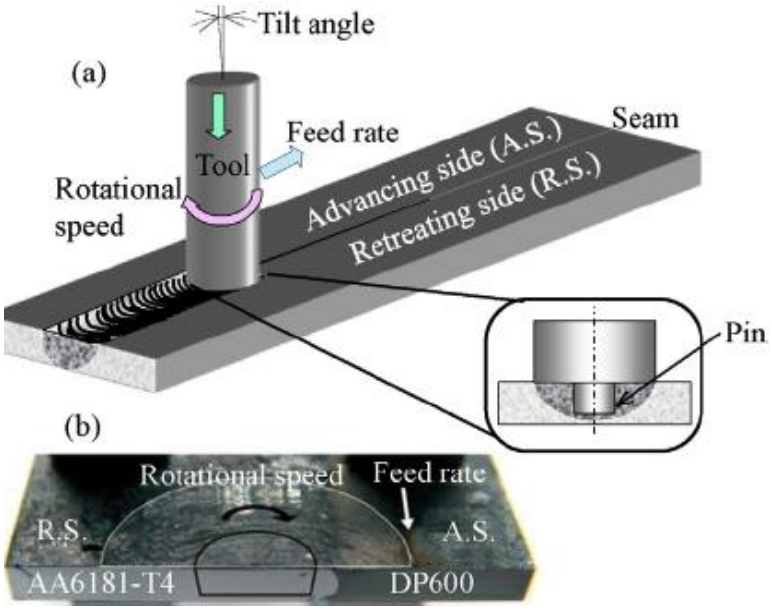


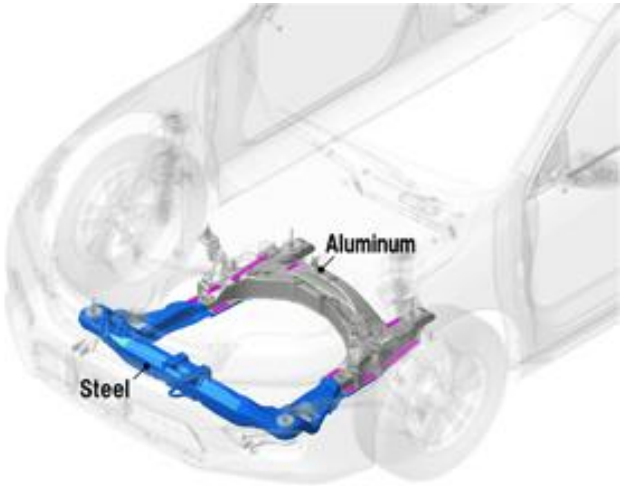




Friction Stir Welding

- Steel-AL, AL-Thermoplastics polymers, Al-Cu
- Small HES, non-consumable tool, little post-processing, residual stresses, corrosion resistance, no filler material, no oxide removal, small IMC





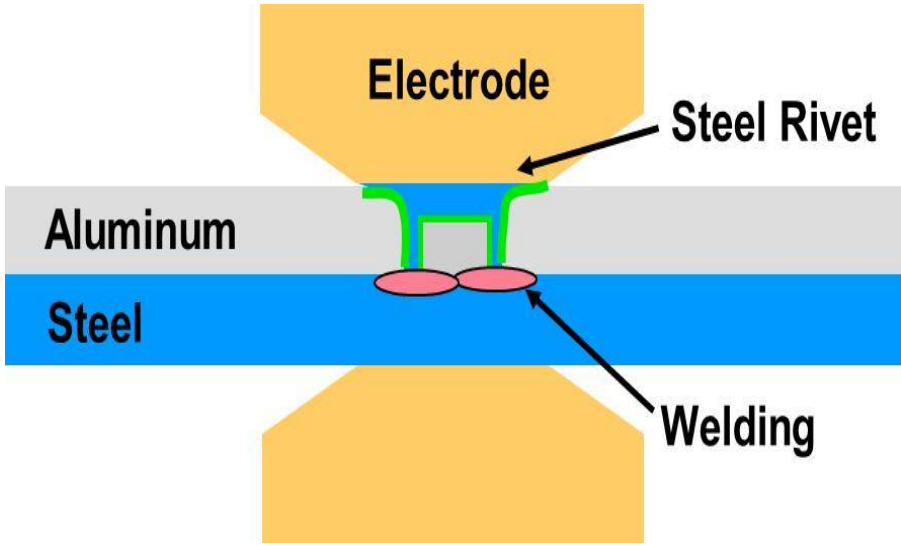
FSW of Aluminium and Steel on Honda Accord front subframe from 2013 (www.honda.com)

W. Hou, SJ. Hu, P-C. Wang, "Method of Joining Dissimilar Materials", US Patent 7,267,736, 2007

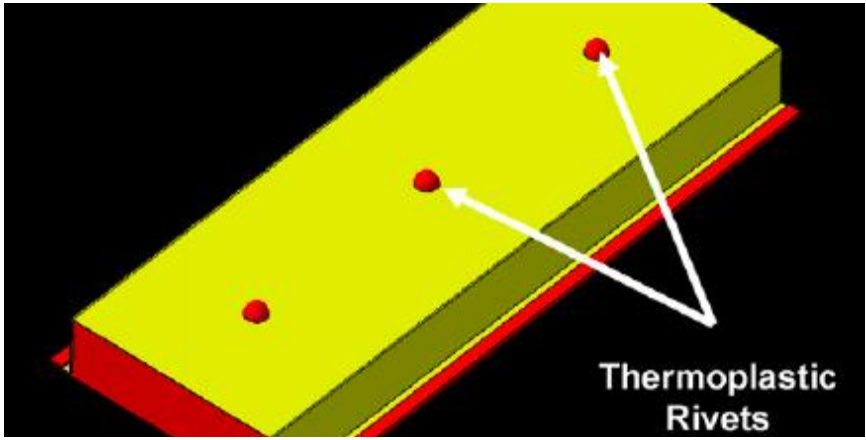
Hybrid processes

- Joining effect typically combination of mechanical and the adhesive effect of the polymer wetting the metal surface, or welding/ cold metal bonding

- Rivet-Weld
- Friction Riveting
- Friction Spot Welding
- Injection over-moulding
- Adhesive/mechanical



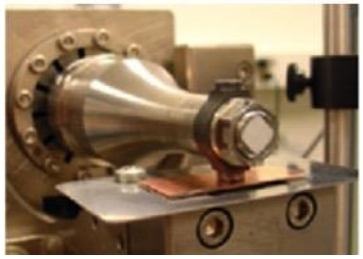
Rivet-Weld

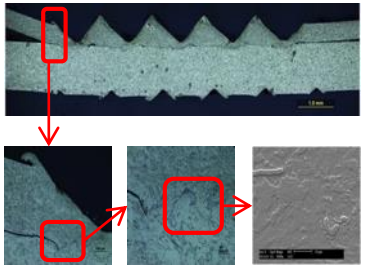


Injection over-moulding

Characterization and testing of multi-material joints

- Pressure
- amplitude
- Time
- ……

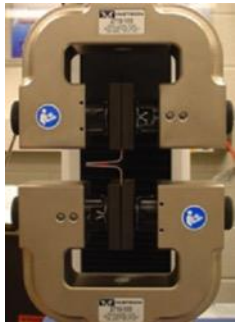


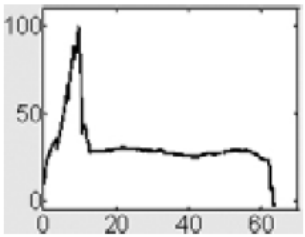


Process Parameters

Joint Attributes

Joint Performance

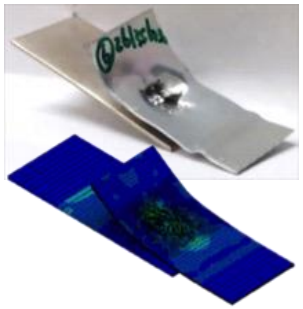


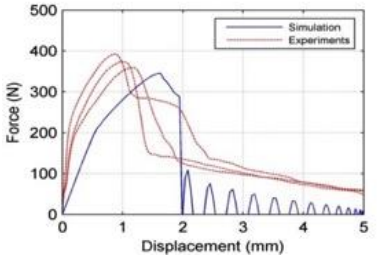


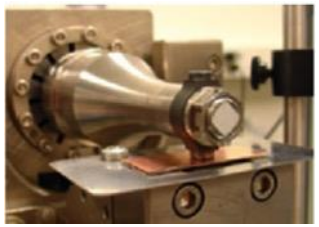
- Bond length
- Post weld hardness
- Weld affected zone
- ……

- Tensile strength
- Peel strength
- Fatigue strength
- ……

Modeling



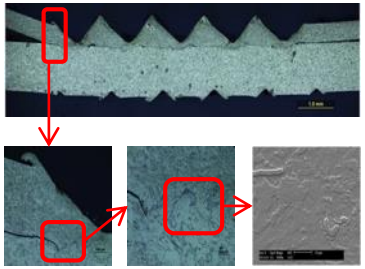




Process Parameters

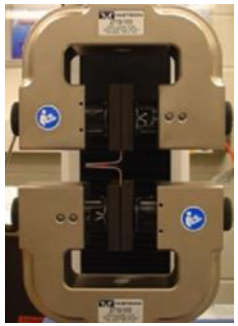
Physics based models, e.g., FEM

Data based models: e.g., Neural Networks



Joint Attributes

Joint Performance



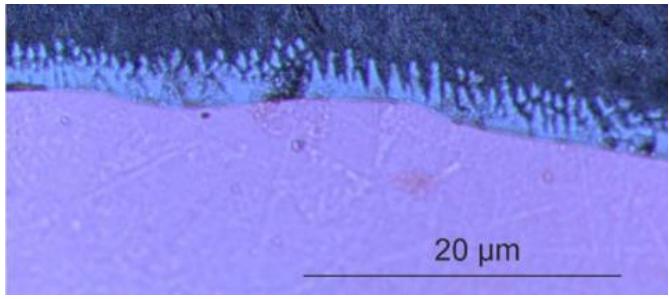
Physics as well as data based models: e.g., FEM, Neural Networks

Selection of Joining Methods

- Design of the joint, selected mateirials and product/structure
- Joining process conditions
- Health and environment safety costs (HES)
- (Flexible) automation and DFx
- Sustainability
- Profitability and robustness

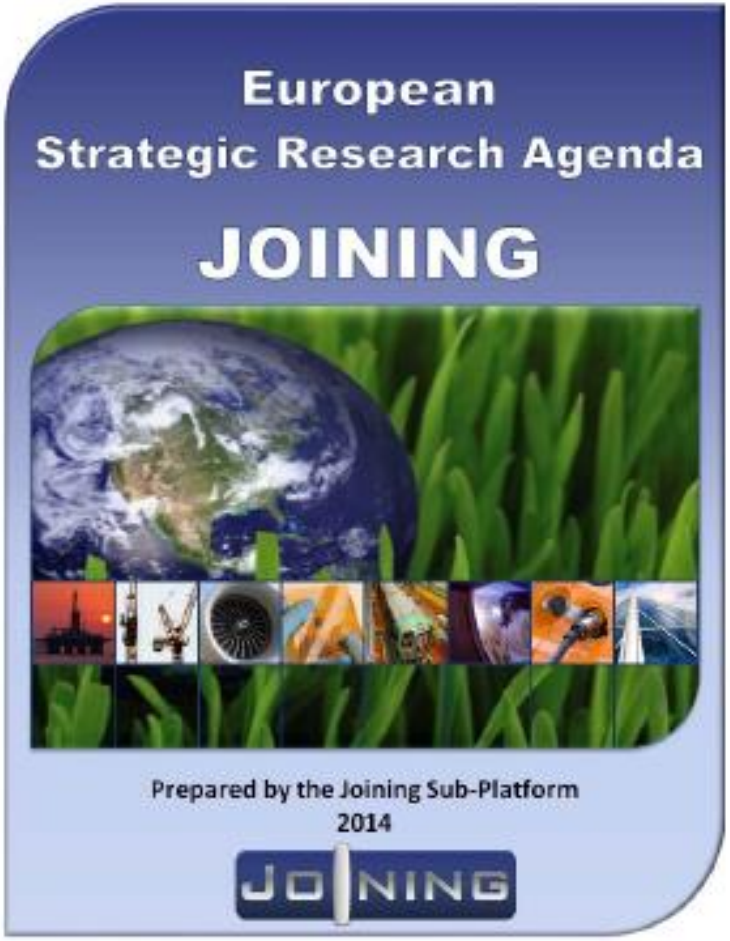
Dissimilar materials		Joining Difficulty	Joining options in perferred order
Material 1	Material 2		
Metal	Metal	1-5	A,B,S,M,F,N
	Ceramic	3-5	B,A,N,M
	IMC	3-5	B,N,M,F
	Termoplastic polymer	1-3	A,M
	Thermoset FR polymer	1-3	A,M
Ceramic	Ceramic	2-4	A,M,B,N,F
	IMC	3-5	B,M,F
	Polymer	2	A
Termoplastic polymer	Termoplastic polymer	1-2	A,F/N, M
	Thermoset FR polymer	1-4	A,F/N, M

Research Challenges for dissimilar materials joining



- Increased understanding of basic bonding mechanisms
- More advanced testing methods and modelling related to life-time, ageing and fatigue
- Calibration and validation of simulation models
- Identify critical and/or main mechanisms for failure
- Identification of critical process, material mismatch situations and/or main mechanisms for failure
- Bridge the gap between modelling scales from atomistic level to macro-level
- Standardisation of testing and characterization of dissimilar materials joints

Manufuture Joining sub-platform
Updated Strategic Research Agenda



- Updated Survey
- Timeline of Priorities Developed
- TRL Identified
- Digitalization of Joining
- Research Priorities Identified

More information:

- Manufuture Sub-Platform for joining: http://www.joining-platform.com/
- CIRP keynote paper on Joining of Dissimilar Materials

CIRP Annals - Manufacturing Technology 64 (2015) 679–699

Contents lists available at ScienceDirect

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