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**Solid state welding of dissimilar materials**

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Solid State Welding of Dissimilar Materials
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THE NORDIC WELDING CONFERENCE
23 August 2018

Solid State Welding...Prior to all Fusion Welding Techniques

Solid State Welding...Forging Leading the Way

Agenda
- Overview of Solid State Welding Techniques
- Overview of Friction Based Techniques
- Friction Stir Welding
  - Fundaments and standardization
  - Examples of industrial applications
  - Characterization of dissimilar joining: Steel/Al and Al/Cu
- Overview of Friction Stir Welding Variants
- Overview of Friction Stir Based Variants
  - Joining aluminium to polymeric based components
Overview of Solid State Welding Techniques

Solid State Welding and Processing Technologies

Overview of Friction Based Technology

Overview of Friction Based Technology...
...Viscoplastic or "Third-body" Domain

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Solid State Welding and Processing Technologies

✓ Overview of Friction Stir Welding

Friction Stir Welding
Features of Industrial Relevance: Patent and Fundaments

One of the most significant development of welding technology in recent history
Last patent (US 5,813,592) assigned to TWI expired on 29 September 2015

Friction Stir Welding
Features of Industrial Relevance: Standardization

Part 2: Design of weld joints
Part 3: Qualification of welding operators
Part 4: Specification and qualification of welding procedures
Part 5: Quality and inspection requirements

Friction Stir Welding
Features of Industrial Relevance: Application Samples

1st know industrial application (~1995)
Production of panels from extruded closed profiles for deep frozen fishing vessels

Friction Stir Welding
Features of Industrial Relevance: Application Samples

AUDI R8 Le Mans

FSW of closed Al hub for wormen Al rim section
Produced by Fundo Wheels for Volvo XC90

Ford GT: FSW of tunnel to Al frame to form housing of transmission system and fuel tank

Sapa Group
Promeco @ Finland

Promeco @ Finland

Audi Q5 Le Mans.
Friction Stir Welding
Features of Industrial Relevance: Application Samples

Medical Industry
- Aluminum/absorptive sheet front cover for Siemens Healthcare 4-ray intensifiers
  - Annual production: 4,000 – 6,000 parts

Building Services
- Weldable high pressure/vacuum cylinders for high efficiency air conditioning units
  - Annual production: 1,000 parts

Military Industry
- Welding headmetal finger protection on the exhaust housing hole for F. Bertini．
  - Annual production: 5,000 – 10,000 parts

Aircraft Industry
- Large flat panels for military transportation
- Components made from high strength extrusions
  - Annual production: 2,500 parts

Water-cooled housing for on-board charger
- Closing of the water cooling channel with an aluminum sheet insert
- Automotive serial production for an European hybrid vehicle
  - Annual production: 30,000 parts

Courtesy by:
RIFTEC (HAI Group)

Friction Stir Welding
Features of Industrial Relevance: Application Samples

Nuclear Fuel and Waste Management
- Cu-OFP Penetration
  -  50mm

Courtesy by:
SBS (Sweden) and Posiva (Finland)

Motivation
All car manufacturers strive for a solution

The ultimate solution to optimized BIW and chassis... with many other applications
**Friction Stir Welding of Dissimilar Materials**

**Joining Aluminium Alloy to Steel Sheet**

**Analysis of Results**

Multi-pass WPS – Optical Microscopy

![Image of weld microstructure showing fusion zone, HAZ, and母 material]

- **Effective thickness of the aluminium alloy sheet**

**Friction Stir Welding of Dissimilar Materials**

**Joining Aluminium to Copper**

**Why to Use Bimetallic Aluminium Copper Busbar?**

- Replacing the connection ends of aluminium busbar with copper:
  - To reduce the electrical contact resistance at the bolted clamped points
  - To promote electrochemical similarity
  - To increase the mechanical resistance at higher temperatures
  - To reduce bolt re-tightening maintenance

**FSW allows efficient joining of Al-Cu needed for high series of high quality busbar products?**

**Friction Stir Welding of Dissimilar Materials**

**Joining Aluminium to Copper**

**Busbar case-study: Coil**

- Clamping force relaxation test:
  - AA6010-T4 x 40% IACS (extruded rectangular shape, with lips compressed to thickness + 0.05mm)
  - Cu-OF x 10% IACS (thickness + 0.05mm)

- FSW weldability analysis:
  - Coil body AA6060-T4, x 67% IACS (annealed plate with thickness + 0.05mm)
  - Coil clamping by Cu-OF, x 100% IACS (extruded bar with thickness + 0.05mm)
Friction Stir Welding of Dissimilar Materials
Joining Aluminium to Copper

FSW DOE optimized joint

Friction Stir Welding of Dissimilar Materials
Joining Aluminium to Copper

Temperature monitoring

Solid State Welding and Processing Technologies

✓ Overview of Friction Stir Welding Variants

Overview of Friction Stir Welding Variants
Friction Stir Welding Variants

- Stationary Shoulder
- Bobbin-Tool

Friction Stir Welding Variants

- FSW Tool - Assisted by Joule Effect

FSW Tool

- Assisted by Joule Effect

Friction Stir Welding Variants

- Ras-Stir
- Skew-Stir
- Com-Stir

Friction Stir Welding Based Variants

- Re-Stir
- Dual-Rotation
- Twin-Stir

Overview of Friction Stir Based Variants
Friction Stir Based Variants

Friction Stir Embossing and Microforming

Near-Net Shaped Manufacture

Friction Stir Based Variants

Friction Stir Processing

Friction Stir Spot Welding

Embedding of SiC particles for FGM

Friction Stir Based Variants

Friction Stir Channeling

Applications of Hybrid Friction Stir Channeling

Al-Al sample

Cu-Al sample

Friction Stir Based Variants

Joining Aluminium to Polymer Based Component

Through Hole Extrusion Welding (THEW) – Aalto, Finland

New manufacturing technique to produce hybrid multilayer structures based on joining Metal to Polymer based components

Variants:

Spot or Multi-spot

Slot (continuous linear or circular)

Joining mechanisms:

Mechanical interlocking

Multi-directional joining

Adhesion

Asymmetric Joint
Final Remark

Techniques based on Solid State Welding and Processing are in permanent advance since many centuries ago resulting in a wide range of solutions (from mature to modern breakthroughs) including some of the most impacting innovations in the Wonderful World Weldability (e.g., Friction Stir Welding).