Solid State Welding
of Dissimilar Materials
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THE NORDIC WELDING CONFERENCE
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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
    o Fundamentals and standardization
    o Examples of industrial applications
    o Characterization of dissimilar joining: Steel/Al and Al/Cu
- Overview of Friction Stir Welding Variants
- Overview of Friction Stir Based Variants
  o Joining aluminium to polymeric based components
Overview of Solid State Welding Techniques

- Diffusion Welding
- Ultrasonic Welding
- Explosion Welding/Cladding
- Friction Based Technology
- High Frequency Welding
- Flash Welding
- Stud Welding

Viscoplastic or “third-body” domain

Overview of Friction Based Technology

- Friction Extrusion
- Friction Hydro Pillar
- Friction Riveting
- Friction Rotary Welding
- Friction Linear Welding
- Friction Flow Drilling

Production of Functionally Graded Materials (FGM)

Friction Flash to Tube (F2T) – Aaltube @ Aalto
Solid State Welding and Processing Technologies

✓ Overview of Friction Stir Welding

Friction Stir Welding
Features of Industrial Relevance: Patent and Fundamentals

- 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

ISO 2538-4:2009, Friction Stir Welding - Aluminium
Part 1: Weldability
Part 2: Design of joint
Part 3: Qualification of welding operators
Part 4: Specification and qualification of welding procedures
Part 5: Quality assurance of welding procedures

Friction Stir Welding
Features of Industrial Relevance: Application Samples

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

Friction Stir Welding
Features of Industrial Relevance: Application Samples

FSW of cast Al hub to strengthen Al rim section
Produced by Fundo Wheels for Volvo XC90

FSW of wheel rims of Samsung Wheels, Australia

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

Promeco @ Finland

Sapa Group

Promeco @ Finland

AUDI R8 Le Mans

Audace @ La Marsee

Coventry (by Sapa Group)

Audace @ La Marsee

Coventry (by Sapa Group)
Friction Stir Welding
Features of Industrial Relevance: Application Samples

New FSW for Space launch System: Vertical Assembly Center (VAC) (NASA Michoud Assembly Facility New Orleans)

Courtesy by: ESAB

Electrical Transformers
Bobbin’s (Siemens, Portugal)

Courtesy by: RIFTEC (HAI Group)

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

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

Friction Stir Welding of Dissimilar Materials
Joining Aluminium Alloy to Steel Sheet

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
Multipass WPS – Optical Microscopy

Friction Stir Welding of Dissimilar Materials
Joining Aluminium Alloy to Steel Sheet

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
Materials

Clamping force relaxation test:
- AA6011-T6, = 65% IACS (extruded rectangular shape, with lips compressed to thickness = 8mm)
- Cu-OF, = 100% IACS (extruded bar with thickness = 8mm)

FSW Weldability analysis:
- Coil body AA6060-H112, = 67% IACS (annealed plate with thickness = 6mm)
- Coil clamping by Cu-OF, = 100% IACS (extruded bar with thickness = 8mm)
Friction Stir Welding of Dissimilar Materials
Joining Aluminium to Copper

FSW DOE optimized joint

Friction Stir Welding of Dissimilar Materials
Joining Aluminium to Copper

Optical microcopy
AA1050-H1424

Friction Stir Welding of Dissimilar Materials
Joining Aluminium to Copper

Temperature monitoring

Friction Stir Welding of Dissimilar Materials
Joining Aluminium to Copper

Electrical properties

Overview of Friction Stir Welding Variants

Solid State Welding and Processing Technologies

✓ Overview of Friction Stir Welding Variants
Friction Stir Welding Variants

- Stationary Shoulder
- Bobbin-Tool

FSW Tool - Assisted by Joule Effect

Ras-Stir
Skew-Stir
Com-Stir

Re-Stir
Dual-Rotation
Twin-Stir

Overview of Friction Stir Based Variants

Solid State Welding and Processing Technologies

✓ Overview of Friction Stir Based Variants

Overview of Friction Stir Based Variants
Friction Stir Based Variants

Friction Stir Embossing and Microforming

Near-Net Shaped Manufacture

Friction Stir Processing

Friction Stir Spot Welding

Friction Stir Embossing and Microforming

Friction Stir Channeling

Applications of Hybrid Friction Stir Channeling

Friction Stir Spot Welding

Embedding of SiC particles for FGM

Engineering Materials Group
Department of Mechanical Engineering

Friction Stir Channeling

Joining Aluminium to Polymer Based Component

Through Hole Extrusion Welding (THEW) – Aalto, Finland

Friction Stir Channeling

Joining Aluminium to Polymer Based Component

Aalto University
School of Engineering

Engineering Materials Group
Department of Mechanical Engineering
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)