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**Solid state welding of dissimilar materials**

*Published in:*
Nordic Welding Conference 2018

Published: 23/08/2018

*Document Version*
Publisher's PDF, also known as Version of record

*Please cite the original version:*
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

Solid State Welding
Leading the Way and… Providing High-Value Modern Solutions

Solid State Welding
...Technological Scope

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

- Diffusion Welding
- Ultrasonic Welding
- Explosion Welding/Cladding
- Friction Based Technology
- High Frequency Welding
- Flash Welding
- Stud Welding
- Viscoplastic or "third-body" domain

Solid State Welding and Processing Technologies

✓ Overview of Friction Based Technology

Overview of Friction Based Technology

...Viscoplastic or "Third-body" Domain

- Friction Extrusion
- Friction Hydro Pillar
- Friction Riveting

Overview of Friction Based Technology

...Viscoplastic or "Third-body" Domain

- Friction Rotary Welding
- Friction Linear Welding
- Friction Flow Drilling

Overview of Friction Based Technology

...Viscoplastic or "Third-body" Domain

- Friction Surfacing
- Production of Functionally Graded Materials (FGM)

Overview of Friction Based Technology

...Viscoplastic or "Third-body” Domain

Friction Flash to Tube (F2T) – Aaltube @ Aalto

IPR: Aalto University, FI 20160043; 2/02/2016
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 developments in welding technology in recent history
Last patent (US 5,813592) assigned to TWI expired on 29 September 2015

Friction Stir Welding
Features of Industrial Relevance: Standardization

ISO 15637-2016 Friction Stir Welding: Aluminium
Part 1: Introduction
Part 2: Design of weld joint
Part 3: Qualification of welding operators
Part 4: Qualification and qualification of welding procedures
Part 5: Quality and inspection requirements

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

Promeco @ Finland

FSW of rear wheels of Renault, France

AUDI R8 Le Mans
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

Engineering Materials Group
Department of Mechanical Engineering

Friction Stir Welding
Features of Industrial Relevance: Application Samples

Medical Industry
Aluminium/ stainless steel front cover for Siemens Healthcare X-ray intensifier
Annual production: 4,000 – 5,000 parts

Building Services
Cable tray, made of extruded thin-gauge aluminium, has high thermal efficiency and conditioning effect.
Annual production: 1,500 parts

Food Industry
Molding shoe metal finger protections on the sandwich diving hoop. Manufacturer: Hertl-Barens.
Annual production: 3,000 – 5,000 parts

Aircraft Industry
Large-frame panels for military transporters. The parts are made from high-strength extrusions.
Annual production: 2,000 parts

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

Courtesy by: RIFTECH (HAI Group)

Engineering Materials Group
Department of Mechanical Engineering

Friction Stir Welding
Features of Industrial Relevance: Application Samples

Nuclear Fuel and Waste Management

Cu-OFP Penetration ≤ 50mm

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

Engineering Materials Group
Department of Mechanical Engineering

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

Joining Aluminium Alloy to Steel Sheet

The Innovative Joint Concept
Promote Joining Mechanism

Innovative lap joint
Conventional FSW lap joint
Clipping

Engineering Materials Group
Department of Mechanical Engineering
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 Aluminum to Copper

Busbar case-study: Coil
Materials

Clamping force relaxation test:
- AA6010-T4, Cu-OF
  (aluminium frame, with lips compressed to thickness = 0.5mm)
  (Cu-OF foil, Cu-OFT, Cu-OF)
  (thickness = 0.5mm)

FSW weldability analysis:
- Cu-OF, Cu-OFT, Cu-OF
  (Aluminium frame, with lips compressed to thickness = 0.5mm)
Friction Stir Welding of Dissimilar Materials
Joining Aluminium to Copper

FSW DOE optimized joint

Solid State Welding and Processing Technologies
✓ Overview of Friction Stir Welding Variants

Friction Stir Welding of Dissimilar Materials
Joining Aluminium to Copper

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

Overview of Friction Stir Based Variants

Solid State Welding and Processing Technologies

✓ 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

- Special oriented for load bearing thick structural 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)