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Application of Friction Stir Welding and Allied Techniques to Aluminium

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Application of Friction Stir Welding and Allied Techniques to Aluminium

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Associate Professor
Materials Joining and NDT

29th October 2014
Turku, Finland

AGENDA

☞ Introduction to School of Engineering of Aalto University
☞ Fundaments of Friction Stir Welding (FSW)
☞ Industrial Application Samples of FSW
☞ Variants of FSW
☞ Innovations Based on Friction Stir Concept
☞ Applications and Developments of FSW at Aalto University
Aalto University
- Where Science and Art meet Technology and Business

Created from the merger of 3 leading Finnish universities 1 January 2010:

- the Helsinki School of Economics (HSE), founded 1911
- the University of Art and Design Helsinki (TaiK), founded 1871
- the Helsinki University of Technology (TKK), founded 1849

Aalto University is a community of:
- 75,000 alumni
- 20,000 students
- 4,700 faculty & staff
- with 340 professors

Aalto University
6 Schools (with a Dean) and Respective Focus Areas

<table>
<thead>
<tr>
<th>School of Engineering</th>
<th>School of Science</th>
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<tbody>
<tr>
<td>• Arctic technology</td>
<td>• Computing and modeling</td>
</tr>
<tr>
<td>• Mechanics and material technology</td>
<td>• Materials physics</td>
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<tr>
<td>• Multidisciplinary energy technologies</td>
<td>• Energy sciences</td>
</tr>
<tr>
<td>• Sustainable built environment</td>
<td>• ITC, software and media</td>
</tr>
<tr>
<td>• Systems design and production</td>
<td>• Neuroscience and technology</td>
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<table>
<thead>
<tr>
<th>School of Chemical Technology</th>
<th>School of Electrical Engineering</th>
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<tr>
<td>• Sustainable use and processing of natural resources</td>
<td>• Energy</td>
</tr>
<tr>
<td>• New materials</td>
<td>• Health and wellbeing</td>
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<tr>
<td>• Energy technologies</td>
<td>• Environment</td>
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<table>
<thead>
<tr>
<th>School of Arts, Design and Architecture</th>
<th>School of Business</th>
</tr>
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<tr>
<td>• User driven design and art</td>
<td>• Strategic management &amp; marketing in the global context</td>
</tr>
<tr>
<td>• Art &amp; design, science and business</td>
<td>• Microeconomics</td>
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<tr>
<td>• Heritage based forerunning</td>
<td>• Behavioral finance &amp; corporate governance</td>
</tr>
<tr>
<td>• Sense based skills and knowledge</td>
<td>• Decision-making</td>
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Welding Technology

History

Materials Joining and NDT
Department of Engineering Design and Production
Welding Technology

Classification

**Welding Process Classification**

**Fusion Welding**
Includes partial fusion of Base Material, with /without application of pressure, with/without filler metal added to weld pool

**Brazing and Soldering**
No fusion of base material components which are joined by inserting melted filler metal in the overlap joint configuration

**Solid State Welding**
Joining is obtained by solid state joining mechanisms

Note: There are (many) others possible classifications
Welding Technology
Solid State Welding History

Iron and coal; 1855-60
(The industrial revolution by William Bell Scott)

Friction Stir Processing

Solid State Welding Classification

High-frequency; Flash; Stud (liquid joining interface)

Mechanical Energy
Cold Pressure

Thermomechanical Activation
Mechanical Activation
Thermal Activation

T_recrytalization
T_forest

Heat Energy
Solid State Welding
Sample of Conventional Solutions

High-Frequency Welding
Stud Welding
Ultrasonic Welding

“Third-Body” Region Based Technologies
Friction Based Technology
Sample of Processes

Friction Welding

Internacional Patent
2/1956 (A.I.Chudikov)

Friction Extrusion  Friction Hydro Pillar  Friction Riveting

© TWI, England
© HGZ, Germany
Friction Based Technology
Sample of Processes

Friction Surfacing
FS Production of Functionally Graded Materials (FGM)

Friction Stir Welding Process
Fundaments and Parameters
FSW was patented by TWI, 1991, W. Thomas et al., UK
Friction Stir Welding Process
Inventor: Wayne Morris Thomas @ TWI (UK)

The responsible for the most significant development of welding technology in recent history


Last Patent (US 5,813592) assigned to TWI Expires: 29 September 2015

Friction Stir Welding Process
Fundaments - Typical Macrostructure
Friction Stir Welding Process
Fundamentals – Heat Input

\[ P_{\text{mech}}[W] = [M[w_{\text{max}}] \times 2\pi \Omega_{\text{rpm}} + F[u] \times v[\text{mm/min}]] \times \frac{1000}{60} \]

\[ \eta_{\text{heat}} = \left(1 - \frac{P_{\text{heat}}}{P_{\text{mech}}} \right) \times 100\% \]

\[ HJ/[\text{J/mm}] = \frac{P_{\text{heat}}[W]}{v[\text{mm/min}]} \times 60 \]

Friction Stir Welding Process
Fundamentals – Tool Geometry

Shoulders

Probes

Aalto University
School of Engineering
Department of Engineering Design
and Production
Materials Joining and NDT
Friction Stir Welding Process
Fundaments – 3D Material Flow

Friction Stir Welding Process
Fundaments – Standards

ISO EN DIN 25239 (03/2012) Friction Stir Welding - Aluminium

Part 1: Vocabulary
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

AWS D17.3 / D17.3M:2010
Specification for Friction Stir Welding of Aluminum Alloys for Aerospace Applications
### Friction Stir Welding Process
#### Fundaments – Advantages versus Disadvantages

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
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<tbody>
<tr>
<td>Welds materials whose structure and properties would be degraded by fusion welding</td>
<td>Wielding anvil required (except bobbin stir tools)</td>
</tr>
<tr>
<td>Minimal distortion + Low residual stress levels compared to fusion welding processes</td>
<td>Keyhole at the end of each weld (except when a tool with a retractable probe is used)</td>
</tr>
<tr>
<td>Environmentally friendly + Safe: No fumes + No radiation + High energy efficiency</td>
<td>Workpiece requires rigid clamping (except when the Twin-stir™ variant is used)</td>
</tr>
<tr>
<td>Easy repeatability + good control: suitable for automation and robotization</td>
<td>Application not as flexible as certain fusion welding processes</td>
</tr>
<tr>
<td>Good mechanical properties: No cracks + No porosity</td>
<td></td>
</tr>
<tr>
<td>No consumables for aluminium alloys</td>
<td></td>
</tr>
<tr>
<td>Joint can be produced from one side and in all positions</td>
<td></td>
</tr>
<tr>
<td>Minimal edge preparation required</td>
<td></td>
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<tr>
<td>Not influenced by magnetic forces</td>
<td></td>
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#### Industrial Application Samples of FSW

**Shipbuilding Industry**

- First vessel (catamaran) in history made from FSW panels was built by Fjellstrand AS in 1996
- The panels were made by Marine Aluminium. This kick started the industrialization of FSW process
- Panels with total FSW length of 110km from 1996 to 1999
Industrial Application Samples of FSW
Aeronautic Industry

- Eclipse Aviation @ USA
- Wing
- Fuselage

Industrial Application Samples of FSW
Aerospace Industry

- Boeing Co @ USA
- FSW facility dedicated for the production of the fuel tanks of Delta IV
Industrial Application Samples of FSW

Aerospace Industry

New FSW for Space Launch System:

Vertical Assembly Center (VAC)
(NASA’s Michoud Assembly Facility New Orleans)

61 m Tall x 8.4 m Diameter

Cryogenic liquid hydrogen and liquid oxygen that will feed the vehicle’s RS-25 engine

Industrial Application Samples of FSW

Automotive Industry

Tailored Blanks joined by FSW and subsequently formed

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

FSW of Tailor Welded Blanks using dissimilar thickness Al sheets - TWI research study

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

Friction Stir Welds
Industrial Application Samples of FSW

Railway Industry

A-Train concept from Hitachi, Ltd @ Japan for rolling stock based on FSW

Features:
- Self-supported module
- Mounting rail fastening by bolts
- Reduced number of parts
- No adjustment work required
- Easier refit/repair and maintenance

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Informatics Industry

Apple 21.5 and 27-inch iMac 2012 @ USA

Apple slims down iMac 40% with 'friction-stir welding' & ditching the disc drive

By Daniel Eran Dilger

Apple’s new iMac updates the company’s flagship Macintosh into a faster, faster and—in particular—thinner version of itself.
Industrial Application Samples of FSW
FSW (kitkahitsaus) in Finland

- Equipment delivered to KMT Oy (PROMECO-Kankaanpää) in 12.2003
- Modular LEGIO 5UT (6m x 0.5m x 0.3m)
- Applied e.g. electromechanical components

Jori Oy (South Ostrobothnia) designed and built their own automatic FSW machine in 2004
Table 14m long for FSW of Al alloy tanks mostly for powder

Industrial Application Samples of FSW
Architecture Application

- Nobel Peace Centre @ Oslo, Norway
  Canopy by David Adjaye that serves as gateway between Oslo City Hall where the Peace Prize Ceremony takes place and the Nobel Peace Center
Friction Stir Welding
Based Innovations

Com-stir™ Welding  Stationary Shoulder FSW  Skew-stir™ Welding
Twin-stir™ Welding  Re-stir™ Welding
Re-stir™ Welding  Bobbin Tool Stir Welding  Dual-rotation FSW

Friction Stir Welding
Variants

Friction Stir Based Innovations

Friction Stir Processing  Friction Stir Channeling
Friction Stir Microforming  Friction (Stir) Spot Welding
Near-Net Shaped Manufacture by FSW  Friction Stir Self Embossing and In-Process Forging/Forging
FSW @ Aalto University
Different Joints and Materials

Overlap

Thick Al alloy

Dissimilar Mg-Al

Polyamide

Dissimilar Al-Cu

SPIF of tailored blanks welded by FSW

Thin Al alloy

Mg Alloy

Cu

Al alloy embedding steel

Dissimilar thickness

FSW @ Aalto University

Thank You / Kiitos / Tack

Department of Engineering Design and Production

29th October 2014
Turku, Finland