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Application of Friction Stir Welding and Allied Techniques to Aluminium

Published: 01/01/2014

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

Please cite the original version:
Application of Friction Stir Welding and Allied Techniques to Aluminium

Professor Pedro Vilaça *

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

School of Engineering
- Arctic technology
- Mechanics and material technology
- Multidisciplinary energy technologies
- Sustainable built environment
- Systems design and production

School of Science
- Computing and modeling
- Materials physics
- Energy sciences
- ITC, software and media
- Neuroscience and technology
- Creating and transforming technology based entrepreneurship

School of Chemical Technology
- Sustainable use and processing of natural resources
- New materials
- Energy technologies

School of Electrical Engineering
- Energy
- Health and wellbeing
- Environment
- Information and communication technology
- Micro- and nanotechnology

School of Arts, Design and Architecture
- User driven design and art
- Art & design, science and business
- Heritage based forerunning
- Sense based skills and knowledge

School of Business
- Strategic management & marketing in the global context
- Microeconomics
- Behavioral finance & corporate governance
- Decision-making
Welding Technology

History

- Bare electrode 1888
- Electric Arc 1904
- Oxifuel 1903
- SAW 1930
- GTAW 1940
- Welding 1950
- Plasma PAW 1958
- EBW 1959
- Electro-slag 1961
- Electro-gas
- Sinergic 1980
- FCAW 1970
- CMT 1990
- CO₂
- Nd-YAG
- Excimers
- Diodes
- Fiber
- Laser 1970
- ... Thermite 1920

Welding Technology

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

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**Solid State Welding**
Classification

Mechanical Energy

Friction; Ultrasonic; Explosion; Diffusion

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

Mechanical Activation

Thermomechanical Activation

Thermal Activation

No-Weld

T_{recrystallization} T_{fusion} T [°C]

Cold Pressure

Heat Energy

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Solid State Welding
Sample of Conventional Solutions

High-Frequency Welding

Stud Welding

Ultrasonic Welding

“Third-Body” Region Based Technologies

Friction Stir Based Technologies

Friction Stir Welding

Friction Stir Welding Variants

Friction Based Technologies

Hybrid Joining (third-body friction joining)

Friction Brazing

Friction Extrusion

Orbital Friction Welding

Radial Friction Welding

Rotary Friction Welding (inertia and continuous drive)

Friction Flow Drilling

Friction Stir Welding

Friction Stitch Welding

Friction Riveting

Aalto University
School of Engineering
Department of Engineering Design and Production
Materials Joining and NDT
**Friction Based Technology**

Sample of Processes

Friction Welding

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

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Friction Extrusion  
Friction Hydro Pillar  
Friction Riveting

© TWI, England  
© HGZ, Germany

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Aalto University  
School of Engineering  
Department of Engineering Design and Production  
Materials Joining and NDT
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
Fundamentals - Typical Macrostructure
Friction Stir Welding Process
Fundamentals – Heat Input

\[
P_{\text{mech}} [\text{W}] = \left[ M [\text{N.m}] \times 2 \pi n_r \Omega [\text{rpm}] + F [\text{N}] \times v [\text{mm/min}] \right] \times \frac{1000}{60}
\]

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

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

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

- Welds materials whose structure and properties would be degraded by fusion welding
- Minimal distortion + Low residual stress levels compared to fusion welding processes
- Environmentally friendly + Safe: No fumes + No radiation + High energy efficiency
- Easy repeatability + good control: suitable for automation and robotization
- Good mechanical properties: No cracks + No porosity
- No consumables for aluminium alloys
- Joint can be produced from one side and in all positions
- Minimal edge preparation required
- Not influenced by magnetic forces

- Backing anvil required (except bobbin stir tools)
- Keyhole at the end of each weld (except when a tool with a retractable probe is used)
- Workpiece requires rigid clamping (except when the Twin-stir™ variant is used)
- Application not as flexible as certain fusion welding processes

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**

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**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

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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

- Double-skirt structure
- Aluminum hollow extrusion
- Easy tightening and loosening

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

Informatics Industry

- Apple 21.5 and 27-inch iMACs 2012 @ USA

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

By Daniel Steinberg

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

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**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

Friction Stir Welding Variants

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

Friction Stir Based Technologies

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

Overlap

"U" "L" "T"

Thick Al alloy
Mg Alloy
Dissimilar Mg-Al
Thin Al alloy
Copper

Alloy embedding steel
Polyamide

Dissimilar Al-Cu

SPIF of tailored blanks welded by FSW

Thank You / Kiitos / Tack

29th October 2014
Turku, Finland