Santos Vilaca da Silva, Pedro

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:
Santos Vilaca da Silva, P. (2014). *Application of Friction Stir Welding and Allied Techniques to Aluminium*. Paper presented at Aluminium Days (Alumiinipäivät), Turku, Finland.

Aalto University
School of Engineering

Department of Engineering
Design and Production

Application of Friction Stir Welding and Allied Techniques to Aluminium

Professor Pedro Vilaça *

* Contacts
Address: P.O. Box 14200, FI-00076 Aalto, Finland
Visiting address: Puumiehenkuja 3, Espoo
pedro.vilaca@aalto.fi ; Skype: fsweldone

Associate Professor
Materials Joining and NDT

ALUMIINIPÄIVÄT

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

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

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

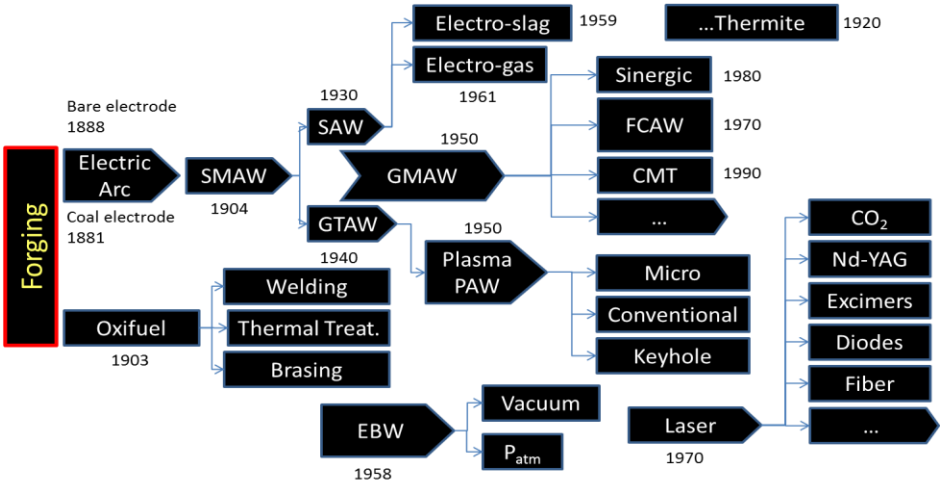
School of Electrical Engineering
- Energy
- Health and wellbeing
- Environment
- Information and communication technology
- Micro- and nanotechnology

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



Welding Technology

Classification

Welding Process Classification

Note: There are (many) others possible classifications

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

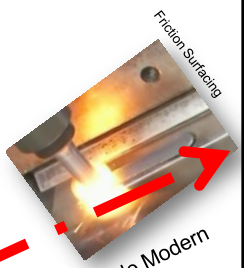
Brazing and Soldering
No fusion of base material components which are joined by inserting melted filler metal in the overlap joint configuration

Solid State Welding
Joining is obtained by solid state joining mechanisms

Welding Technology

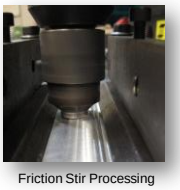
Solid State Welding History

1904 – "Welding he big ring"

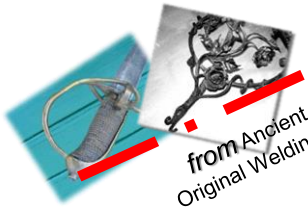


Friction Surfacing

…*into* Most Reliable Modern Joining Techniques



Friction Stir Processing



from Ancient Original Welding…

…*through* Industrial Revolution…

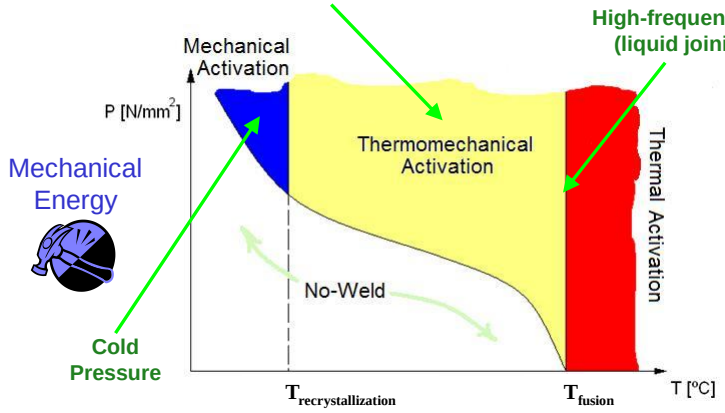
Iron and coal ; 1855-60 (The industrial revolution by William Bell Scott)

Solid State Welding

Classification

Friction; Ultrasonic; Explosion; Diffusion

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



Mechanical Energy

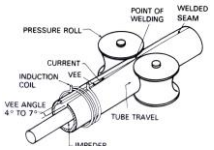
Cold Pressure

Heat Energy

Solid State Welding

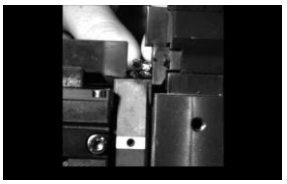
Sample of Conventional Solutions

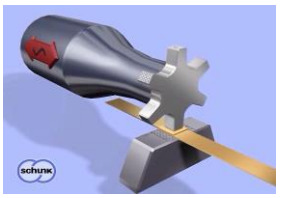
High-Frequency Welding



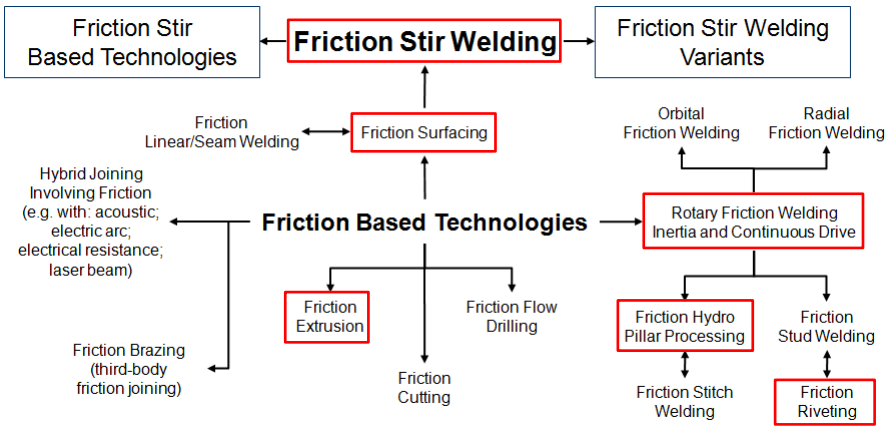
Stud Welding

Ultrasonic Welding





"Third-Body" Region Based Technologies

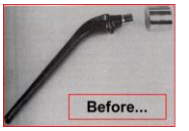


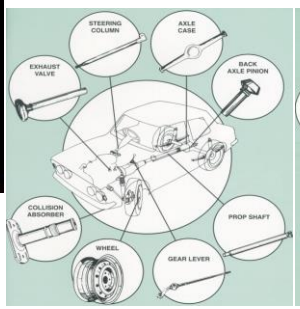
Friction Based Technology

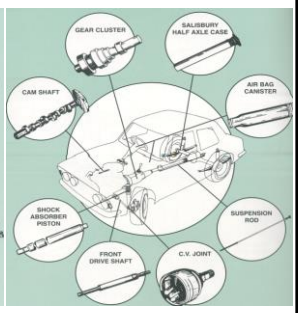
Sample of Processes

Friction Welding

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





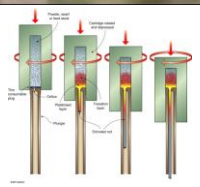


Friction Based Technology

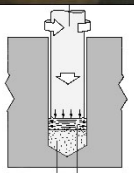
Sample of Processes

Friction Extrusion

© TWI, England

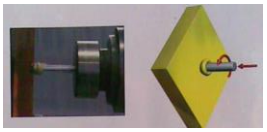


Friction Hydro Pillar



Friction Riveting

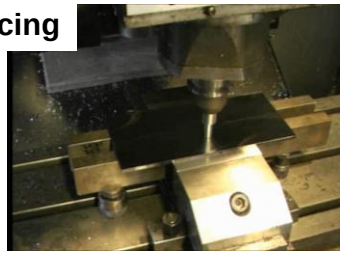
© HGZ, Germany

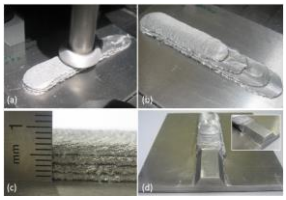


Friction Based Technology

Sample of Processes

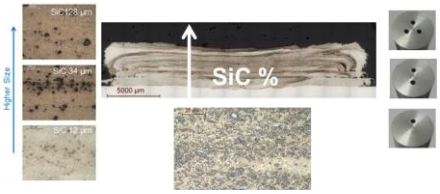
Friction Surfacing





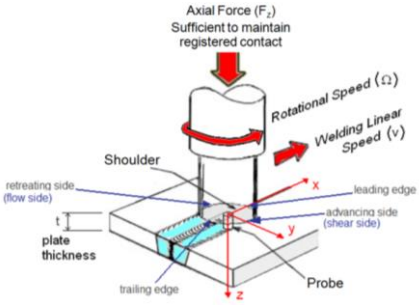
FS for **Built-Up**

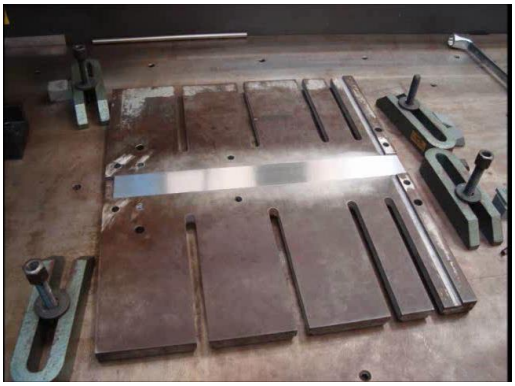
FS Production of
Functionally Graded Materials (**FGM**)



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)

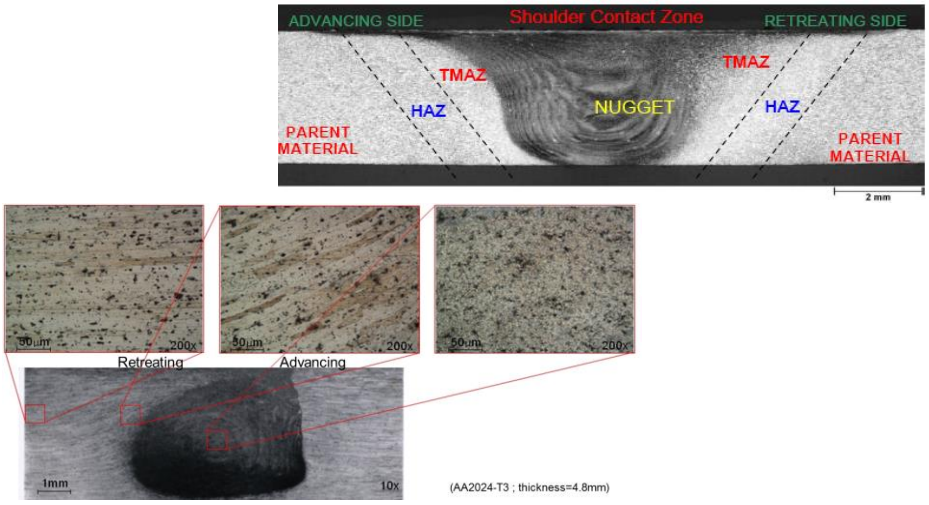
☞ The responsible for the most significant development of welding technology in recent history

1. Thomas W M, Nicholas E D, Needham J C, Murch M G, Temple-Smith P, and Dawes C J, 'Improvements relating to friction stir welding'. **US Patent** No. 5,460,317, **1991**
2. Nicholas E D and Thomas W M: 'Improvements Relating to Friction welding'. **International Patent Application,** B23K 20/12, b29C 65/06, May 30t**h 1995**

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

Friction Stir Welding Process

Fundaments - Typical Macrostructure



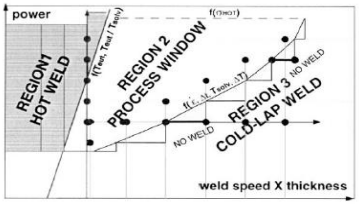
Friction Stir Welding Process

Fundaments – Heat Input

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

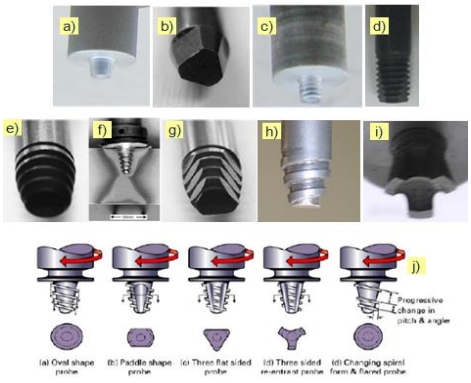
$$\eta_{heat} = \left(1 - \frac{P_{heat}}{P_{mech}}\right) \times 100\%$$

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



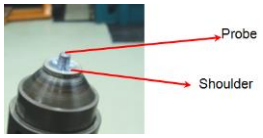
Friction Stir Welding Process

Fundaments – Tool Geometry



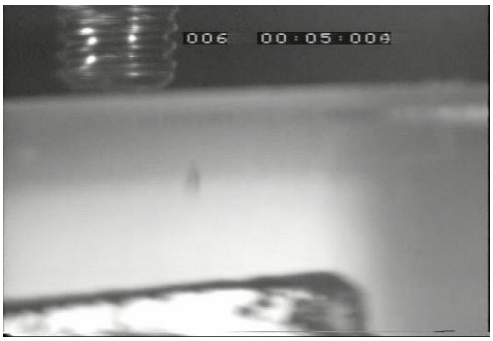
Shoulders

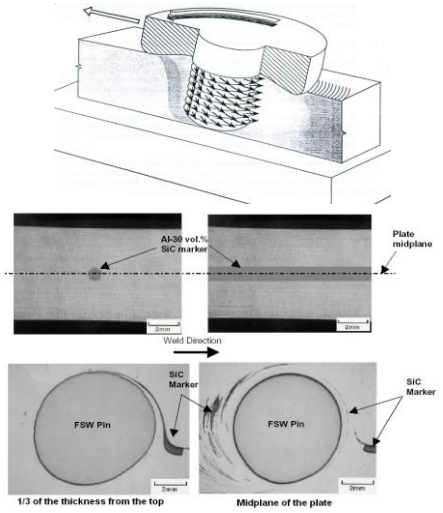
Probes



Friction Stir Welding Process

Fundaments – 3D Material Flow





B. London

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

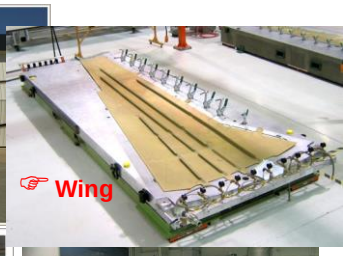
Shipbuilding Industry

- ☞ 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 lenght 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

☞ Vertical and orbital FSW joints: 1998-2000

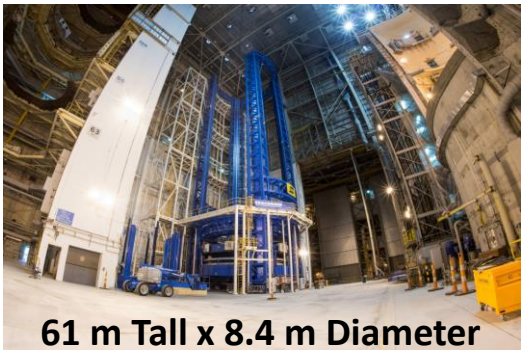
Industrial Application Samples of FSW

Aerospace Industry

New FSW for Space Launch System:

☞ **Vertical Assembly Center (VAC)**

(NASA's Michoud Assembly Facility New Orleans)

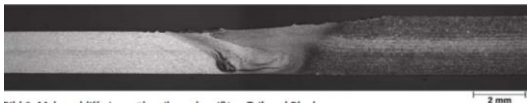


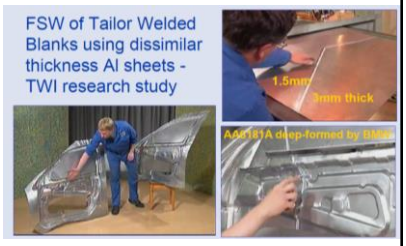
Cryogenic liquid hydrogen and liquid oxygen that will feed the vehicle's RS-25 engine

Industrial Application Samples of FSW

Automotive Industry

☞ Tailored Blanks joined by FSW and subsequently formed

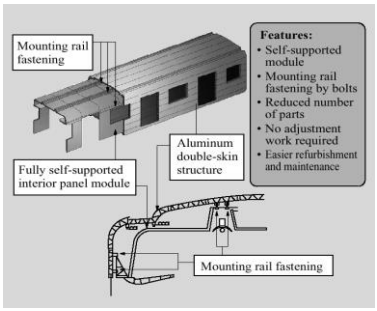


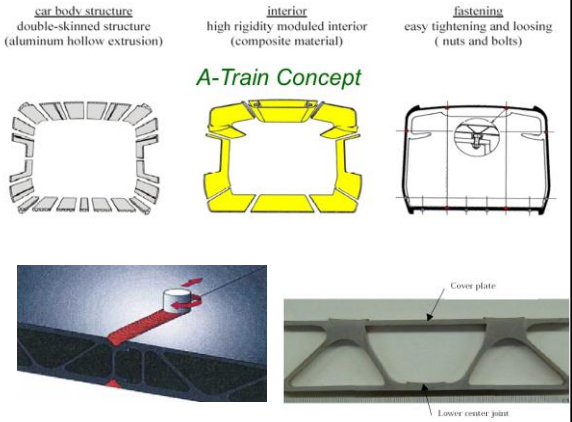


Industrial Application Samples of FSW

Railway Industry

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





Industrial Application Samples of FSW

Informatics Industry

☞ Apple 21.5 and 27-inch iMACs 2012 @ USA

Wednesday, October 24, 2012, 04:53 pm

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

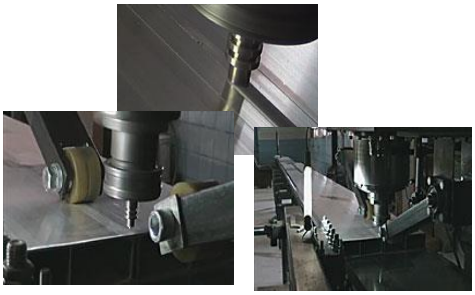
By Daniel Eran Dilger

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



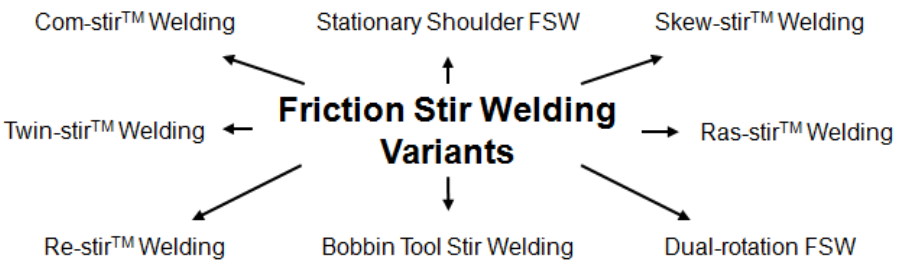
Industrial Application Samples of FSW

Architecture Application

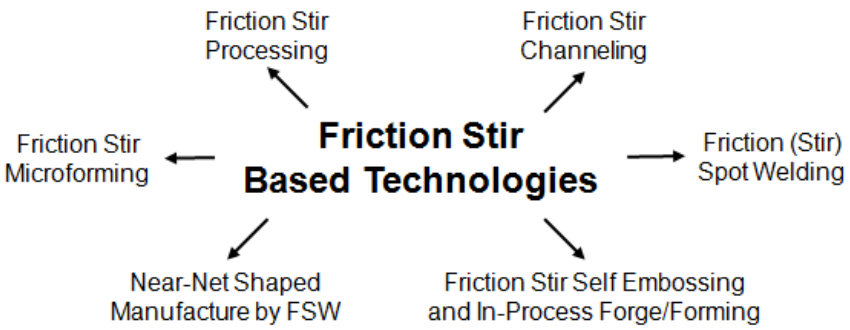
- Nobel Peace Centre @ Oslo, Norway

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

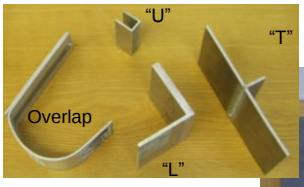


Friction Stir Based Innovations

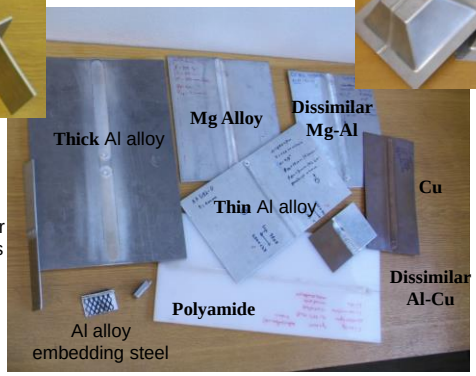


FSW @ Aalto University

Different Joints and Materials



SPIF of tailored blanks welded by FSW



Dissimilar thickness

Aalto University
School of Engineering

Department of Engineering Design and Production

Thank You / Kiitos / Tack

ALUMIINIPÄIVÄT

29th October 2014
Turku, Finland