Joining Dissimilar Materials for Transport Applications

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A rotating bar is held against a stationary bar. Friction between material surfaces generates heat. The two bars are then forged together to produce a solid phase joint.
Rotary Friction Welding - Overview

• Rotary Friction Welding (RFW) is a solid phase joining technology based on rotary motion.
• RFW is typically a high productivity process capable of high weld quality and excellent repeatability.
• RFW machines are normally relatively large and can be relatively expensive items.
• RFW is therefore most commonly used for high value and/or high volume component manufacture.
• RFW is a mature production technology, with many applications worldwide. Key industry sectors include Aerospace, Oil and Gas, Automotive, Construction.
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<thead>
<tr>
<th>Material</th>
<th>Aluminium Alloys</th>
<th>Copper Alloys</th>
<th>Medium Carbon Steel</th>
<th>Low Alloy Steel</th>
<th>Through Hardening Steel</th>
<th>High Speed Steel</th>
<th>Austenitic Stainless Steel</th>
<th>Ferritic Stainless Steel</th>
<th>Duplex Stainless Steel</th>
<th>PH Stainless Steel</th>
<th>Martensitic Stainless Steel</th>
<th>Nickel</th>
<th>Nickel Alloys</th>
<th>Niobium</th>
<th>Titanium Alloys</th>
<th>Tungsten</th>
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Matrix courtesy of British Standards International / Thompson Friction Welding
Common applications include Al-Ti, Al-steel, Ni-steel, Al-Cu and many dissimilar alloys and product forms.

R+D work concentrates on new and/or challenging combinations and opportunities for tailored properties and optimised performance.

For example: New “CleanTools” project on RFW of SMAs (Nitinol).
Recent R+D Work - RFW

Rotary Friction Welding of Dissimilar Materials

• TWI exploratory project work has been conducted to develop effective procedures for Ti-Stainless Steel joints.

• Promising results achieved by optimisation of parameters and metallurgical control at interface.
Emerging Technology - Hybrid RFW

New Hybrid RFW Machines

MTI 125 Ton Tri-Mode
Feb 2011

MTI 300 Ton Tri-Mode
April 2012
**Tri-Mode Welding**

- **3 Welding Modes**
  - Pure Direct-Drive
  - Pure Inertia
  - & now a combination of both

- **Several benefits of tri-mode operation:**
  - Flexibility to customise the weld cycle without any of the limitations of a single style machine – combine any desirable portion of the weld cycle to optimise welding performance for particular material combinations and part geometries
  - In addition, these machines have a spindle drive motor to employ length and orientation control during an inertia weld.
  - Enhanced weldability window for difficult to weld materials and improved control for dissimilar materials welding.
Linear Friction Welding

Linear Friction Welding Applications - Blisks

LFW of Blisks for the Eurofighter Typhoon by MTU, Munich
LFW Process
Materials Welded by LFW at TWI

- Titanium and Ti alloys
- Nickel alloys
- Stainless steels
- Carbon Steels
- Aluminium alloys
- Copper and alloys
- Refractory alloys
- Intermetallics
- ODS Alloys
- MMCs

- Titanium – Steel
- Titanium – Nickel
- Titanium – Stainless
- Aluminium – Steel
- Aluminium – Stainless
- Aluminium – Copper
- Copper - Stainless
- Thermoplastics
- Wood!
LFW of Dissimilar Ti Alloys

\[ \alpha-\beta \text{ forged } \alpha-\beta \text{ alloy} \]

\[ \beta \text{ forged } \beta \text{ alloy} \]

Fracture

Weld Line

AG1-01T01

25mm
LFW of Machining Preforms

- Material and machining costs can be reduced by using machining preforms produced by LFW.
- Typical applications include components that are currently machined from solid blocks of high value materials.
- Materials chosen to optimise performance, minimise cost, reduce weight.
**LFW of Preforms - Examples**

**Example 1 – Ti-6Al-4V Demonstration Part:**

Part Specification

LFW Preform (part machined)

Demonstration work carried out in conjunction with Thompson Friction Welding, LFW machine suppliers: (www.linearfrictionwelding.com)
Example 2 – Ti-6Al-4V Demonstration Part:

Part Specification

LFW Preform (part machined)

Demonstration work carried out in conjunction with Thompson Friction Welding, LFW machine suppliers: (www.linearfrictionwelding.com)
Example – Ti-6Al-4V Demonstration Part:

Part Specification

LFW Preform (part machined)

Demonstration work carried out with Thompson Friction Welding
New State of the Art E20 LFW machine

- Enhanced controls for difficult to weld materials
- Programmable weld profiles
- Variable waveforms
Friction Stir Welding (FSW)

- A rotating FSW tool is plunged between two clamped plates.
- Friction between the tool and the plate material generates heat, which causes a plasticised zone to form around the tool.
- The rotating tool is then traversed, frictionally heating and plasticising material as it moves, forming a solid-phase joint.
**Materials Weldable by FSW**

- Wrought aluminium alloys (virtually all grades/tempers)
- Aluminium extrusions (6xxx, 7xxx, all tempers)
- Aluminium castings (Al-Si and Al-Mg based)
- Magnesium alloys (Pressure die castings and wrought)
- Copper alloys (electrical grades, pure copper, brasses etc)
- Zinc alloys
- Lead alloys
- C-Mn and Alloy steels
- Stainless steels
- Titanium alloys
- Nickel alloys

Plus a range of dissimilar material combinations
FSW Applications - Automotive

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

Wheel courtesy of Fundo wheels

Friction Stir Welds
AdStir Technique

Internal Corner Configuration

Into the weld view  Away from the weld view
AdStir Technique
AdStir

8mm thick plate AA6082-T6 tee weld with AA6082-T6 filler
8mm thick plate AA5083-O tee weld with AA6082 Filler
8mm thick plate AA7075-T6 and AA2014-T6 tee weld with AA6082-T6 filler
CompoSurf™ Coating Technologies

- Increasing use of composites
- Need for functional coatings
- Often difficult to coat composite materials:
  - Composite surface finish
  - Resin type (and associated $T_{\text{max}}$)
  - Resin thickness
  - Process selection
- CompoSurf™ coatings offer increased functionality for composites in automotive, aerospace, defence and power applications
CompoSurf™ Coatings

- CompoStrike™ - Lightning strike coatings
- CompoIR™ - Reflective coatings for thermal management
- CompoTherm™ - TBC type coatings
- CompoWear™ - Wear / erosion resistant coatings
- CompoConduct™ - Conductive coatings for faraday applications and electrical distribution
- CompoDec™ - Decorative coatings e.g. architectural
Examples of CompoSurf™ Technology
Summary

• Solid state welding techniques are already widely used for welding of dissimilar materials
• Many material combinations can be welded and close control of the process is required to optimise weld quality/performance
• Enhanced functionality of new equipment and new process variants have the potential to further widen the range of materials that can be welded and the performance of resulting welds
• Further potential for mixed material components with optimised properties/performance
• Technique for spraying of functional coatings on to composite materials shows promise for enhancing properties/performance of lightweight components