RESURGAM
Training WEBINAR:
Other potential markets

TWI

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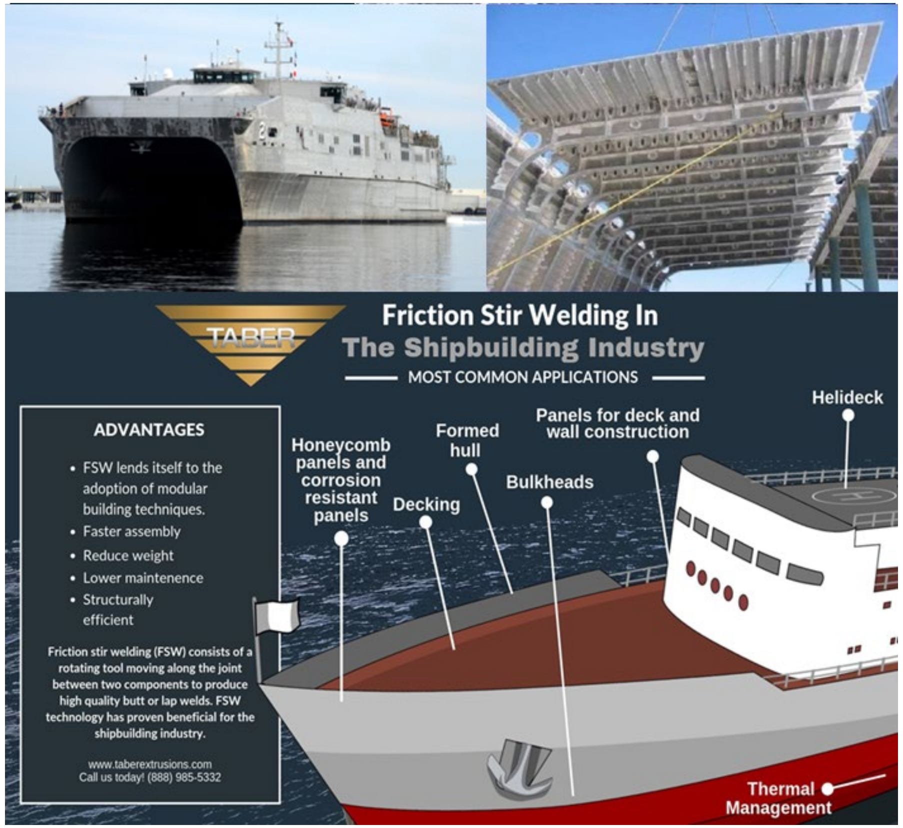
FSW – quo vadis?

- In the first webinar in this training programme we looked at how FSW was invented, the principles behind it and its many potential advantages over conventional fusion welding for both fabrication and repair.

- The technology has been transferred from aluminium to steel under project RESURGAM, primarily for the shipbuilding industry. However, a number of other market sectors have expressed an interest in our findings and in this seminar we will look at some of those opportunities.

Benefits: proven in aluminium for 30 years

- Solid phase joining process
- Single pass welding
- 1mm to 75mm per pass in Al alloys.
- Mechanised, repeatable process
- No specialised pre-weld edge profiling or cleaning
- No shielding gas or filler wire required for most materials
- Low distortion and shrinkage
- Weld in any orientation
- Excellent weld mechanical properties
- High efficiency process with very low energy consumption
- Typically lower cost than competing processes
- Health & Safety benefits
    - No welding fume or spatter
    - No UV or electromagnetic radiation



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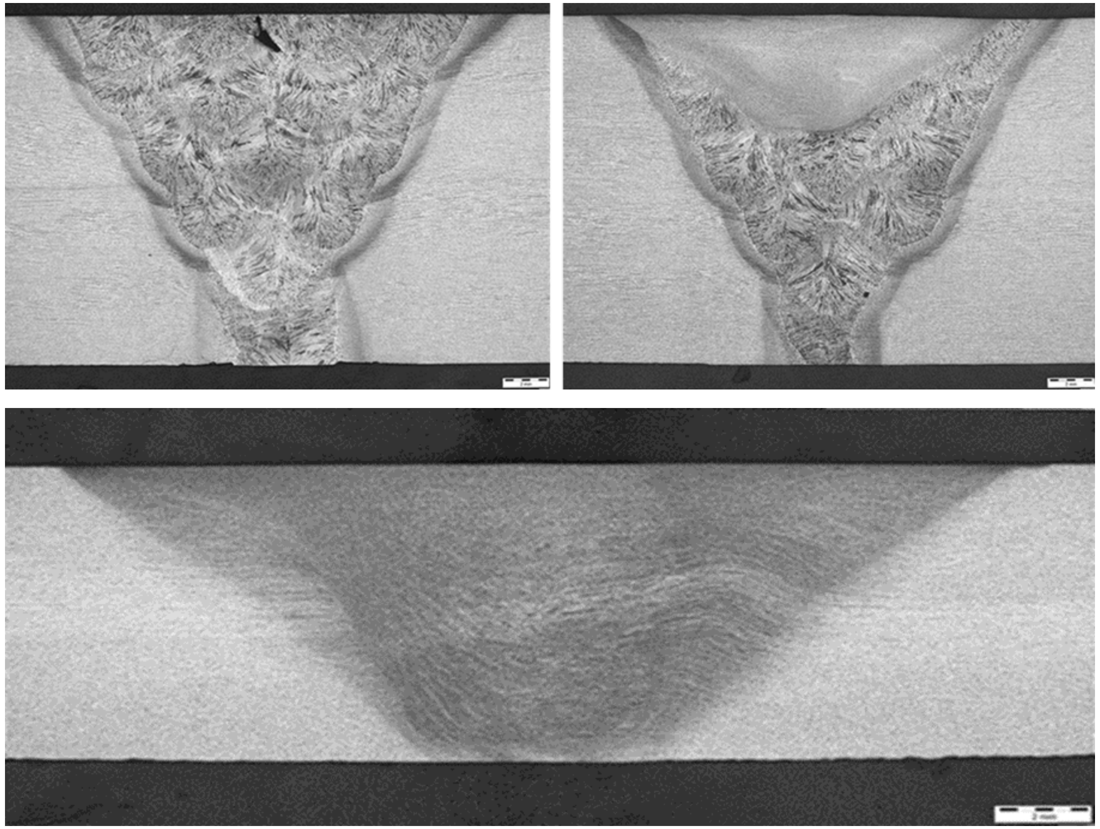
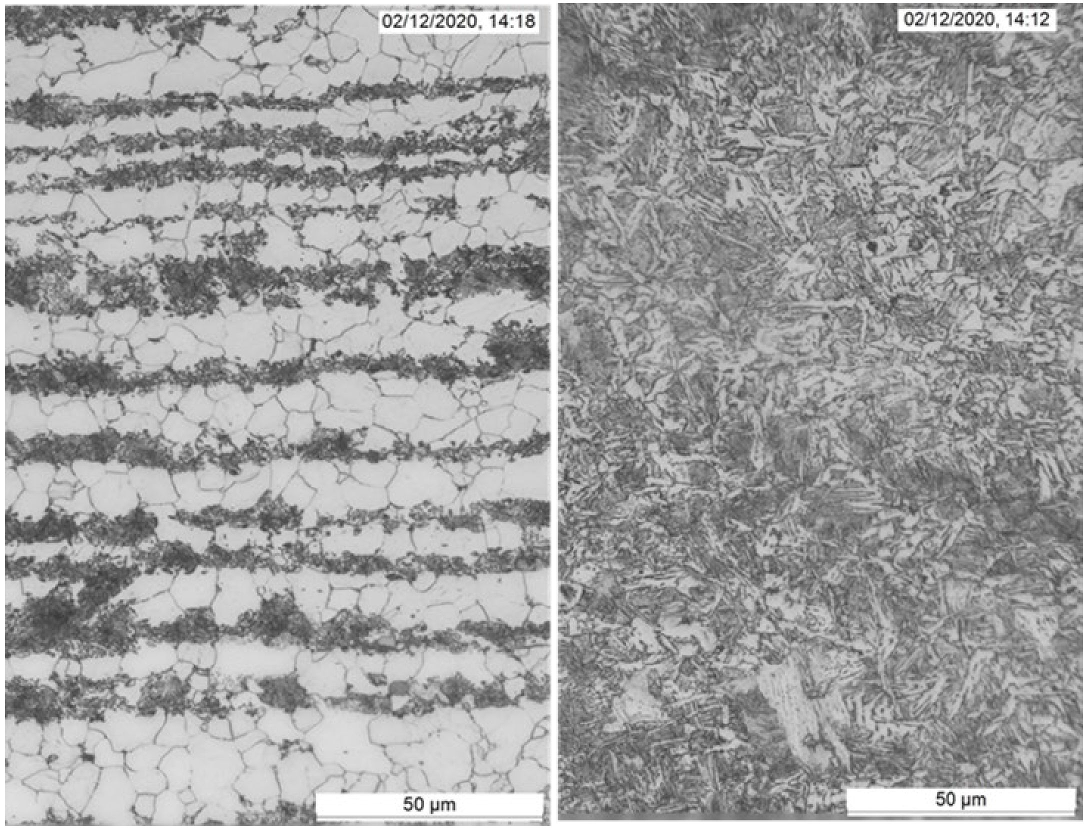
FSW – it’s in more products than you realise !

Why FSW steel ?





Market drivers for steel FSW

Why transfer the technology to steel?

- Enhanced mechanical properties
- Automation
- Potentially improved fatigue life
- Possibility of joining very hard to weld steel grades
- Ability to weld dissimilar steel grades
- Able to weld under water
- Reduced susceptibility to hydrogen effects

Weld refurbishment for cryogenic and hydrogen applications

FSW is a solid state, low temperature welding process. As it does not utilise either an arc or a high power energy beam, it does not dissociate any moisture present into its constituent hydrogen and oxygen, nor does it provide a liquid metal melt pool for hydrogen to dissolve into. Friction stir welds are thus far less likely to be prone to hydrogen embrittlement issues than conventional fusion welds.

The fine grained microstructures generated by friction stir welding are already known to be tough and fatigue resistant and there is some limited data to suggest that they are also less susceptible to hydrogen permeation. FSW may thus be suitable both for the fabrication of new pipelines and storage systems for applications requiring high toughness and resistance to hydrogen induced cracking, and for the refurbishment of existing pipeline welds to permit them to be re-purposed for the transport of hydrogen, ammonia or sequestrated CO_2.

Fatigue life enhancement / damage remediation

Welds can experience cracking at the toes (root or cap) due to a variety of reasons but typically arising from local stress concentrations due to geometry or section changes, or thermal stresses induced by welding. In service, particularly under fluctuating load conditions, these cracks can propagate, leading eventually to fatigue failure of the weld.

Using higher strength steels does not reduce such fatigue failures as the initiation phase of the crack, where the metal strength is a significant factor, has already occurred.

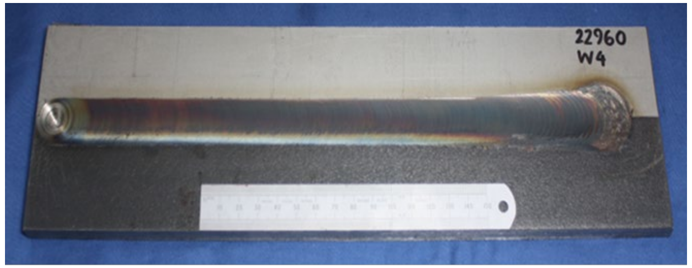
For structures containing fatigue cracks, interest is being shown in using FSW as a crack sealing and fatigue mitigation technique. A FSW pass through the affected region can seal up existing cracks, and the transformation of the local microstructure to a finer grained, often acicular ferrite dominated form, toughens the region and acts against the recurrence of cracking.

The macro above shows a multipass weld in carbon steel with the typical columnar grained microstructure of a fusion weld. A partial penetration FSW pass has been made through the weld cap, demonstrating how FSW generates a fine grained, defect free, microstructure much more akin to that of the original parent metal.

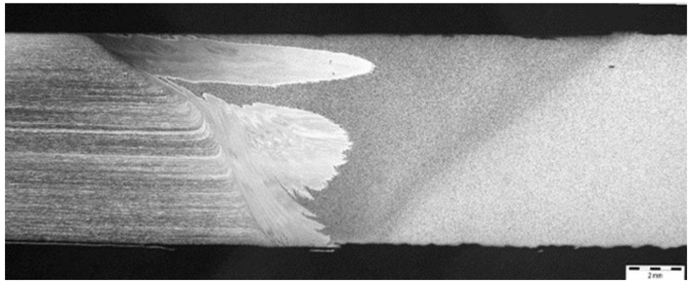
Welding dissimilar materials

FSW can join different metals if they have similar softening temperatures. This allows very different grades of the same metal to be joined, for example stainless steels to carbon steels, or even different metals – for example gold, silver and copper can all be mutually joined without alloying occurring.

Interest has been expressed in investigating the use of FSW for joining steel to corrosion resistant alloys (CRA) for such applications as joining pipes to CRA valves and flow control devices without the need for complex and expensive multiple buttering layers of metals such as nickel.



Examples of a friction stir weld between a carbon and a super duplex stainless steel. From the macro section, below, it can be seen that no melting or alloying of the two different metals occurs. Both retain their original composition and properties, with the duplex steel also retaining its original phase balance. The samples pass face and root bend testing without cracking and under tensile loading failure occurred in a ductile manner in the weaker parent metal away from the weld zone.



Underwater

- FSW can weld under water without the need for divers or hyperbaric chambers.
- The process is not affected by depth.
- It could be used for on site fabrication or maintenance and repair

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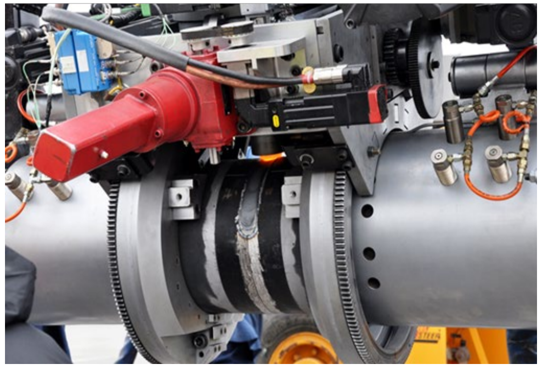
RESURGAM Robotic Survey, Repair and Agile Manufacture

Pipewelding

FSW offers the potential of producing automated, low distortion, strong, fatigue resistant welds in pipelines both for onshore and offshore applications. FSW has already been proven to work both under water and in oil.

When FSW a pipe, a mandrel must be inserted into the pipe to react against the welding forces and prevent the pipe being distorted. If this mandrel were replaced by a second, internal welding head, this could work together with an external orbital FSW. This double sided welding approach would increase weld productivity, potentially enhance tool life, guarantee full weld root penetration and increase the thickness of the pipe walls that can be joined.



The resulting joint would be strong, tough and fatigue resistant, an important aspect for pipes delivering pressurised product, perhaps at low temperatures.

Clad and mechanically lined pipe

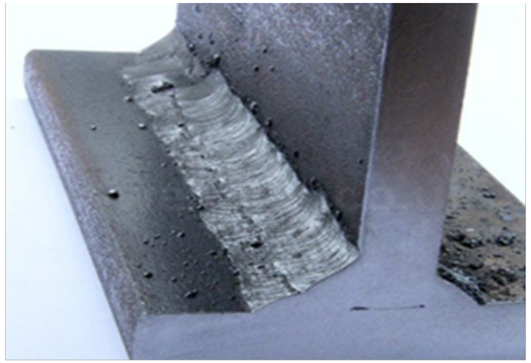
Many pipes that are to be used to transport corrosive fluids are lined with corrosion resistant liners. These linings may be roll bonded, explosively bonded, weld overlays or mechanically lined. All present difficulties for joining by welding, with conventional welding process usually melting the liner material and so compromising the pipe's corrosion resistance and requiring subsequent treatments to restore the anti-corrosion coating around the weld zone. In addition, cracking can often occur at the weld due to the thermal stresses induced by welding in materials with different compositions and thermal expansivities.

FSW is a solid state process that has been shown to be capable of welding dissimilar metals without intermixing them if the correct welding parameters and tool designs are used. This thus presents the potential for welding clad or mechanically lined pipes without compromising the coating layer or liner.

Stiffened panels

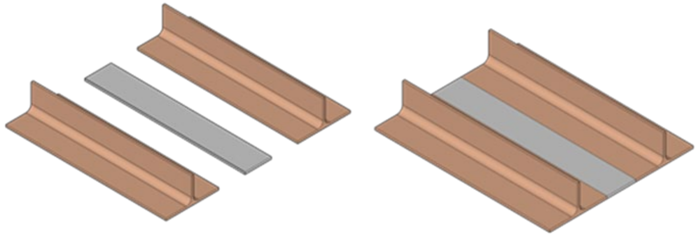
Many engineering structures, for example ships, building floors, bridge decks and formworks are built up from stiffened panels. These are typically manufactured by fillet welding and this process can produce a number of problems including significant distortion due to high heat inputs, lack of penetration defects, fatigue cracking arising from stresses at weld toes and difficulties with some inspection techniques.

An alternative method would be to fabricate stiffened panels using rolled T sections, available as commodity items, spaced apart by butt welded plates. This would replace two arc fillet welds by a single FSW butt weld, utilising a lower temperature, low distortion process that produces a fully forged microstructure that requires less post weld clean up and is easier to inspect. It also offers the potential to use different thicknesses and grades of plate, along with different section profiles, to tailor the properties of the panel produced.



Above. A fillet weld showing a lack of penetration defect.

Below. Concept of an integrally stiffened panel made from plate and rolled T sections



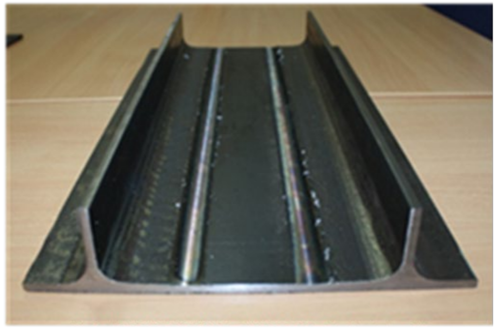
Hybrid SAW / FSW

Many fabricators utilise automated SAW systems for welding large flat panels and pipes. These are particularly prevalent in shipbuilding and civil engineering facilities as well as on pipelines. Many of these systems utilise a stiff, travelling gantry to support the SAW head. It seems likely that such welding machines could be adapted at very low cost to allow a hybrid SAW / FSW process to be performed, combining the advantages of the two welding techniques at low cost by adapting existing equipment.

The SAW head, with its excellent penetration and gap filling capabilities, would traverse along the weld line, melting the steel and generating a weld as normal. The FSW head would then follow on closely behind, friction stir processing the solidified weld metal, grain refining, strengthening and toughening it. As the FSW tool is only stirring the metal rather than heating and melting it, the FSW tool life will likely be much enhanced, improving the process economics as well as giving a high quality, low distortion weld.

Above: Automated SAW gantry system on a panel line.

Below. Small demonstrator integrally stiffened FSW panel

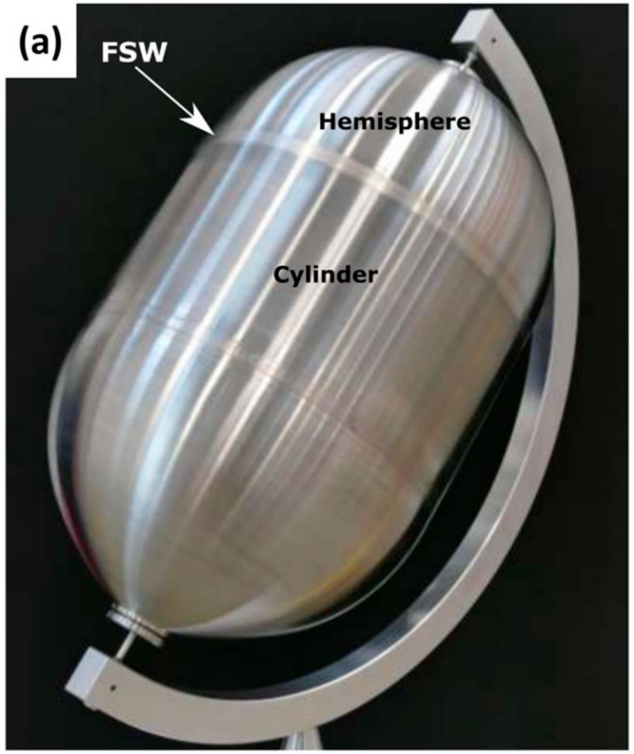


Summary

FSW provides the capability to use an automated, repeatable system to produce welds in air, under water, under oil and in vacuum, in almost all grades of steel, that are potentially:

- Stronger than the parent steel ;
- Tougher than the parent steel;
- As fatigue resistant as the parent steel;
- As corrosion resistant as the parent steel.

What could you use it for ?



Any Questions?

Thank you.

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