Futuristic Welding Does not Melt Metal or Generate Sparks

Friction stir welding has innovated the aluminum LNG tank manufacturing process

Friction Stir Welding (FSW) is attracting attention today as a new technique for manufacturing aluminum LNG tanks. As this technique uses frictional heat to soften and join members, without the welding filler materials or shielding gas essential for conventional arc welding, it generates little welding distortion. This joining technique overturns the conventional concept of welding.

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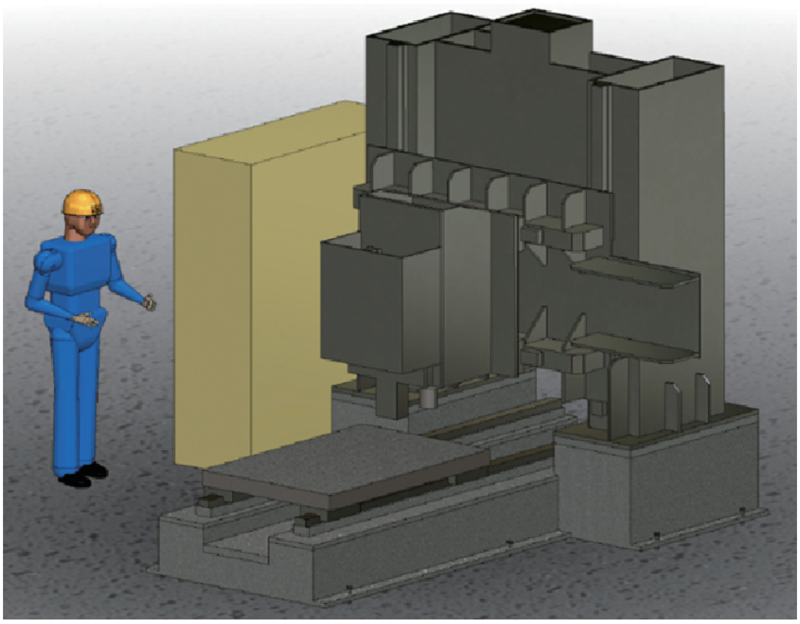
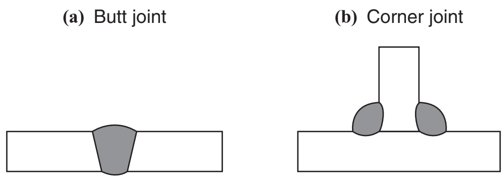


FSW equipment under development

Joining technology essential to manufacturing

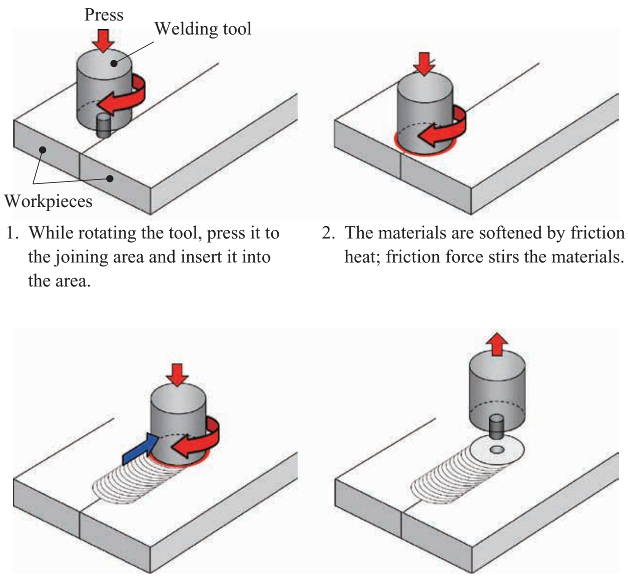
Joining technology is one of the fundamental technologies of manufacturing. Material (metal) joining processes can be roughly categorized into three types: mechanical joints, material joints, and chemical joints. Mechanical joints use bolts and rivets, and chemical joints use adhesives. Material joint techniques are in other words welding and joining techniques, which include welding, which melts base materials to join them, and diffusion bonding, which does not melt base materials. Welding and joining uses various joint forms, such as butt and corner, each of which requires a unique technique.



Welding joint types

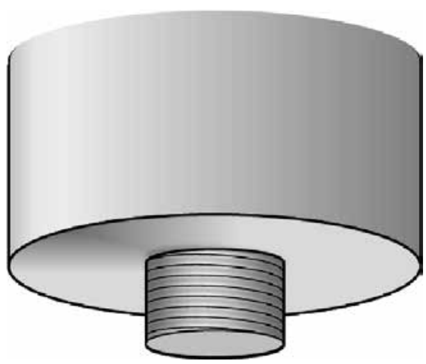
Innovative welding technique “FSW”

Friction Stir Welding (FSW), currently being developed for practical applications, provides sound joints without melting base materials. FSW is a joining process invented by The Welding Institute UK (TWI) in 1991. First, two workpieces are butted together at the edges, then a welding tool with a probe at the tip is pressed on the boundary of these workpieces while being rotated. Workpiece materials are softened by friction heat, and the tool tip is plunged to the workpiece boundary to mix the materials without melting them. The probe has a thread to promote stirring. While rotating, the tool is moved along the boundary to expand the joining zone.



1. While rotating the tool, press it to the joining area and insert it into the area.
2. The materials are softened by friction heat; friction force stirs the materials.
3. While maintaining stirring, move the tool along the butted line to weld the workpieces.
4. Finally, remove the tool to finish the welding process.

FSW principles and a typical welding process



FSW tool shape

Since FSW uses a solid-state plastic flow to perform weld joint, it does not cause solidification shrinkage common to melt welding. It also causes little thermal contraction due to lower heat input into workpieces, for almost no distortion after joining. It can perform high-quality joining of materials hard to join through melt welding such as aluminum alloys and magnesium alloys.

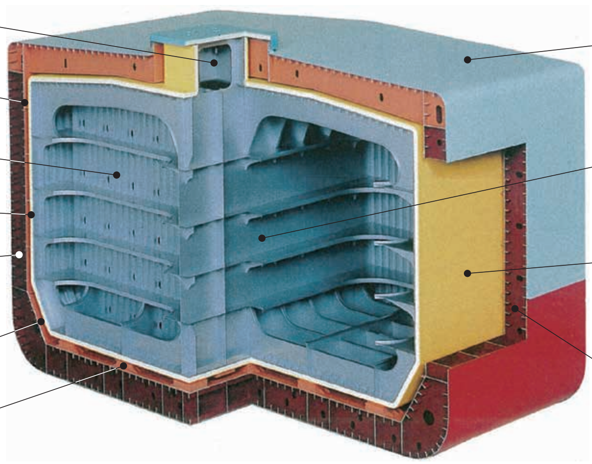
When applying this process to practical construction, labor saving can be achieved by employing full-automatic processing. Skilled workers are not required as arc welding does to provide consistent high quality. It consumes a relatively small amount of electric power and does not generate the harmful rays or fumes (metal vapor) that arc welding does, so a good work environment can be maintained reducing worker burden. FSW has been applied in recent years mainly to railroad vehicle and automobile industries as it has advantages in construction quality, uses unskilled workers, and saves energy. IHI is currently working to apply FSW, with its various advantages, to joining thick aluminum plates for floating offshore LNG (Liquefied Natural Gas) tanks.

Growing demand for IHI-SPB LNG tanks

As energy demands grow worldwide, unconventional energy sources, such as shale gas, are being developed. Also, previously difficult to drill deep-water and great-depth oil and gas fields are now being developed. Particularly, the demand for natural gas is expected to grow significantly as a clean energy source, so many great-depth gas fields are now being developed. Unlike coastal seabed gas fields, deep-water gas field development requires facilities to purify, store, and offload natural gas on the sea. Tanks that store LNG at −162°C are a main component in floating LNG production, storage, and offloading facilities, or FLNG (Floating LNG) facilities.

Unlike tanks on land, FLNG tanks need to meet various requirements for use on the sea. Among these, slosh suppressing measures are most important. LNG in a tank moves with the vessel body impacting the tank structure. This is known as the sloshing effect. It can damage the tank. As the amount of LNG stored in an FLNG tank is always fluctuating with production and shipment, FLNG tanks need anti-sloshing properties superior to those of tanks on LNG tankers, which are either empty or full.

The Self-supporting Prismatic shaped IMO type B developed by IHI (IHI-SPB) LNG tank is equipped with inner bulkheads to shorten the motion period of LNG in the tank. Thus, it prevents resonance, or sloshing, between LNG motion and the natural vibration of the tank structure.



IHI-SPB LNG tank

Applying FSW to the IHI-SPB LNG tank

Cryogenic LNG tanks use thick aluminum alloy plates. Arc welding has been used to weld them. Performing arc welding with no defects requires an experienced expert. In addition, arc welding tends to generate melting, solidification, thermal expansion, and thermal contraction of materials, causing distortion in welded workpieces. Distorted members cannot be assembled, so a process to correct distortion must be inserted after the welding step.

FSW causes no material melting or solidification, and inputs little heat into workpieces. From here, the FSW joining process generates little distortion, eliminating the need for distortion correction, and reducing costs. This is one reason we are trying to apply FSW to the IHI-SPB LNG tank. Another reason is that FSW allows a fully automatic process independent of worker skill, consistently producing high quality joints. Furthermore, FSW produces fine and recrystallized microstructures at the weld for excellent mechanical properties.

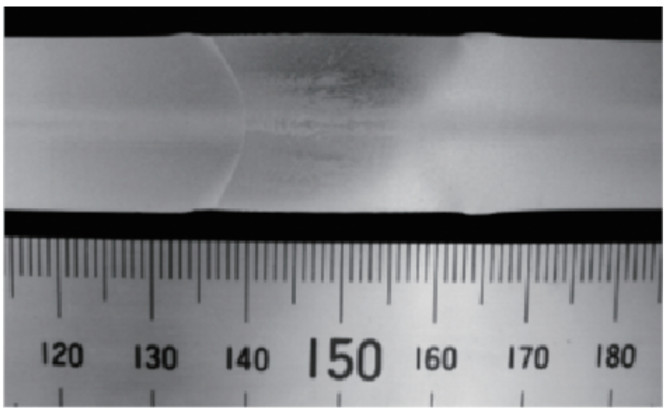
Thus, FSW is expected to solve various problems at one time. IHI has worked to develop the application of FSW to butted joints first. On the other hand, beyond butt-welded joints the IHI-SPB LNG tank also has many corner joints in the inner structure and in inner reinforcing members. However, there were few examples that applied FSW to corner joints, so we had to develop new technology.

Developing practical application of FSW to corner joints

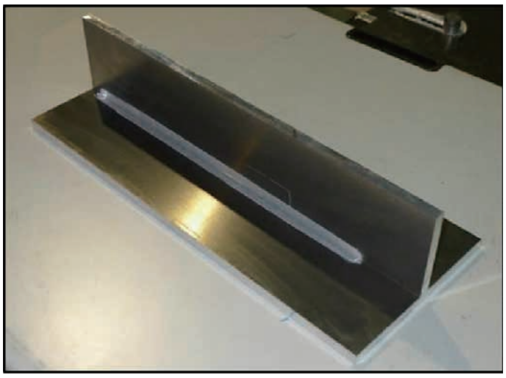
IHI participated in a joint research project related to corner FSW, organized by TWI and started in 2010. In addition, we introduced original techniques in efforts toward practical corner FSW.

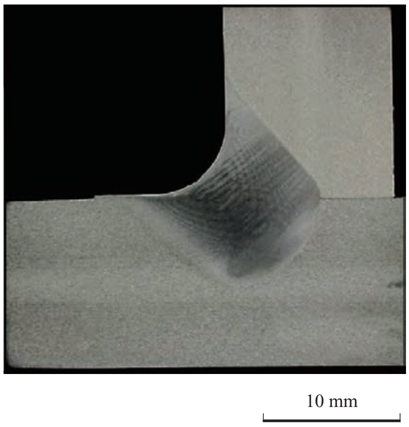
One of the problems to solve before applying corner FSW to practical use is supplying filler material. The joint research project improved the tool shape making the tool moveable while supplying filler material.

Another variance from normal FSW of butt joints is the need for stable rotating tool contact with the joint boundary at an oblique angle. Pressing force can be several kN more

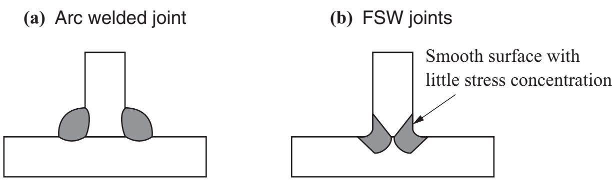


Cross section of a butted FSW joint





Cross section of a corner FSW joint



Cross section of corner FSW joints

than normal, and sometimes tens of kN. A newly invented non-rotating support, called a stationary shoulder, stably supports the probe, even when obliquely pressed to a joint. New IHI-developed techniques were fully employed in precisely operating the tool while pressing it with strong force.

Using these newly developed techniques, we achieved corner FSW with low welding distortion, without a distortion correcting process. Furthermore, the joint areas have ideal form with smooth surfaces and no stress concentration, formed using a stationary shoulder. Long-life joints with improved reliability were simultaneously achieved.

In the future, we will improve the FSW tool and equipment, further reduce costs, improve welding quality, stabilize long-length welding, and improve applicability. FSW is expected to be effective in joining metals beyond aluminum alloys, including titanium and nickel alloys, which are difficult to join using melt welding. In addition to the practical use of corner FSW, we will expand the application range of FSW techniques to various other materials and structural areas.

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