The I-STIR Plug Welding System (PWS) is a critical component for researchers, manufacturers of space structures, or other industries that employ friction stir welding (FSW) in their production processes. Developed by the global leader in FSW innovation, this system has proved to be an effective, reliable solution for closing self-reacting weld key holes and repairing defective friction stir and fusion weldments. Engineered to deliver maximum flexibility, it can be readily equipped to perform both friction push and pull plug welding.
Friction Plug Welding System

<table>
<thead>
<tr>
<th>FRICTION PUSH PLUG WELDING</th>
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<th>A COMPLETE SOLUTION</th>
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<td>Is an ideal technique for closing self-reacting weld keyholes and repairing defective welds on a very broad range of alloys. After heating phase, a rotating tapered plug is forced into a tapered hole until a preprogrammed distance is achieved. Plug rotation is then stopped very quickly; and force is maintained while the materials cool down. Excess plug material and back side extrusion are then removed.</td>
<td>Allows for more flexibility in tooling design and is well suited for closing self-reacting weld key-holes and repairing defective welds on structures where access is limited primarily to exterior surfaces. After a heating phase, a rotating tapered plug is pulled into a straight hole until a pre-programed distance is achieved. Plug rotation is then stopped very quickly; and force is maintained while the materials cool down. Excess plug materials and back side extrusions are then removed.</td>
<td>The I-STIR PWS is a complete, integrated friction plug welding solution, featuring:</td>
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<td><strong>PRECISION CONTROLS, INSTRUMENTATION &amp; SOFTWARE</strong></td>
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<td>• Precision I-STIR controls, instrumentation and software</td>
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<td>Friction plug welding is an extremely dynamic and quickly occurring event; tight control of the spindle stopping process and plug indicated runout are critical for achieving consistent plug weld quality. The I-STIR PWS control system is engineered to deliver the precise, closed-loop position and load control required to meet these critical needs. The I-STIR PWS control system integrates three major components: an FSW real-time controller, personal computer (PC) running I-STIR PWS software, and a remote pendant. These components work together seamlessly, enabling engineers to spend more time running process trials and less time learning to use and program the</td>
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<td>• Proven independent forge actuator technology</td>
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<td>The FSW real-time controller and underlying codebase are the product of years of development and close FSW customer collaboration. It is built on the widely accepted platform and is easily adapted to meet evolving needs. The platform allows for control and sampling rates at 1 KHz or better, essential for driving extremely rapid friction plug welding events.</td>
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<td>I-STIR PWS software is a full-featured tool kit for building real-time industrial control and simulation applications. It includes a comprehensive set of FSW process development tools, as well an intuitive, easy-to-use graphical user interface designed to enhance operator efficiency during production. I-STIR PWS software runs in a Windows operating environment, simplifying data sharing and integration into an organization’s computer network.</td>
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Photo Courtesy of NASA/MSFC
The I-STIR PWS employs an innovative, high-speed weldhead spindle to deliver exceptional position and load control. The spindle is coupled to the forge actuator using patented I-STIR independent spindle technology. Standard spindles allow the spindle shaft to rotate, but are fixed axially. The I-STIR PWS weldhead spindle shaft rotates, like a standard spindle, but it is also a precision linear actuator. Therefore, it can travel along the forge axis, allowing control of plug penetration or forge load to be maintained completely by the weldhead.

Travel along the forge axis is controlled with a high-performance I-STIR servovalve to provide the smooth, responsive and programmable motion necessary for the friction plug weld process. In addition, the actuator design allows for forge load measurement directly at the weld site. The weldhead spindle is fully instrumented to provide highest levels of precision in position or force control:

- Forge force is measured with two precision (.01% F.S.) pressure transducers connected to the piston control ports
- Forge displacement is measured with a LVDT attached near the top of the spindle assembly
- Spindle speed is measured with a Hall Effect sensor. Limit protection is accomplished with pressure relief valves and software limits on the torque and/or speed
- Spindle torque is measured with a differential pressure sensor across the control ports of the spindle motor
- The system software monitors programmable force and displacement limits and action options - E-stop, C-stop, etc. A mechanical stop limits the force of the piston.

The I-STIR PWS employs reliable hydraulic power generation and distribution products, including:

- The HPU is the cleanest and quietest hydraulic power supply available. It can be deployed directly in the lab, eliminating the need for special pump housing facilities and reducing supply line length and space requirements. The flexible HSM is used to control and distribute hydraulic flow, smooth pressure transitions, and provide isolation between stations. It can provide rapid pressure reduction to ensure safety, as well as storing energy for transient events requiring peak performance.

The I-STIR PWS is available with an optional multi-degree-of-freedom manipulator capable of articulating the weldhead in the X, Y, Z, H, Pitch, Yaw, and Roll axes (see diagram). The manipulator assembly features an articulated arm to ensure smooth, precise motion of the weldhead. The manipulator design allows for complete integration with customer provided rigging and support structures. The manipulator enables the weld head to be positioned within the tight space constraints of the part fixtures and clamps.
PROCESS DEVELOPMENT EXPERTISE

As the world’s leading friction welding innovator, I-STIR is uniquely qualified to ensure the successful transition of this technology from the laboratory to your production floor. We can help you fully explore the feasibility of any given application, and create and implement a sound process development strategy that meets your organization's unique needs within the constraints of available technology, time and budget.

UNRIVALED SERVICE & SUPPORT

I-STIR is the friction welding partner you can trust. A key component of our success over the decades has been our global support organization. Regardless of your size or location, we are committed to helping you optimize the return on your I-STIR system investment through planned professional maintenance, responsive local service, expert training, and accredited calibration services. To resolve more complex engineering or process challenges, we field an experienced global consulting team. Contact us today to learn why the world turns to I-STIR for intelligent, cost-effective friction welding solutions.