I-STIR™ Friction Stir Welding Solutions

Ensure the successful transition of FSW from your laboratory to your production floor.
You have recognized the promise of friction stir welding (FSW)—the potential benefits of this rapidly maturing technology are numerous: reduced assembly costs, higher quality joining, stronger and lighter joints, less pollution, and significantly reduced production cycle times.

Bringing FSW to the production floor, however, is neither a simple nor risk-free endeavor. Successfully implementing this rapidly evolving process requires considerable process expertise, a sound development plan, and reliable, technologically advanced equipment. Carefully weighing such factors as budgetary limitations, time constraints, and your organization’s level of FSW process development expertise, you must choose a realistic approach that is appropriate to your specific circumstances—a faulty strategy will prove costly and time-consuming.

I-STIR Technology: A Uniquely Qualified FSW Solution Provider

As a leading provider of precision force and motion control systems and recognized innovator of cutting edge FSW technology, I-STIR Technology is uniquely qualified to help you mitigate these risks and formulate a sound FSW process development strategy. We can provide you with the level of FSW process development expertise that you require to understand the full benefits of this promising technology, explore its feasibility for a 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. Your solution may entail the formulation and implementation of a detailed FSW process development plan, the delivery of one of our proven development systems, a transfer of technology, or merely the performance of a feasibility study. No matter what your needs, I-STIR Technology is the best-qualified organization to ensure the successful transition of FSW from your laboratory to your production floor.
I-STIR™ Friction Stir Welding Development Model

From our deep understanding of complex FSW processes and tooling gained from a wide variety of development efforts we have developed Intelligent Stir Welding for Industry and Research (I-STIR), an FSW development model that employs an inter-organizational team approach and a progressive three-phase program to put FSW into production as efficiently and cost-effectively as possible. Employing the I-STIR model, we can equip you with the world’s most versatile and reliable FSW development systems and, if necessary, provide additional levels of guidance to ensure the successful transition of FSW from your laboratory to your production floor.

The I-STIR model’s progressive, phased development program is based upon a best practices model developed through decades of producing complex, turnkey systems. Adapted for friction stir welding, this program consists of three phases: Application Assessment, Process Development & System Design, and Implementation for Production.

Collaborative Team Approach

One of the primary strengths of the I-STIR model is its team approach to friction stir welding development, which emphasizes the free and efficient flow of ideas and information. You supply design, analysis, materials and process engineering expertise specific to your industry, while I-STIR Technology provides the critical design, controls, and process knowledge required to move the friction stir welding process past the laboratory stage and into production. Team members from both organizations are encouraged to maintain frequent, direct contact with their counterparts to review the various design and manufacturing program aspects.

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I-STIR Technology has developed an array of leading-edge friction stir welding systems capable of providing the advanced capability and versatility required for research, process development, prototyping and production:

**The I-STIR PDS** (Process Development System) solution is a fully instrumented research system that is capable of simultaneous force-controlled operation of three independent axes (X, Z, and Pin). This system features Adaptable Adjustable Pin Tool (AdAPT™) weld head technology, enabling it to perform self-reacting welds and join materials of varying thickness. The I-STIR PDS can support up to 5 DOF to produce welds with double curvature. The I-STIR PDS has successfully joined materials less than 1mm and up to 40mm in thickness.

**The I-STIR PDS Jr.** solution is a single-axis system designed to perform linear welds. As a lower cost alternative to I-STIR PDS, this system features many of the same innovations as the PDS solution, such as AdAPT weld head technology. The PDS Jr. has been deployed to perform process research.
The I-STIR™ 10 Gantry is a 5-DOF system capable of producing parts requiring multi-axis welding. This system features AdAPT™ weld head technology and a 10-ton forge load capacity, which is needed for thicker section welds and hard metals.

The I-STIR™ Aero system is a 5-DOF system for use with thin-gauge aluminum alloys. Capable of producing high-speed welds of complex contours, this system features data collection of all critical parameters so that Statistical Process Control (SPC) can be used to ensure quality. The system's control software is compatible with most standard CAM programs. The I-STIR Aero system is also capable of performing basic machining tasks such as drilling, trimming and rough machining.
Solution Profile: Eclipse Aviation Corporation

We can work closely with you from the outset, guiding you through application assessment, process development, and implementation for production to ensure that the process you implement and the equipment you deploy are the best possible match for your unique FSW application.

Early in the design cycle of the Eclipse 500 jet aircraft, Eclipse Aviation Corporation explored the efficiency and reliability of using friction stir welding in the production of primary aircraft structures. By successfully integrating FSW into the production of the Eclipse 500 the company could eliminate 60 percent of the rivets from the aircraft’s design, resulting in reduced assembly costs, better quality joining and stronger and lighter joints. Because FSW is significantly faster than other structural joining processes the aircraft’s cycle time in production would decrease drastically as well.

Following the I-STIR development model, a powerful team of aircraft design and FSW process development talent was assembled. Eclipse supplied the critical design, analysis, materials and process engineering expertise to address the service-life details of the aircraft; and I-STIR Technology supplied the design, controls, and process expertise needed to move the FSW process past the laboratory stage and into production. Using the I-STIR PDS, the team produced thousands of development welds & prototype panels in support of the FAA certification effort.

This collaboration yielded the first production application of friction stir welding technology for the fabrication of primary aircraft structures, the I-STIR Aero system. This 5-DOF system features AdAPT™ weld head technology and is capable of producing high-speed welds of complex contours in thin-gauge aluminum alloys. The system’s control software is compatible with most standard CAM programs, and additional sensors enable data collection of all critical parameters so that Statistical Process Control (SPC) can be used to ensure weld quality.

Eclipse Aviation has since used the system to manufacture many of the skin assemblies on the Eclipse 500. The successful joining of these first components represents a major step forward in the validation and certification of friction stir welding in the assembly of this aircraft.
When Lockheed Martin Space Systems Company needed a manufacturer for its innovative universal friction stir welding system it turned to I-STIR Technology. The system’s initial application would be to join full size test panels representative of the domed section of a reusable cryogenic tank, which is similar to the external fuel tank of NASA’s space shuttle. From the outset Lockheed Martin understood that successfully applying friction stir welding to such large and complex geometric shapes would demand the simultaneous control of both position and load within highly accurate and precise tolerances. As a leading supplier of complex motion systems and proven innovator of advanced FSW technology, I-STIR Technology was the logical choice to design and manufacture such a system.

Prior to enlisting I-STIR Technology expertise to produce the system, Lockheed Martin engineers had performed much of the critical application assessment and process development work themselves — what remained was to apply what they had learned to design and fabricate the system. Applying the flexible I-STIR™ development model to accommodate a more supporting role, I-STIR Technology teamed with Lockheed Martin experts to address the remaining design and fabrication challenges efficiently and cost-effectively. The product of this collaboration was the Universal Weld System (UWS), a 5-axis friction stir welding system capable of producing precise, high-quality friction stir welds on complex curvature components.

In December of 2002 the National Center for Advanced Manufacturing (NCAM) awarded I-STIR Technology several contracts to produce the UWS to support its Complex Curvature Friction Stir Welding Risk Reduction Program. NCAM is a partnership between NASA, the State of Louisiana, the University of New Orleans and Lockheed Martin Corporation to explore advanced manufacturing technologies for NASA’s Next Generation Launch Technologies Program. NCAM will operate and maintain the UWS at the Michoud Assembly Facility in New Orleans.
Our commitment to becoming the world’s leading FSW equipment supplier is exemplified best by our aggressive technology development efforts, which have already yielded several innovative breakthroughs and continue to push the state-of-the-art.

We recognized early on that the precise control of force and motion is pivotal to realizing the full promise of FSW.

Unrivaled Process Control:
I-STIR Technology has achieved the seamless integration of innovative mechanical, electrical and software systems to deliver unrivaled control over all aspects of friction stir welding processes. Advanced application software and powerful TestStar™ controllers allow you to:
- Integrate CAD/CAM packages into the process to accurately track weld paths
- Perform offline CAD/CAM planning
- Accurately acquire and manage weld data
- Measure and control key process parameters to achieve six-sigma weld quality
- Record all welding parameters for use in Statistical Process Control (SPC) programs
Advanced Tooling & Techniques:

I-STIR Technology drives the state-of-the-art of FSW tooling with innovative pin tool and forge load control technologies. Utilizing a highly accurate, low-friction independent forge actuator (patent pending) and advanced Adjustable Adaptable Pin Tool (AdAPT™) weld head technology, the first fully instrumented friction stir welding system capable of performing load-controlled welds along multiple axes was produced. Additionally, the AdAPT packaging allows the weld head to be integrated into custom configurations or mounted to existing equipment. These same FSW tooling innovations will enable you to:

- Employ three welding modes (tooling types) - fixed, adjustable, and self-reacting - to accommodate both linear and complex, non-linear contour weld configurations
- Switch between welding modes on-the-fly
- Maintain a controlled, perpendicular forge load in vectored x, y, z, pitch and roll space
- Produce quality joints in materials from 1mm to over 40mm thick
- Operate in up to 5 degrees-of-freedom.
I-STIR Technology has an outstanding team of experienced FSW and manufacturing process experts ready to help you successfully plan and execute your FSW process development strategy.

Leveraging nearly 40 years of design and manufacturing expertise, this team has fielded solutions to some of the world’s most challenging test and manufacturing problems. Through decades of providing innovative force and motion control equipment they have gained unparalleled expertise in the design and implementation of force and motion sensors, data acquisition and control systems, and force and motion actuating components – technology that is crucial for overcoming the challenges of providing effective FSW solutions. And as this group ventures further into the growing array of potential FSW applications the innovation continues, as evidenced by such recent technical advances as:

- The ability to produce double curvature welds and the welding of tapered materials
- Real time process sensors for the intelligent processing of materials
- The ability to weld high temperature alloys

Worldwide FSW Leadership:

In addition to our in-house development efforts, I-STIR Technology plays a leading role in fostering the worldwide development of FSW through numerous teaming efforts with many active participants in the friction stir welding industry, government, and academia. The following collaborative efforts have produced several successful system configurations to fulfill a broad array of production applications.

- University of South Carolina
- Lockheed Martin
- Eclipse Aviation Corporation
- South Dakota School of Mines & Technology
- Institute de Soudure

We have also secured several licensing agreements to augment our FSW development capabilities and have patented a number of leading edge technologies.

- TWI Machine Supplier License for Friction Stir Welding (U.S. Patent 5,460,317 & 5,813,592)*
- Self-reacting Welding Head (U.S. Patent 6,199,745)
- Co-Exclusive NASA License for Adjustable Pin Tool (U.S. Patent 5,893,507)
- Independent Forge Actuator (Patent Pending)

* International patent numbers are available upon request
A key component of our success over the decades has been our industry-leading, worldwide service organization. Regardless of your size or location, I-STIR Technology is committed to optimizing your return on your I-STIR™ system investment. To help you maximize the productivity of your system we offer planned professional maintenance, responsive local service and spare parts support, hands-on training programs, and accredited calibration services. To resolve more complex engineering or process challenges, we field an experienced global consulting team. The world relies on I-STIR Technology for cutting-edge force and motion control technology, technical know-how, and service excellence. Can you afford to trust your critical friction stir welding development project to anyone else?
Friction stir welding is a promising new welding technique that delivers higher quality joining, faster, more cleanly, and less expensively than most conventional fusion welding and riveting processes.

Invented by The Welding Institute (TWI) in 1991, FSW is a revolutionary solid-state joining process that combines extruding and forging. Joining occurs when a shouldered, profiled pin is rotated and plunged into the joint line between two pieces of sheet or plate material that are butted together. Frictional heat is generated between the wear-resistant pin and the work pieces. This heat causes the work piece material to soften without reaching its melting point, allowing the pin to traverse the weld line. As it does, the plasticized work material is transferred from the leading edge of the rotating pin to the trailing edge, leaving in its wake a solid phase bond between the two work pieces. Since the joining process occurs at a temperature below the melting point of the work piece material, FSW has several distinct advantages over fusion welding:

**Faster, Simpler Process**
- Higher speed joining when compared to automatic riveting and most fusion welding processes
- Fewer parameters to control

**Higher-Quality Joining**
- Solid-state process – zero defects
- Ability to control process to 6 sigma
- Consistent weld properties
- Ability to join aluminum alloys that are unweldable by fusion welding methods
- Produces desirable microstructures in the weld and heat-affected zones
- Minimal distortion and less residual stress than fusion welding

**More Efficient**
- Very low energy consumption
- Requires minimal, if any, consumables
- No filler wire required

**More Environmentally Friendly**
- No fumes – no need for bulky and intrusive fume extractors
- No noise
- No spark showers
- Safe – no UV or electromagnetic radiation hazards

### Explaining Detail of Friction Stir Weld

Friction stir welding is a process that involves the use of a rotating pin to create a bond between two work pieces without melting the material. The pin is forced into the joint line, creating frictional heat that plasticizes the work material. This plasticized material is then transferred from the leading edge of the rotating pin to the trailing edge, forming a solid phase bond. The process occurs below the melting point of the work piece material, providing several advantages over traditional fusion welding.

**Diagram Details**
- **Joint**: The point where the two work pieces are joined.
- **Leading Edge of the Rotating Tool**: The edge of the pin that first contacts the work pieces.
- **Trailing Edge of the Rotating Tool**: The edge of the pin that last contacts the work pieces.
- **Advancing Side of Weld**: The side of the weld where the pin is advancing.
- **Retreating Side of Weld**: The side of the weld where the pin is retreating.
- **Fz, Fy, Fx**: Forces acting on the pin tool.
- **RPM, Torque**: Parameters that control the pin tool.
- **Sufficient downward force to maintain registered contact**: The force required to keep the pin in contact with the work pieces.

**Weld Cross-Section**
- The cross-section of the weld shows the solid phase bond formed by friction stir welding.
**Testimonials:**

“The benefits of friction stir welding are numerous. It eliminates the need for thousands of rivets resulting in reduced assembly costs, better quality joining and stronger and lighter joints. Because this process is significantly faster than other structural joining processes we can drastically reduce the cycle time in production.”

*Oliver Masefield*  
Vice President of Engineering  
Eclipse Aviation Corporation

“Friction stir welding is a relatively new process that is rapidly maturing and the I-STIR Technology technology is advancing the state of the art. The universal friction stir welding system will provide an accurate, consistent means for implementing conventional friction stir welding on complex curvature components.”

*Paula Hartley*  
Manager, Large Metallic Structures  
Lockheed Martin