ISTIR™ 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.

MTS: A Uniquely Qualified FSW Solution Provider

As the world’s leading provider of precision force and motion control systems and recognized innovator of cutting edge FSW technology, MTS 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, MTS is the best-qualified organization to ensure the successful transition of FSW from your laboratory to your production floor.
**Collaborative Team Approach**

One of the primary strengths of the ISTIR 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 MTS 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.

**ISTIR 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 (ISTIR), 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 ISTIR 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 ISTIR model’s progressive, phased development program is based upon a best practices model developed by MTS 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.

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**PHASE I: Application Assessment**

- **Input**
  - Requirements
  - Customer Specifications
  - Analysis
  - Experience

- **Output**
  - Requirements Specification
  - Output
  - Design Concept

**PHASE II: Process Development & System Design**

- **Input**
  - Requirements Specification
  - Experience
  - Design Concept

- **Output**
  - Design Concept
  - Drawings
  - Weld Specifications

**PHASE III: Implementation for Production**

- **Input**
  - Weld Specifications
  - Drawings
  - Experience

- **Output**
  - Weld Specifications
  - Drawings
  - Experience
  - Customer Specifications
  - Functional Specifications
  - Experience

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We employ a progressive three-phase program to help you put FSW into production as efficiently and cost-effectively as possible.
MTS 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:

**Versatile ISTIR Friction Stir Welding Equipment**

The ISTIR 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 MTS Adaptable Adjustable Pin Tool (AdAPT™) weld head technology, enabling it to perform self-reacting welds and join materials of varying thickness. The ISTIR PDS can support up to 5 DOF to produce welds with double curvature. The ISTIR PDS has successfully joined materials less than 1mm and up to 40mm in thickness.

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

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

This productive collaboration yielded the world’s first production application of friction stir welding technology for the fabrication of primary aircraft structures, the ISTIR Aero system. This 5-DOF system features MTS 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 MTS Systems Corporation. 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 the world’s leading supplier of complex motion systems and proven innovator of advanced FSW technology, MTS was the logical choice to design and manufacture such a system.

Prior to enlisting MTS 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 ISTIR development model to accommodate a more supporting role, MTS 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. This leading-edge system features the world’s largest FSW working envelope and advanced technology based on NASA’s Auto-adjustable Pin Tool for Friction Stir Welding (U.S. Patent 5,893,507), for which MTS has signed a co-exclusive license agreement.

In December of 2002, the National Center for Advanced Manufacturing (NCAM) awarded MTS 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. MTS has a history of innovation evidenced by the patenting of a number of technical advances for force and motion control systems, including the self-reacting weld technique.

Maintaining optimal pin position, especially in nonlinear applications, is the most daunting obstacle to producing consistent, high-quality FSW joining. As a pioneer and leader in precision force and motion control, MTS has embraced this challenge, developing sophisticated new load control technologies and system innovations that have proven to be robust and reliable in both linear and nonlinear applications.

Unrivaled Process Control:
MTS 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 MTS 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

MTS has developed sophisticated new load control technologies and system innovations that have proven to be robust and reliable in both linear and nonlinear FSW applications.
MTS 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, MTS was able to produce the first fully instrumented friction stir welding system capable of performing load-controlled welds along multiple axes. Additionally, the AdAPT packaging allows the weld head to be integrated into custom configurations or mounted to existing equipment. These same MTS 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.
MTS has an outstanding team of experienced FSW and manufacturing process experts ready to help you successfully plan and execute your FSW process development strategy - some team members have been working on this technology since the initial TWI group sponsored project.

Leveraging nearly 40 years of MTS 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, MTS 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, MTS is committed to optimizing your return on your ISTIR 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 MTS 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?

MTS Corporate Advantages

MTS Systems Corporation is a global provider of innovative hardware, software, and know-how that enables our customers to produce higher quality materials, products, and structures more efficiently and cost-effectively. We supply products for determining the mechanical behavior of materials, products and structures - including computer-based testing and simulation systems, modeling and testing software, and consulting services - as well as products for automating manufacturing processes. MTS has a proven track record of commercializing new technologies.
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 shoulder, 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
LONGITUDINAL SECTION OF FRICTION STIR WELD

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 MTS 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