



ADVANCED FRICTION STIR WELDING (FSW) SOLUTIONS



Join the Mazak

HYBRID MULTI-TASKING REVOLUTION

Today's manufacturers know that they need a technological edge in order to remain competitive in a global marketplace. And to help those manufacturers meet their production goals and outpace the competition, Mazak has taken Multi-Tasking to the next level: HYBRID Multi-Tasking.



These innovative machine tools take Mazak DONE IN ONE® metalcutting efficiency and add in groundbreaking technologies that expand your shop's capabilities, including:

- **Additive Manufacturing (AM)** which includes laser metal deposition and multi-laser metal deposition, two additive techniques that allow for fast part-feature building and cladding with metal powder.
- **Hot Wire Deposition (HWD)**, a high-speed 5-axis additive solution perfectly suited for high-speed near-net-shape part building and repairs by utilizing an arc torch, laser and pre-heated wire feedstock.
- **Friction Stir Welding (FSW)** which applies highly precise levels of frictional heat and forging pressure to create full-penetration, defect-free welded joints, even for dissimilar materials.
- **Auto Gear (AG)** which leverages the power of SMOOTH Gear Milling, Gear Skiving and Gear Hobbing to simplify gear production, reducing the need for complex programs, specialized machines or outsourced low-volume gear production.

Reimagine Welding with Friction Stir Welding (FSW)

Transform Your Welding Capabilities

First introduced by The Welding Institute in 1991 and incorporated into Mazak's technology portfolio with the acquisition of the Provo, Utah-based MegaStir, Friction Stir Welding (FSW) generates heat with friction using a rotating pin pressed against a workpiece. Particularly useful with metals with low melting points, including aluminum, FSW creates joints that require little post-processing, use no filler material, resist corrosion and produce a wide range of joint types, including hollow ones. FSW can even join dissimilar metals, which represents a major step forward in welding technology. The nonconsumable FSW tool and its unique tool holder also include thrust and temperature sensors to allow for continual Z-axis adjustment via the MAZATROL Smooth CNC for closed-loop process control and optimal welds.

Using precise amounts of heat and pressure, Friction Stir Welding creates flawless and full-penetration welded joints. This innovative technique makes joining dissimilar metals or making weld repairs easier than ever while minimizing heat-affected zones for both fine and rough applications. The process moves material from one side to the other, breaking down grain structure and allowing the grains to regrow while the tool shoulder constrains the direction in which they form. FSW creates a refined grain structure throughout the welded joint, making the material stronger while retaining its original thermal and chemical properties.

Benefits of Friction Stir Welding

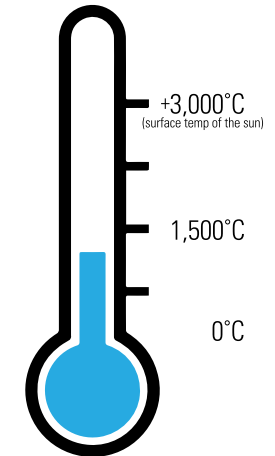
- No need for filler wire or shielding gas.
- Expanded types of welds.
- Improved safety due to the absence of toxic fumes and molten splatter.
- Lower setup costs and less training.
- Great weld appearance and minimal under/over matching
- Operate in all positions and orientations.
- Reduced distortion compared to conventional welding.
- Welds with similar mechanical and physical properties as the base metal.
- Low environmental impact.
- No cooldown period boosts efficiency and reduces costs.



Exceptional Joining Capabilities at Any Temperature

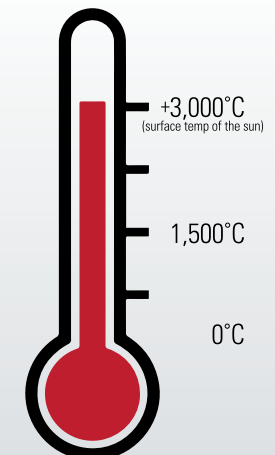
Low-temperature Friction Stir Welding

Friction Stir Welding for low-melting-point metals, such as aluminum alloys, has been used in the aerospace, marine, and transportation industries for many years. Benefits include low distortion, greater weld strength, little or no porosity, no filler metals, little or no post-weld repair, no solidification cracking, no welding fumes or gases, improved corrosion resistance, and lower cost in production applications. The process uses tools made from hardened tool steels that are inexpensive to fabricate and possess sufficient hardness and abrasion resistance.



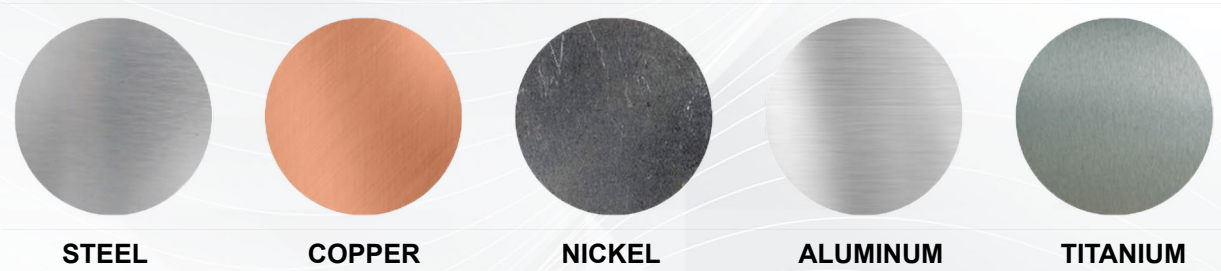
High-temperature Friction Stir Welding

Because metals such as steel, stainless steel and nickel-based alloys have high melting points, they have posed many challenges for FSW. The Mazak MegaStir proprietary solid-state joining process combines cutting and friction to join high-temperature alloys quickly and consistently, resulting in a superior weld without pollution or unwanted alloying. Using its own patented polycrystalline boron nitride (PCBN) formulas, Mazak MegaStir tools offer high friction and durable tool wear. Designed for applications ranging from elastomeric products rated for extreme temperatures and pressures in oil and gas wells and aerospace engines to recreational products, Mazak MegaStir tools can handle your high-temperature friction stir welding needs.



FSW Tool Materials

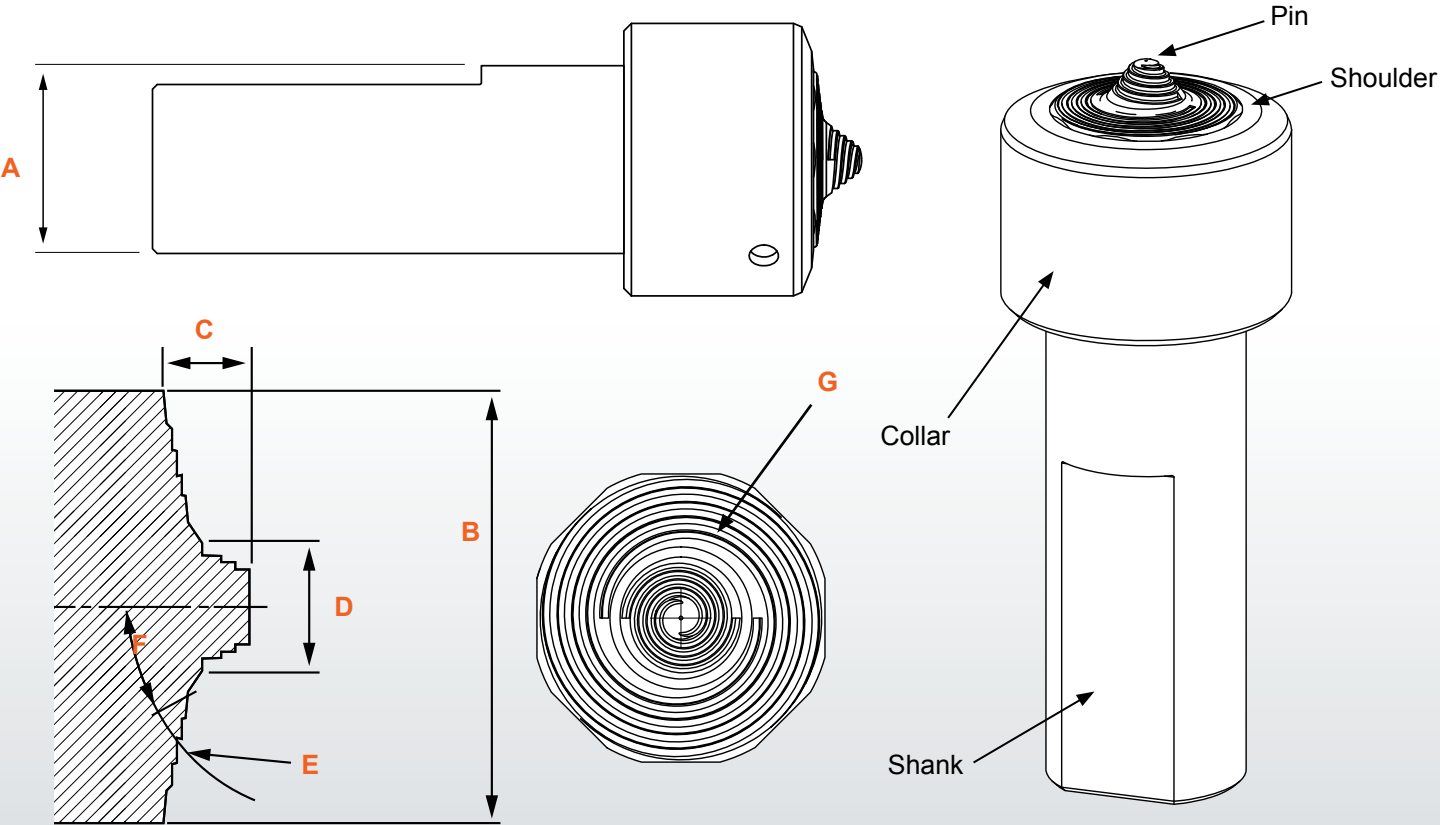
Selecting the correct tool material requires knowing which material characteristics are important for each friction stir welding application. When choosing your tool material, consider the material of the work piece, the expected life of the tool, and your own experiences and preferences. Use this chart to help you determine what tool material may be best for your friction stir welding application.



TOOL MATERIAL	PROPERTIES	WELDABLE METALS
PCBN	High temperature High hardness (~3,600 HV)	Steel, stainless steel, nickel, copper, metal matrix composites
PCBN/W-Re	High temperature Excellent toughness Good hardness (~2,000 HV)	Steel, stainless steel, nickel, copper, metal matrix composites
H13 Steel	Good toughness Good strength	Aluminum alloys, manganese alloys
MP159 Cobalt	Highest toughness Highest strength Highest thickness	Aluminum alloys, manganese alloys
Tungsten	Good toughness at low temperatures	Copper, metal matrix composites, testing of steel and titanium alloys
Polycrystalline Diamond	High wear resistance High toughness	Aluminum alloys, metal matrix composites

FSW Tool Design

Mazak MegaStir tools consist of a protruding “pin,” which is plunged into workpieces, and the larger concentric “shoulder,” which is maintained on the surface of the joint. The shoulder’s surface produces a combination of frictional heating and forging pressure. To create an optimal weld, operators adjust the tool’s rotational speed, travel speed and applied pressure. These parameters are governed by the tool geometry (shoulder and pin diameter), mechanical properties of material to be joined (flow stress) and material thickness. When the shoulder and pin rotate in contact with the base material, it creates frictional heat, producing a local plasticized region that is displaced around the tool. The high degree of deformation and the large forging pressures applied by the tool shoulder produce a full metallurgical bond.



- A** Shank Diameter

B Shoulder Diameter

C Pin Length

D Pin Base Diameter

E Convex Radius

F Pin Angle
- G** Shoulder & Pin Features

 - Threads
 - Step Spirals
 - Flats
 - Other

Closed-loop Software for Powerful Process Control

To help shops maximize efficiency and throughput, Mazak MegaStir has created a fully closed-loop human-machine interface (HMI) that allows operators to create FSW programs with the power of MAZATROL Smooth CNCs. The wireless telemetry system equipped in the Mazak MegaStir instrumented toolholder sends thrust and temperature information directly to the CNC, which adjusts the Z-axis position automatically for consistent forging pressure.

Monitor FSW status

With the MAZATROL Smooth CNC platform, operators can monitor FSW processes and machine status in real time. Alert messages and alarms are displayed automatically when machine load exceeds configured limitations.

Manual thrust offset

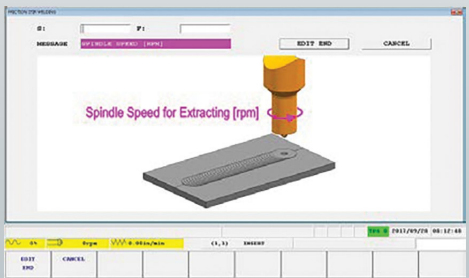
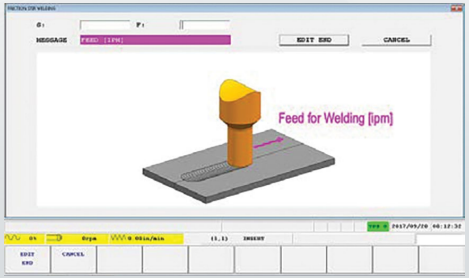
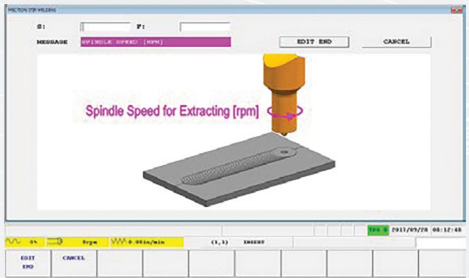
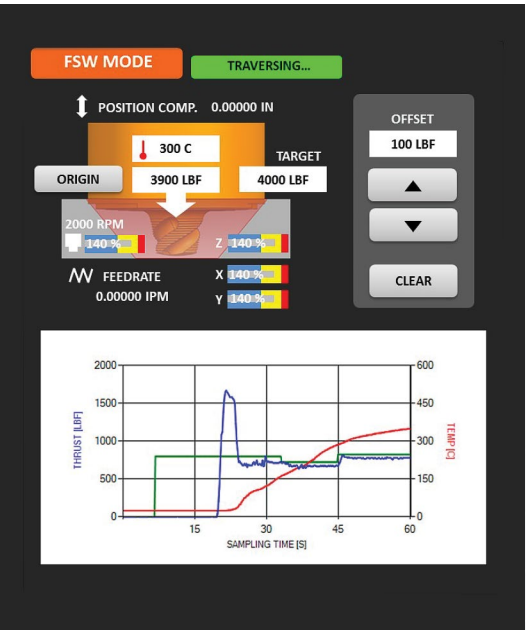
While an FSW program includes target thrust data, operators can fine-tune thrust during welding operations to make necessary adjustments.

Process logging function

All FSW process data is logged and stored, allowing operators easy access to the data they need to optimize their part-production processes. Logs include timestamps, program names/sequence numbers, feedback thrust and temperature, and machine load.

FSW program menu

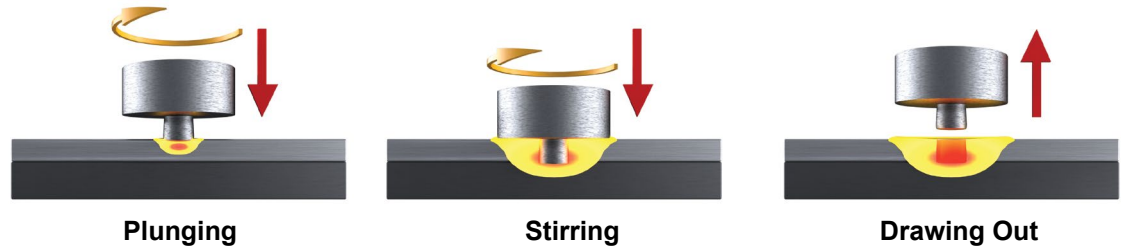
A conversational programming system allows operators to enter the FSW parameters for the three main processes – plunging, traversing and extracting – and easily create EIA/ISO programs.



Flexible, High-performance Processes

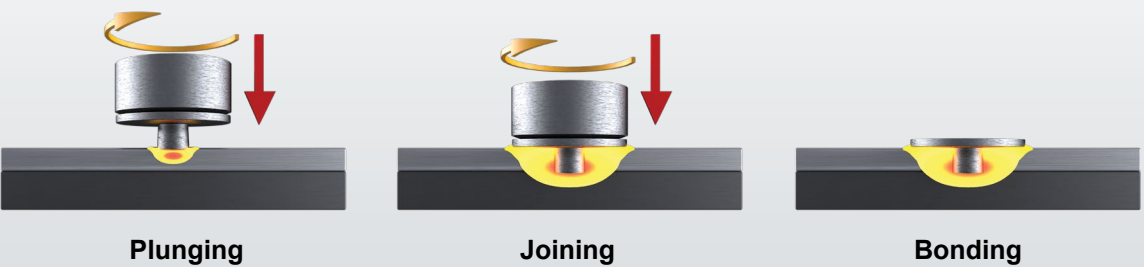
Friction Stir Spot Welding (FSSW)

When an application only requires spot welding, FSSW brings the advantages of FSW to a single spot on the workpiece. For low-temperature applications, solid tungsten carbide FSSW tools are available; for higher temperatures, such as FSSW applications in steel, the tool comes with a smaller steel tool holder and separate PCBN and composite metal matrix (CMM) tips.



Friction Bit Joining (FBJ)

Used primarily in the automotive industry, friction bit joining is a proprietary friction spot welding technique developed by Mazak MegaStir. This method is used to join steels and dissimilar metals with a consumable bit featuring optimized tool geometry that produces greater heat for more efficient “stirring” to improve the breaking and mixing of oxide layers. With greater heat generation efficiency, the FBJ process enables higher welding speeds and enhanced quality.



FSW Machine Tool Technology

VTC-300C FSW

Control Type: MAZATROL SmoothG CNC

As a HYBRID Multi-Tasking system, the VTC-300C FSW combines vertical machining center capabilities with those of Friction Stir Welding (FSW). The machine features a powerful CAT 40 taper spindle, full vertical traveling-column design and a fixed table for machining extremely long and heavy workpieces. With a table center partition, the machine work envelope can be transformed into two separate work areas. This allows the machine to be in cycle in one work area while a part is being set up in the other. The machine also delivers fast rapid traverse rates to reduce non-cut times.

Machine Characteristics:

- FSW package for full-penetration, defect-free welded joints with minimal heat.
- Easy-to use MAZATROL SmoothG CNC for advanced high-speed, high-accuracy performance.
- Long fixed-table design.
- Optional table partition available.
- Standard 15,000-rpm CAT 40 taper spindle.
- 1,574 ipm rapid traverse rate.
- 24-tool (48 optional) storage capacity.
- Automatic tool changer.
- Maximum table load of 3,300 lbs.

Custom FSW Head Package

Interested in adding FSW capabilities to your existing Mazak machine tools? Mazak MegaStir is working toward the development of FSW heads that can be customized to fit your unique operational needs and custom pin sizes for all FSW. Contact your Mazak representative for more details.



VTC-300C FSW

FSW Tool Types

A Series

The most flexible FSW tool option, A Series tools have interchangeable pins with adjustable lengths and geometries to enable a wide range of applications, especially tough aluminum welds.

- Tip Material:** MP159
- Shank/Shoulder Material:** H13
- Use:** Appropriate for many different alloys and weld thickness
- Temperature Monitoring Port:** Yes



P Series

Used for extreme wear resistance in low-temperature applications, particularly aluminum welding, P Series tools have the hardest tip available: polycrystalline diamond (PCD), which has a hardness of ~4,000 HV.

- Tip Material:** PCD
- Shank Material:** Tungsten carbide
- Use:** Low-temperature or abrasive applications
- Temperature Monitoring Port:** Yes



H Series

As solid, one-piece tool designed as a long-lasting solution for low-temperature welding applications, H Series solid tools are made with standard H13 tool steel to offer all-around good wear.

- Tool Material:** H13 steel
- Wear:** Cost-effective tool life
- Use:** Aluminum and magnesium welding
- Temperature Monitoring Port:** Yes



M Series

Made with a polycrystalline cubic boron nitride (PCBN) tip with a hardness of roughly 3,600 HV, M Series tools provide excellent wear resistance for high-temperature steel and stainless steel welding applications.

- Tip Material:** PCBN with ceramic binder
- Shank Material:** Tungsten carbide
- Use:** Most steel and stainless steel applications
- Temperature Monitoring Port:** Yes



Q Series

Q Series tools use PCBN tips with tungsten rhenium binder for the toughest, most crack-resistant tip available. This premium high-temperature tool welds the toughest and thickest metals, including nickel-based alloys and higher-strength stainless steels, with a hardness of roughly 2,000 HV.

- Tip Material:** PCBN w/ tungsten rhenium binder
- Shank Material:** Tungsten carbide
- Use:** When toughness and torque are critical
- Temperature Monitoring Port:** Yes



S Series

The S Series tools are designed as a cost efficient, high-performance solution for low-temperature welding applications. These tools are manufactured using high-grade H13 tool steel and use a precision spline coupling device to optimize performance and reduce the cost of replacement in high-production operation.

- Tool Material:** H13 Steel
- Wear:** Cost-effective interchangeability
- Use:** Aluminum and magnesium welding
- Temperature Monitoring Port:** Yes



SPECIFICATIONS	
Shank Size:	1 inch, 25 mm, 38 mm, 50 mm or custom
Shoulder Diameters:	25 mm, 38 mm, 50 mm or custom
Pin Length:	1-12 mm, 19-20 mm
Threading:	C4 or MM

FSW Accessories and Kit

Instrumented Tool Holder

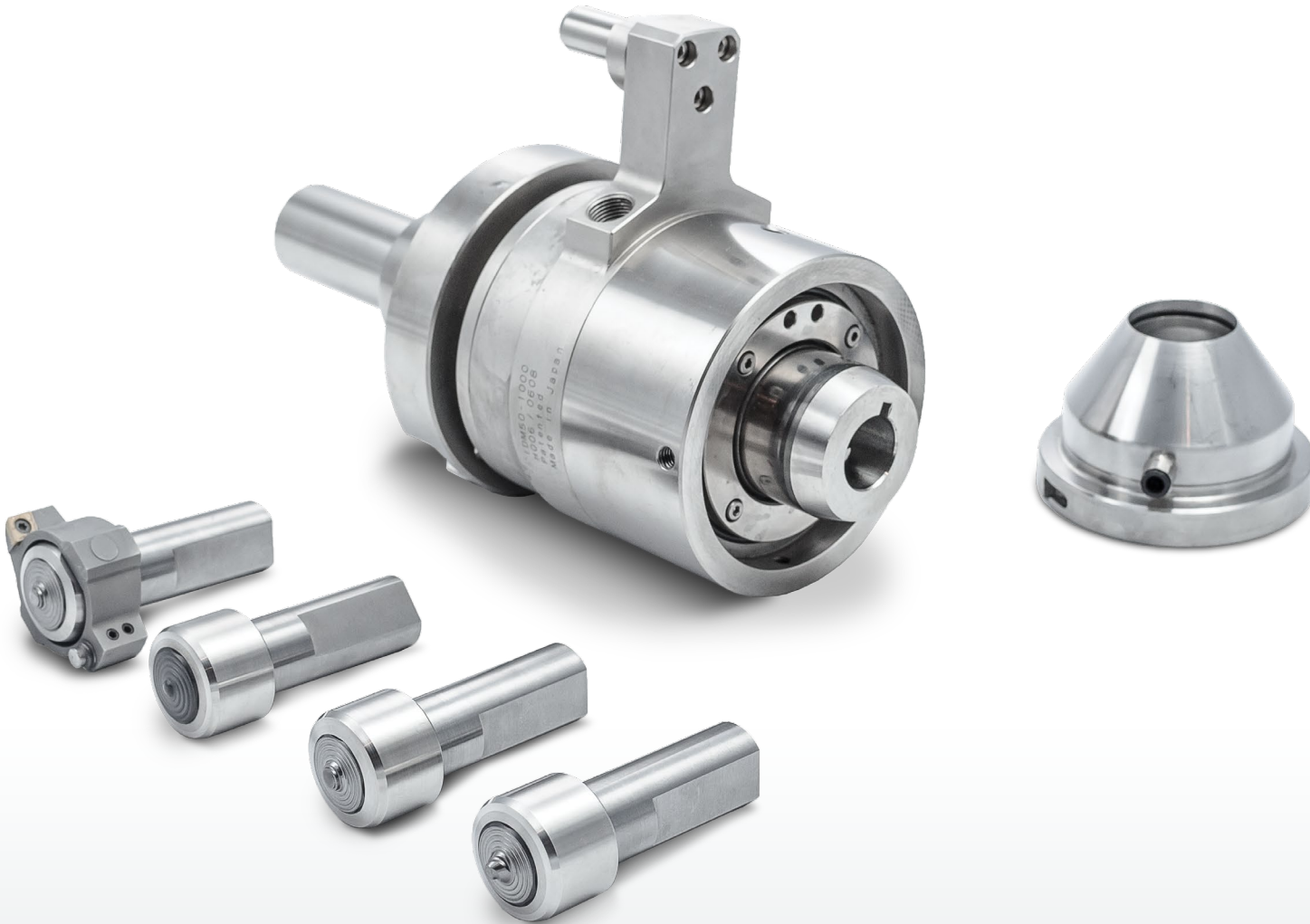
The FSW Instrumented Tool Holder is an all-in-one tool holder and telemetry system that offers the ability to use Friction Stir Welding (FSW) on Mazak machine tool platforms. The system collects tool temperature, Z-axis load, and data wirelessly for fine-tuning the FSW process, while analog outputs enables integration with MAZATROL Smooth controls for temperature or force-based algorithmic control of the process.

Features:

- Wireless telemetry system allows for real-time welding process adjustments using a K-type thermocouple inserted into the FSW tool.
- Can be used as a stand-alone device or in combination with a PC via a USB interface for added utility.
- Up to eight analog outputs for PID control including output replicates.
- Fully integrated with MAZATROL Smooth CNC technology for a complete closed-loop software solution.

Specifications

Maximum load capability	6,000 lbf (26.6 kN)
Maximum spindle speed	4,000 rpm
Wireless frequency	2.4 GHz IEEE 802.14.4 compliant
Analog output	8-channel analog outputs (0-3vDC)
Temperature sample rates	64 hertz
Load sample rates	512 hertz
Tool shank size	25 mm diameter



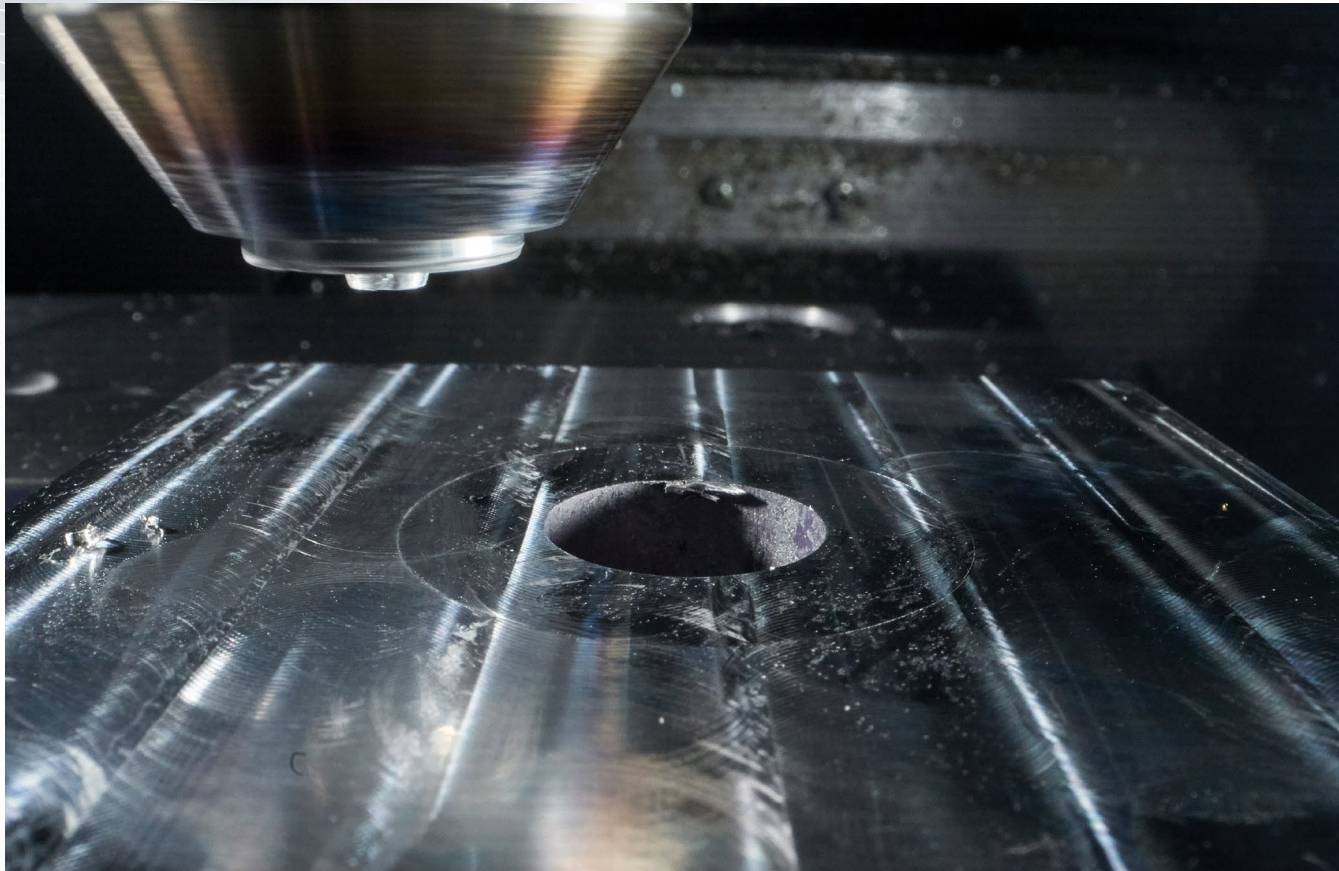
Instrumented Liquid-cooled Tool Holder

For even greater accuracy and process security, the FSW Instrumented Tool Holder is also available with a liquid-cooled variant that provides all the same integrated features with the addition of advanced temperature-control capabilities. Liquid cooling ensures the longest tool life and the strongest possible welds, especially in high-temperature applications or those performed with softer FSW pin materials.

Specifications

Maximum load capability	20,000 lbf (88.9 kN)
Maximum spindle speed	1,000 rpm
Wireless frequency	2.4 GHz IEEE 802.14.4 compliant
Analog output	8-channel analog outputs (0-3vDC)
Temperature sample rates	64 hertz
Load sample rates	512 hertz
Tool shank size	25 mm diameter

Mazak MegaStir Production Services



Using its full metallurgical lab and testing services, Mazak MegaStir offers a variety of Friction Stir Welding production services, from R&D and prototyping to alloy development and full production.

Engineering and R&D

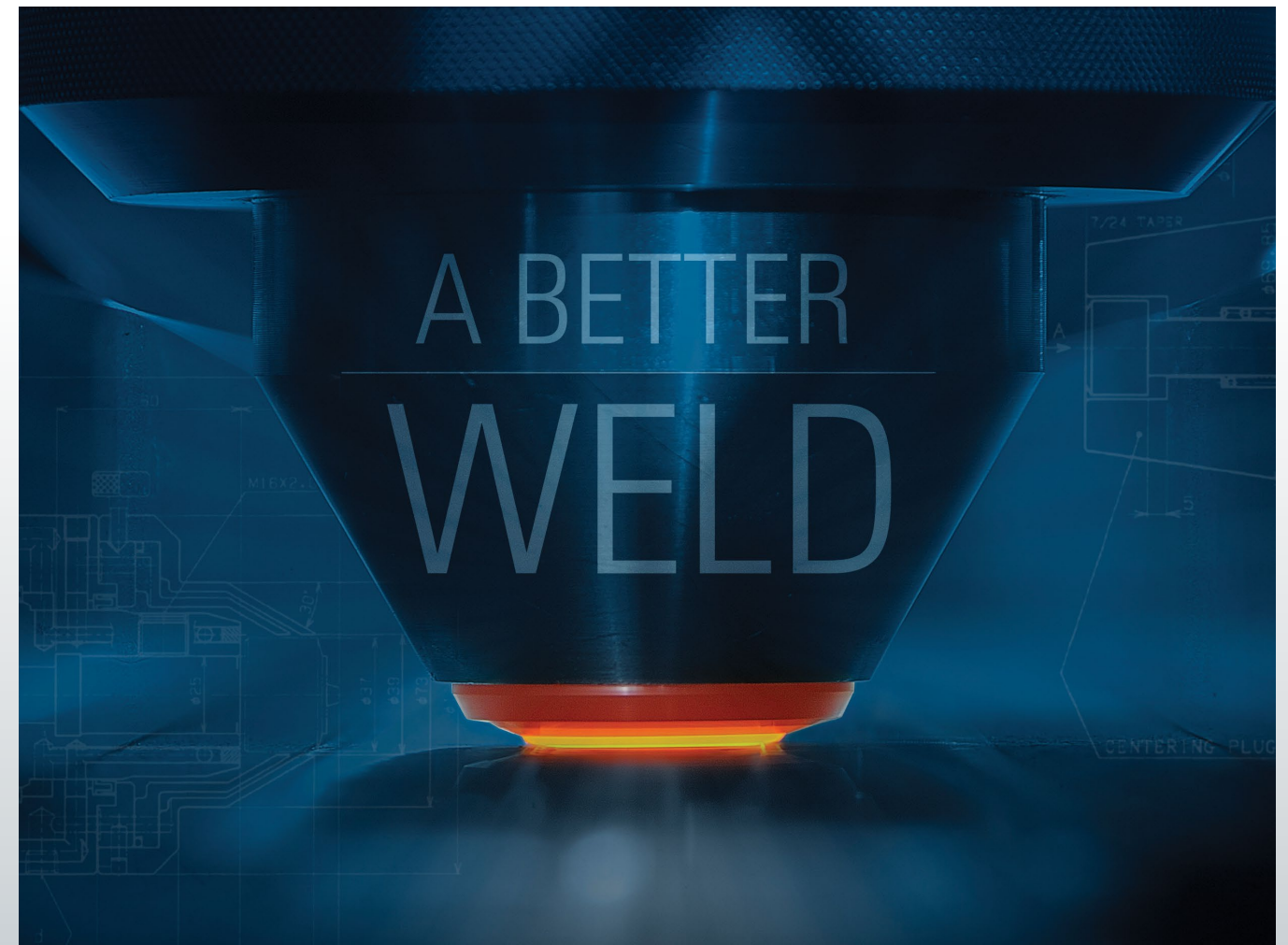
Mazak MegaStir application engineers are highly skilled and constantly engage in new research and development regarding tools, tool materials and the FSW process. They are also available for custom R&D and engineering projects.

Prototyping

Mazak MegaStir has full prototyping facilities, with engineers on staff to develop and prototype parts and components.

Full-production Friction Stir Welding

Mazak MegaStir's expertise in Friction Stir Welding, combined with Mazak's industry-leading machine tool technology, gives customers access to services that range from simple plate welding for mechanical and metallurgical samples to long welds with complex geometries. In addition to performing full-penetration and partial-penetration single-pass welds up to 32 mm in thickness in steel and over 50 mm in aluminum, Mazak MegaStir also specializes in circumferential welds, which are produced around the outer surface of a cylindrical piece and are used to fabricate structural pipes. FSW services are offered for all alloys, including aluminum, steel, stainless steel, and nickel-based alloys.



Application Areas



High-tech industries

The nature of the electronics industry is always to improve and evolve to control costs and integrate the new technology that empowers that constant change. And for that reason, it continues to be a leader in developing Friction Stir Welding applications. Mazak MegaStir has supported customers in this market segment on FSW operations on materials from 0.030" to 0.5" in thickness.



Aerospace

Early adopters and innovators who engineer, design and fabricate large aluminum structures, manufacturers in the aerospace industry pioneered Friction Stir Welding (FSW) technology in the late '90s. The ability to reduce weight with FSW translates to a greater payload, while the avoidance of slight weld distortions over a given length caused by competing weld technologies significantly increases propellant volume – all of which serves to create aircraft capable of higher speeds and/or reduced fuel consumption.



Automotive

As the automotive industry increases its use of aluminum to help improve fuel efficiency, FSW offers many potential benefits. In contrast to most other joining processes, Friction Stir Welding can handle the variations inherent in high-volume production at the same time it provides improved mechanical properties. The resulting interest among automakers has resulted in the successful use of this technology for everything from drive shafts and wheel assemblies to intake manifolds and cylinder heads.

Rail

To meet the growing transportation needs of countries around the world with the highest level of safety and environmental sustainability, the railcar industry has worked to improve the efficiency of car designs. And to achieve this, many railcar companies have turned to FSW, which creates car bodies with extrusions designed for stiffness and lightness without any sacrifice in the ability to endure the long service life required for rail applications. Increased joint efficiencies, reduced post-weld clean-up and higher processing speeds serve as additional advantages, giving railcar suppliers the ability to optimize processes and stay ahead of the competition.



Oil & gas

Constructed and installed both onshore and offshore, pipelines can require welding applications that range from 12" to 42" in diameter, with wall thicknesses up to 1.75" thick. With FSW, oil and gas industry suppliers can handle walls up to 1.25" thick at the same time they minimize defects. Likewise, for down-hole drilling and service equipment, FSW enables the joining of dissimilar high-temperature or high-wear alloys with a single-pass thermoplastic joining process that reduces or eliminates post-weld heat treatment and with minimal defects.



Marine

Shipbuilding companies have realized the economic value Friction Stir Welding brings to their manufacturing processes. The need for lightweight and more efficient ships has required shops to use FSW technology to develop creative aluminum extrusions into panels for several different seafaring applications. The low heat input minimizes stress and creates a superior microstructure, minimizing distortion and eliminating the need for further operations to improve flatness or remove defects.



Mazak Technology Centers

As a key component of Mazak's comprehensive customer support, its network of Technology and Technical Centers strategically located across North America puts component machining demonstrations, experienced applications engineers and training in close proximity to customers. These Technology Centers also provide a channel for customer input to Mazak manufacturing for the development of new machine tool technology.

Technology Centers offer advanced application support, education and training, new technology and manufacturing systems, along with on-site training and technology seminars.

Advanced application support

- Expert applications engineers help customers optimize part-production processes and create effective manufacturing solutions.
- Mazak-certified cutting tool, workholding and automation partners collaborate to develop optimized turnkey manufacturing solutions.
- Test cuts of customer parts run on the latest, most-advanced machine tools.
- Secure applications development and complete design privacy of each customer's individual manufacturing system.

Education and training

- Education, training and seminar events in cooperation with Mazak technology partners.
- Free access to the most advanced machine tools.
- Industry focused education - general aerospace, energy, jet engine and construction.



New technology and manufacturing systems

- The latest, most-advanced manufacturing systems that can optimize the processing of industry-specific components.
- Productivity experts help customers select the best new machine tool technology for their particular businesses.

On-site training and technology seminars

- Hands-on applications and operator development courses.
- Regularly scheduled market-focused events that provide valuable industry insight.



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Optimum Plus Service and Support

Mazak Optimum Plus

To maximize machine tool investments, the [Mazak Optimum Plus](#) program represents a company-wide commitment to provide the best-possible, most-comprehensive support.

The Optimum Plus program encompasses Five Pillars – distinct yet interrelated areas:

- Single-source service
- Technical support – machine and CNC
- Parts support
- Progressive learning
- Spindle and unit rebuild

Single-source Service

Mazak is a single point of contact for any Mazak-related service need, whether it involves a machine, control, accessory or automation solution. This effective service approach helps customers maintain the highest possible level of productivity.

Benefits of [Mazak’s single-source approach](#) include:

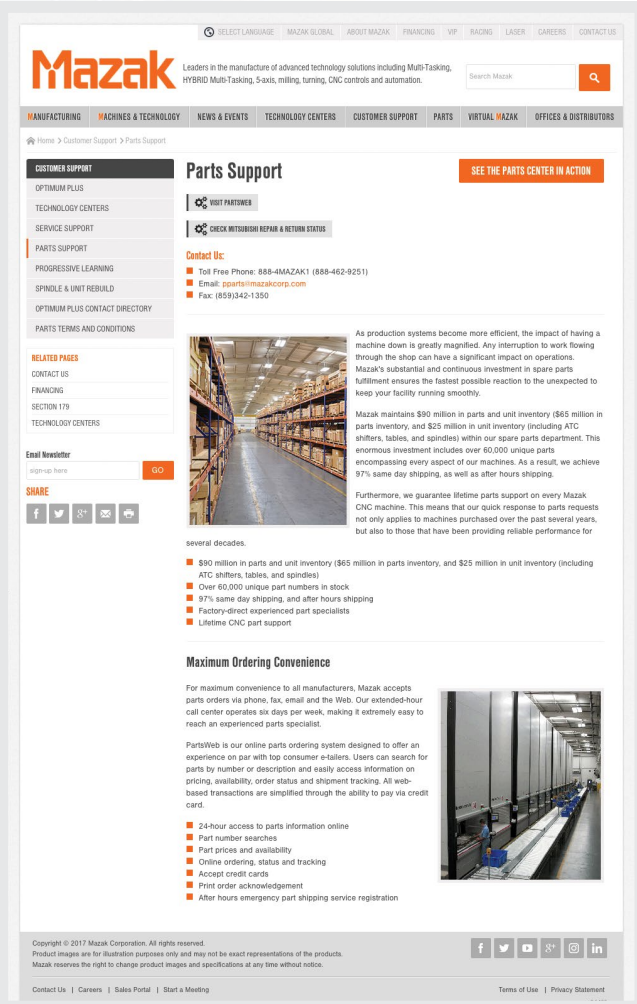
- Free technical phone support and software upgrades for the life of a Mazak machine.
- Software support that provides instantaneous diagnostic services via remote real-time systems.
- Guaranteed phone response to any technical question within one hour via a 24/7 technical phone support system.
- More than 350 factory-trained Mazak service representatives and certified distributor personnel who can be at a customer's site within 24 hours under most circumstances.
- Wide variety of services, including laser calibration to ISO, ANSI and JIS standards; ball bar qualification and analysis; preventive maintenance plans and programs; and vibration analysis and benchmarking.

Technical support – machine and CNC

Comprehensive warranties on every Mazak machine tool component, including a two-year part warranty on CNC control components.

[Technical support](#) for machines and CNCs also includes:

- Additional warranty coverage (available upon request).



The Mazak Optimum Plus program enables customers to maximize the value of their Mazak purchases.

Parts Support

Mazak’s spare parts fulfillment ensures the fastest possible reaction time. The state-of-the-art Mazak North American Parts Center uses the latest AS/RS fully automated warehouse storage system technology and maintains a \$65 million parts inventory.

Benefits of the North American Parts Center include:

- Average 97% same-day parts shipment and after-hours shipping.
- Over 60,000 part numbers in stock.
- Convenient web-based parts ordering.
- Factory-direct experienced part specialists.
- Lifetime CNC parts support.



Fully automated warehouse storage systems ensure the fastest delivery of Mazak spare parts.

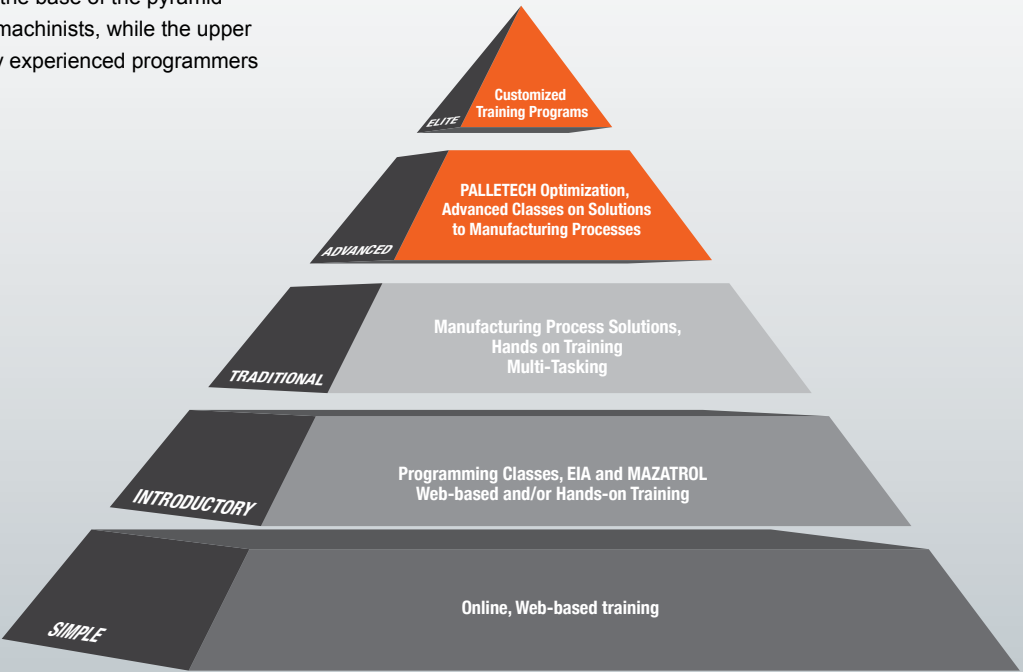
Progressive Learning

[Mazak’s Progressive Learning](#) represents a unique, phased approach to education and training for customers, combining hands-on training, web-based instruction and real-world examples. The program's tiers of offerings – Pyramid of Learning – range from self-paced coursework to highly advanced classes. Every Mazak machine includes three years of programming training at no charge to customers.

[Mazak’s Pyramid of Learning](#) is a visual representation of its approach to training. The lower levels at the base of the pyramid represent basic skills education for new machinists, while the upper levels signify advanced training for highly experienced programmers and operators.

Pyramid of Learning levels include:

- Simple online training
- Introductory programming training
- Traditional hands-on training
- Advanced training
- Customized training





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