

Friction Stir Welding

A Lasting Bond



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You Can **Rely** on This Weld

STRUCTURAL COMPONENTS NEED TO BE CRASH TEST SAFE AND SOLID AT ALL TIMES!

Friction stir welding (FSW) is an innovative technology with which aluminum materials can be durably and robustly welded.

The principle: a rotating tool generates the necessary process heat at the weld site by means of friction and pressure. The material becomes plastically malleable due to the heat, and the rotation of the tool "stirs" it along the weld seam. The tool shoulder compresses the softened material, and a strong bond is created between the workpieces that is media-tight and pressure-proof.

This is a relatively new process, but it has already proven itself many times in practice. FSW creates a weld that is very mechanically stable and able to support extremely heavy loads. Since the components are not melted, the structure is barely changed. The result: a high-quality weld that is optically so smooth and subtle that it's hard to believe what extreme loads it can stand up to.

FSW is an excellent solution for components that are used in areas where structural integrity and safety are key. In the automotive, aerospace and rail transportation sectors welds that can withstand high stress are essential; they're also crucial in making new developments like electric vehicles possible.

The benefits and advantages at a glance:

- » **Durable welds that are media-tight and pressure-proof**
- » **High and reproducible weld quality**
- » **Low-distortion welds**
- » **No porosity or hot cracking**
- » **Ideal for creating joints with aluminum casting**
- » **Emission-free process**
- » **No adjuvants such as protective gas, powder or filler wire required**
- » **Low energy consumption**



Welded Together!

We're Your FSW Lifecycle Partner

For many years now, FSW has demonstrated its strengths in 24/7 series production of high-quality components. Compared with other processes, it is still a relatively young technology. For that reason, most manufacturing facilities cannot yet rely on years of experience and their own experts—a situation that often gives rise to uncertainty and questions.

WITH US, YOU KNOW YOU'RE SAFE

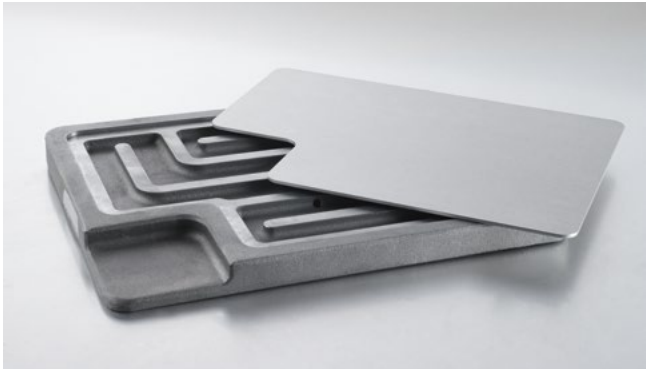
Here at Grenzebach, we know all about these challenges. As experts, we support you, educate your employees and are happy to share our knowledge. Consequently, you'll soon be able to stand on your own two feet and master the technology. Working on so many projects, Grenzebach's specialists acquire wide-ranging, intensive know-how, and we work every day to enable you to get more from the FSW process. However, we're also aware of the limits and suggest solutions to you as soon as possible. We are pleased to accompany you throughout the entire friction-stir-welding process, including the design of components.

Together with Grenzebach, set off on the road to the future of technology: we're exactly the partner you always wanted.

From **Concept** to Welded Component: We're at Your Side

ALL-ROUND SUPPORT FOR YOUR FSW PROJECTS

What Grenzebach's customers have always valued is our holistic view. Our experts advise you from the initial concept to the FSW process and support you with product design as well. You can count on this worldwide: as a global player, we can make equipment and know-how available practically anywhere in the world. Together with your product developers and process experts, Grenzebach's specialists are constantly refining FSW technology. In addition, we have an extensive portfolio of examples, so that you can precisely meet your individual requirements.





DEVELOPMENT
 Count on innovation.

The development phase is critical for the success of FSW technology. We bank on teamwork, cultivate ongoing exchanges with you and remain by your side as an advisory partner during component development. Together, we create the product step by step, in accordance with the FSW system concept. Thus, you are optimally positioned and ensure the maximum benefits throughout the full lifecycle.

- » FSW process and application consulting
- » Feasibility studies
- » Prototyping
- » FSW process development and optimization
- » Development of custom FSW tools, especially for your process and your component



PLANNING
 Count on trust.

Listen, understand and integrate. During the project planning phase, we do our utmost to determine your requirements in detail so that, together with you, we can achieve the optimal solution. That's what we mean by customer focus. Our goal is to meet or exceed your expectations both technical and commercial. The outcome is an excellent planning guide for creating your FSW system.

- » Simulation, construction and assembly of component-specific welding clamps, and feed and handling systems for the entire FSW system
- » One-stop shopping for all-in-one solutions
- » Dedicated contact person



EXECUTION
 Count on experience.

Based on the results of the planning, and in constant communication with you, your system is created, first virtually, then in real life in our facilities. The system's performance is validated in shop tests and, after a short start-up phase on-site, the equipment is ready for operation. Thanks to our professional project management, we ensure the agreed-upon performance of your FSW system, as well as outstanding Grenzebach quality and respect for your budget. We react to changing requirements and challenges flexibly and with commitment.

- » Professional project management
- » Respect for schedules and budgets
- » Trouble-free execution
- » Training and instruction on system operation, service and maintenance
- » Production support



UTILIZATION
 Count on safety.

We provide competent support and future-proof further development of your systems and solutions during their entire service life. What this means for you, in concrete terms, is less downtime, plannable maintenance and thus lower costs. With your personal service manager, you have an expert at your side, who will advise you constantly on all questions regarding the use of your investment. Thus, you're optimally prepared for changing market demands or necessary modernizations.

- » 24/7 (remote) technical support
- » FSW tools and parts service
- » Customized service agreement
- » Extended warranty
- » Our service manager as your personal contact



|| Friction stir welding is a relatively young, but undeniably leading-edge, welding process for industry. Together with you, we determine how FSW can be optimally applied to your components. Our experts will provide you with the appropriate system and will remain at your disposal—anywhere in the world—whenever questions or concerns arise. And it goes without saying that that applies not only during commissioning but throughout the system's lifecycle. ||

Sahin Sünger, Head of Friction Stir Welding
Grenzebach Maschinenbau GmbH

A photograph of three people in a factory setting. On the left, a man with glasses and a dark polo shirt is looking at a metal component. In the center, a woman with long brown hair and a light grey sweater is also looking at the component. On the right, a man with a beard and a dark jacket is pointing at the component. The background shows industrial machinery and a computer monitor.

An Extensive Portfolio of Systems, **Tailored** to Your Needs

The right choice of tools, the precise deployment of force sensor technology, the control of all processes, the lead machine, and machine and process control: all of these contribute to an optimal weld seam and surface finish and thus to the quality of your component. We support you with everything so that you can capitalize on the strengths of the friction-stir-welding process.

While developing the welding technique, we remain in close communication with our customer. The welding system, process parameters and welding tool are always optimally calibrated to each other: that provides the best possible bond quality.

As early as the component design phase, we support you with the selection of the module that is best adapted to the FSW process. Test, model and prototype welding, as well as contract production mandates, are all possible on Grenzebach's in-house FSW facilities.

Ideal Tooling Technology



EXACTLY THE SOLUTION THAT YOU NEED

In addition to installation engineering, tooling technology is critical for the FSW process's success. Grenzbach presents two options for the friction tool: **a one-piece (MonoSTIR) or a two-piece (DynaSTIR) tool**. We have both in our portfolio.

It's important to us to give you exactly the right tool: our robust, wear-resistant FSW tools are developed by Grenzbach experts in-house individually for your requirements.



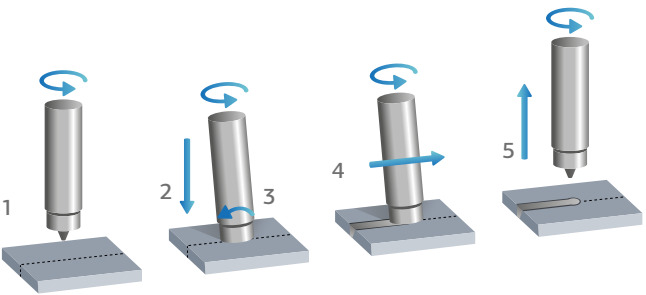
MonoSTIR

ONE-PIECE TOOL WITH ROTATING SHOULDER

The process in brief: the rotating, wear-resistant welding tool (1) dips into the weld seam (2), tilts to an angle of 0 - 5° (3) and generates heat through friction. The material becomes malleable and is stirred by the tool's forward progress along the seam (4). When the tool is removed from the seam, the result is a firm, media-tight, pressure-proof bond between the two workpieces (5).

Characteristics compared to DynaSTIR:

- » Rougher surface
- » A burr is usually formed
- » Higher heat input and thus greater warping
- » Higher welding speed as of a welding depth of 4 mm (0.16 in)
- » Wider shoulder



The MonoSTIR friction-stir-welding process
1. Rotating welding tool 2. Immersion 3. Tilt angle 0 - 5° 4. Feed 5. Removal



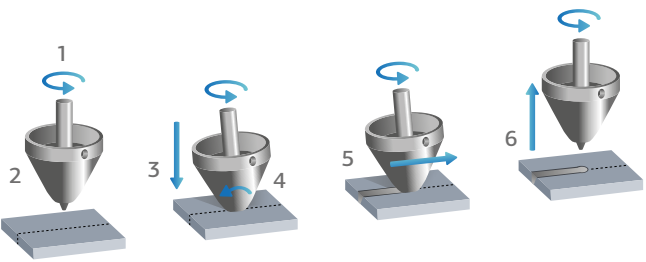
DynaSTIR

TWO-PIECE TOOL WITH NONROTATING SHOULDER

We asked ourselves how we could make a good process even better. The answer is DynaSTIR tool technology. The special feature: the welding tool is built in two pieces and the tool shoulder glides over the weld seam without rotating. The results of numerous installations speak for themselves.

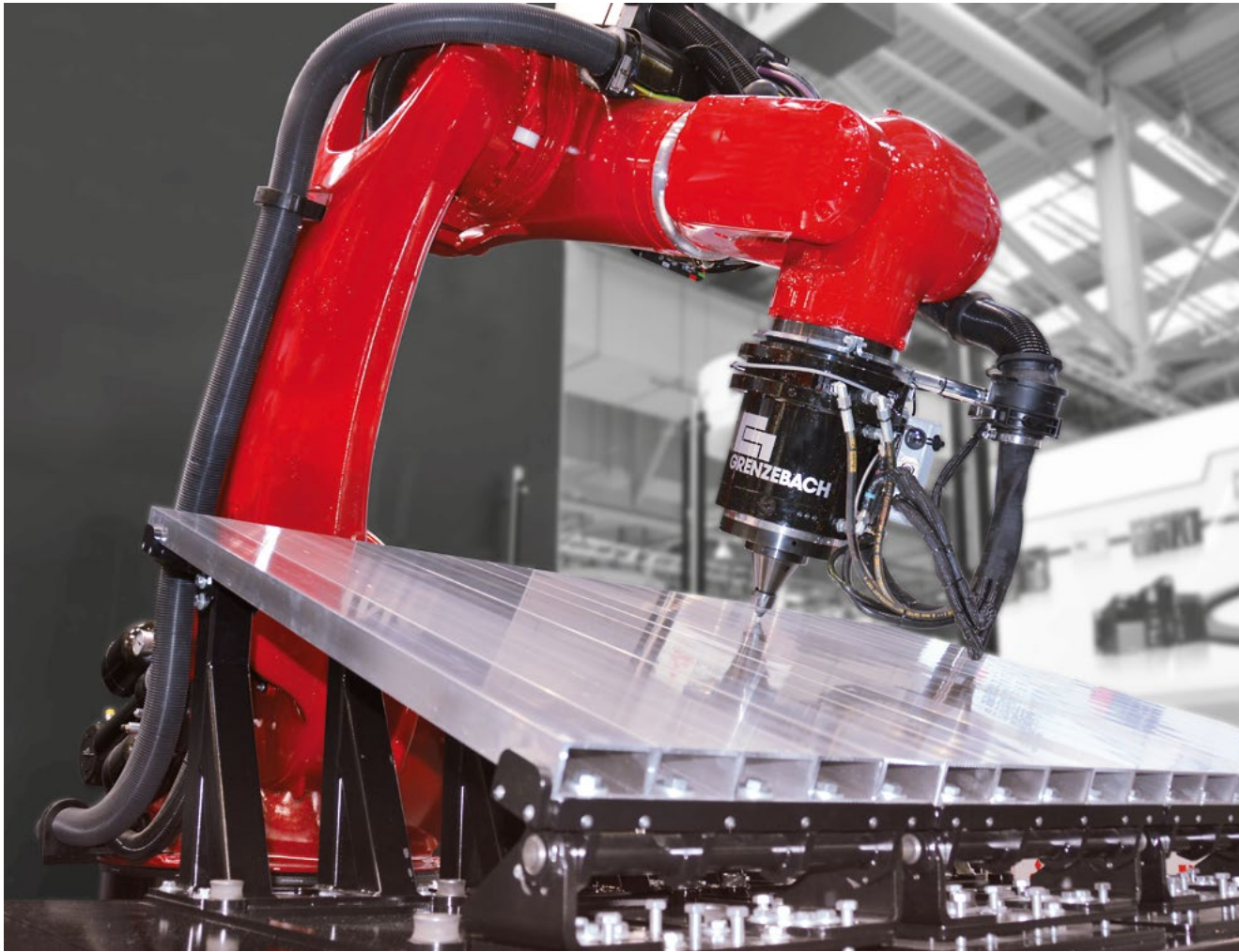
Characteristics compared to MonoSTIR:

- » Smoother surface
- » Usually no burr is formed
- » Lower heat input and thus less warping
- » Slower welding speed as of a welding depth of 4 mm (0.16 in)
- » Narrower shoulder



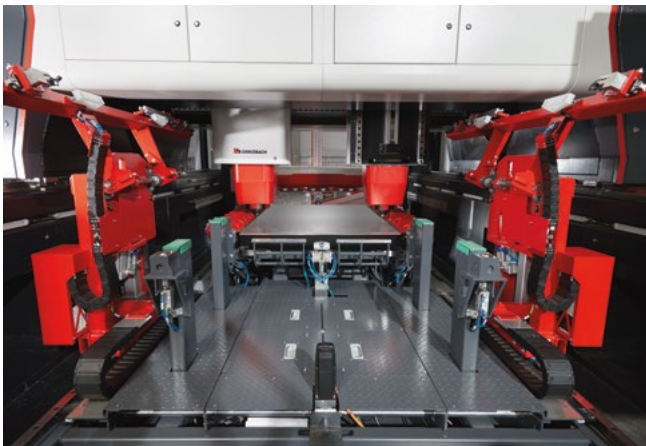
The DynaSTIR friction-stir-welding process
1. Rotating friction pin 2. Nonrotating tool shoulder 3. Immersion 4. Tilt angle 0 - 5° 5. Feed 6. Removal

A Comprehensive Portfolio of Systems



DSR ROBOT-ASSISTED FSW SYSTEMS: VERY FLEXIBLE FOR 3D ENVIRONMENTS

With its robot-assisted friction-stir-welding systems, Grenzbach has opened completely new areas of application for FSW technology. Welding robots already support numerous applications in industrial 24/7/365 series production; they can also be used in research and development, and for working on prototypes and small batch series. Active power control combined with robot kinematics not only allows for FSW's 3D capacity but also makes it possible to weld awkwardly placed parts, such as those in horizontal-vertical positions. With our CAD/CAM programming system, even complex welding lines and parameters can be handled without problems.



DSM 4-AXIS FSW GANTRY MACHINES: PRECISE, DYNAMIC, INTUITIVE

The gantry system is based on a HYDROPOL machine bed or a structure-optimized steel welded-construction, which are specifically designed for very high rigidity and low dynamic instability and deformation.

You retain real flexibility regarding individual workspaces with 4-axis gantry systems. Even large components such as battery trays fit within a workspace of up to 1.90 x 3.00 m (6,2 x 9,8 ft). Therefore, you can rely on a robust process that delivers a reliable, reproducible weld seam over the entire workspace. The gantry machines are designed so that a robot has easy access to load and unload them even with large modules.

Of course, the workspace has protected access. The service portals on the back make it possible to access the control hardware and the central power supply at any time.

A BOOST FOR PRODUCTIVITY: TWO GANTRY BRIDGES AND TWO WELDING HEADS IN A SINGLE GANTRY SYSTEM

With its double-spindle FSW gantry machines in the D-DSM series, Grenzbach enables you to work even faster and more efficiently. D-DSM stands for 'Double-Spindle Dynamic Stirring Machine'. By adding an additional gantry bridge to the DSM, we were able to give users two independently operating welding heads and an increased workspace up to 2.60 x 3.60 m (8,5 x 11,8 ft).

Advantages:

- » Reduction in real cycle time
- » Faster, but still flexible work
- » Less space required



A Step Forward: FSW Helps You Reach New Dimensions

These days, aluminum is used increasingly often in place of steel. The automotive and aircraft industries require lighter components. In machine construction too, aluminum can easily handle demanding specifications. And this is where friction stir welding really shows off its strengths.

When innovative FSW technology is used, components can be developed that meet the latest demands: light, sturdy and high-end. At the same time, FSW enables you to achieve hitherto impossible levels of optimization and thus to substantially improve your product.

The process is ideally suited for welding nonferrous metals and alloys with low melting points, as well as for welding different metals together:

- » Aluminum
- » Copper
- » Magnesium

Your investment in an FSW system is sure to pay off: friction stir welding is a process for serial mass production, which enables high process robustness with a low rejection rate. In addition, you minimize expenses for weld-seam preparation and reworking and consequently cut production costs.

Moreover, we take an interdisciplinary approach, meaning that we consider each customer's production chain in detail, with all upstream and downstream processes. Bottom line: there's practically always a clear advantage for you: **FSW the future of welding.**

Thinking Productivity Ahead:

With FSW, You Can Simply Do More



|| Grenzebach has always striven to respond in full to our customers' questions and concerns. Our FSW specialists support you with integrated solutions. We also know their limits – so we're the right people to talk to when you want to install new welding technology. We advise you about product design and process control right from the initial idea, and we can provide the appropriate equipment for any requirements. ||

Christian Herfert, Senior Vice President Special Technologies
Grenzebach Maschinenbau GmbH

FSW technology opens up possibilities that are difficult or impossible to achieve with conventional welding techniques:

- » Welding of all aluminum alloys, including cast aluminum
- » Qualitatively superior welding of different metals: nonferrous metals such as aluminum, copper, magnesium and alloys with low melting points
- » Unproblematic processing of porous cast metals and uneven surfaces

Additional advantages:

- » The purchasing and storage of operating supplies are substantially reduced, since adjuvants such as protective gas, powder or filler wire are not required
- » Low energy consumption compared to classic welding
- » No extraction system required
- » Low rejection rate thanks to process robustness
- » Online quality control
- » Lower rework expenses, since the process is low-distortion
- » Substitution of additional manufacturing steps, since the weld is media-tight and able to withstand mechanical stress

QUALITY THAT LASTS—YOUR COMPONENT FIRMLY BONDED

Is the weld pressure-proof and media-tight? Can it stand up to the loading? With Grenzebach, the answer is loud and clear: yes!

A broad spectrum of quality and precision tests contribute to this: welding technology examinations and visual inspection, tension and bending tests, coordinate measuring machine (CMM) testing, weld surface analysis, macrographic tests including evaluation, and hardness measurements (Vickers VH/Brinell BH). Grenzebach's quality control experts support you with more in-depth analysis tools.

SUSTAINABILITY: FSW PROTECTS THE ENVIRONMENT AND YOUR EMPLOYEES

MINIMAL MATERIAL AND ENERGY CONSUMPTION

Since adjuvants such as protective gas, powder or filler wire are not used, resources are saved and production waste is avoided. Moreover, the energy requirements are much lower than with classic welding.

HEALTHY WORK ENVIRONMENT

The FSW process is emission-free: dust, gases (including CO₂), smoke or radiation, none of those are produced. That means a healthy workplace and protects the climate. In addition, the technology is quieter than conventional welding processes.

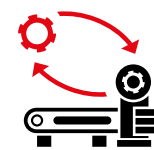
Grenzebach's Service Promise: You Can Build on It

It's clear to us that your production lines run seven days a week, round the clock, so you need 24/7/365 service. Rely on Grenzebach, a global leader: we're there for you, throughout the whole operational phase, whenever you need us.

Our service doesn't begin when you have a problem. It starts the moment you choose Grenzebach as an FSW partner and travel companion. From the outset, our specialized service team is fully committed to your system. And if ever a problem arises, we do whatever it takes to make sure your gantry machine or welding robot is back in action as soon as possible. We speak your language, we're in your time zone and we're ready to act without delay—on-site or remotely.



EVERYTHING TO KEEP YOUR FSW PROCESS RUNNING:



ORIGINAL PARTS

Long service life, reduced downtime: Our replacement parts enable the best possible performance for your FSW technology.

- » Outstanding quality
- » One-stop shopping
- » Maximum process and product quality
- » Highest possible availability
- » Optimized delivery time for parts
- » Individualized customer advice
- » Long service life
- » Worldwide delivery
- » Electronic parts catalogue



EXCELLENT SERVICES

Our constantly available full care service enables consistently high output, maximum availability, and ongoing use of your system.

- » 24/7/365 hotline
- » Remote support
- » Health checks
- » Preventive maintenance
- » Training with gantry machines and robot cells
- » Service calls on-site
- » Flexible service contracts
- » Extended warranty
- » Disassembly and reassembly of systems and components for moves



ROLLING UPGRADES

Our continuing upgrade offers help you boost your FSW system's productivity, increase its output and extend its service life.

- » Process optimization
- » System overhaul
- » Hardware and software upgrades
- » System-specific retrofits
- » Professional CAD/CAM programming software



FUTURE SERVICES

Make use of Grenzebach's SERICY digitalization platform and benefit from smart, robust processes:

- » Predictive maintenance
- » Online documentation
- » Digital service analyses

We Accompany You Into the Future of Welding and Beyond



In the automotive industry, progress needs to happen fast. That's especially true of one of the industry's megatrends: intelligent lightweight construction. FSW can give you a leg up: not only does it help you simplify handling, but it also makes components possible that simply couldn't be made with other techniques.

HIGH-DENSITY HEAT EXCHANGER

FSW is the technology of choice for heat exchanges, because porous cast components are often used here. The coolant must flow freely, and the heat exchanger must always remain airtight. "Pressure test passed" are the words you want to hear. FSW makes production considerably simpler and assures you of first-class results—a real step forward for productivity and quality.

HIGH-STRENGTH BATTERY TRAYS

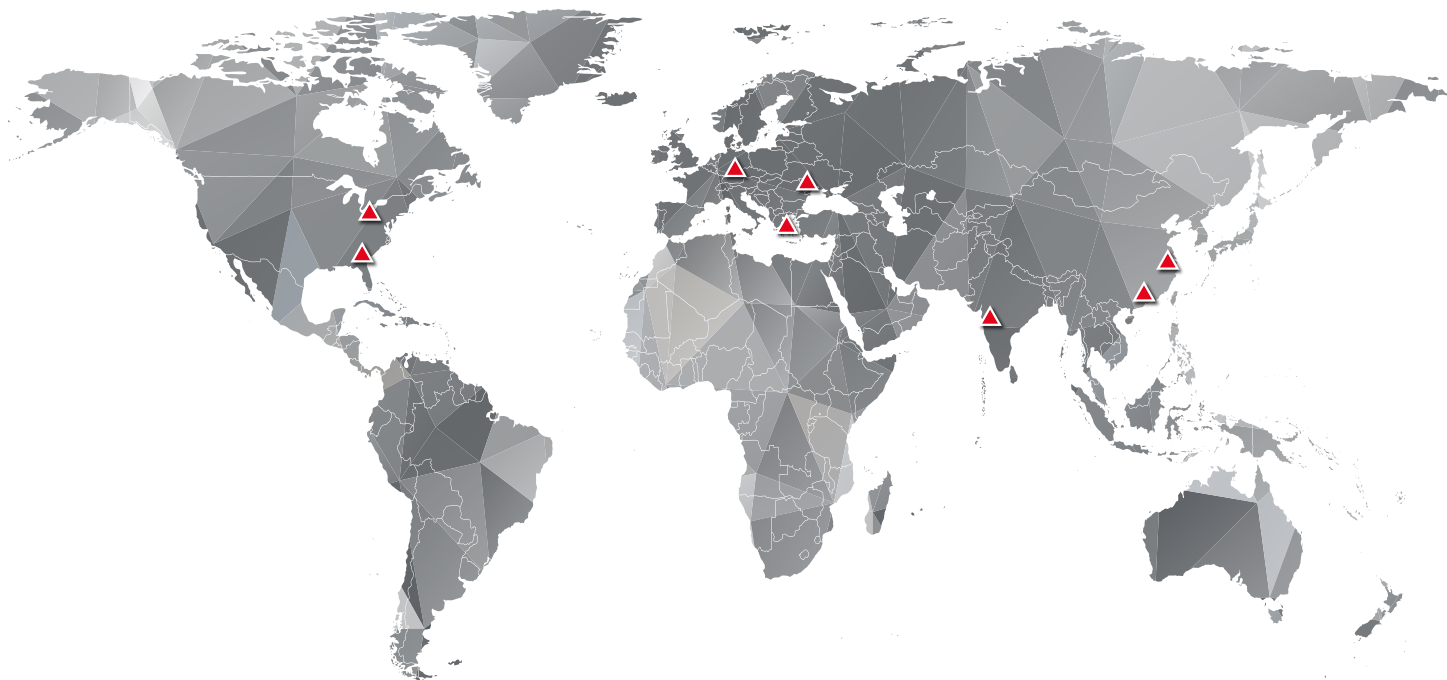
FSW is also the best process for cast or extruded battery trays. With Grenzebach's DSM 4-axis FSW gantry machines, no ablation is necessary for rotating weld seams, so that perfect seal welds are created. The welds are very strong and can withstand potential impact forces, which means they can be used in crash-relevant parts of the battery tray.

WANT TO LEARN MORE?

Visit our website and discover lots of descriptive practical examples and videos.



GRENZEBACH WORLDWIDE



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