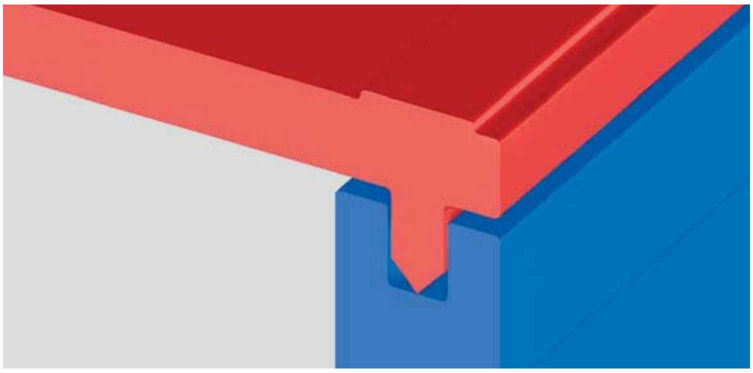




ULTRASONIC WELDING TECHNOLOGY

FUNDAMENTALS OF PLASTICS

Herrmann Ultraschall

Ultrasonic welding technology.
For thermoplastic materials.

Herrmann Ultraschall is a world-leading company in the field of ultrasonic welding. For our customers, we assume both the role of consultant and application problem solver with regards to the ultrasonic joining and sealing technology for plastics. This brochure contains practical advice and introductory information for welding plastics by means of ultrasonics.

In addition to leading-technology products, we provide excellent, in-depth application consulting to solve joining tasks, taking economic aspects into account. Please note that this brochure is intended to be an introduction to joining technology for plastics using ultrasonics and in no way replaces application-specific consulting given by our experts.

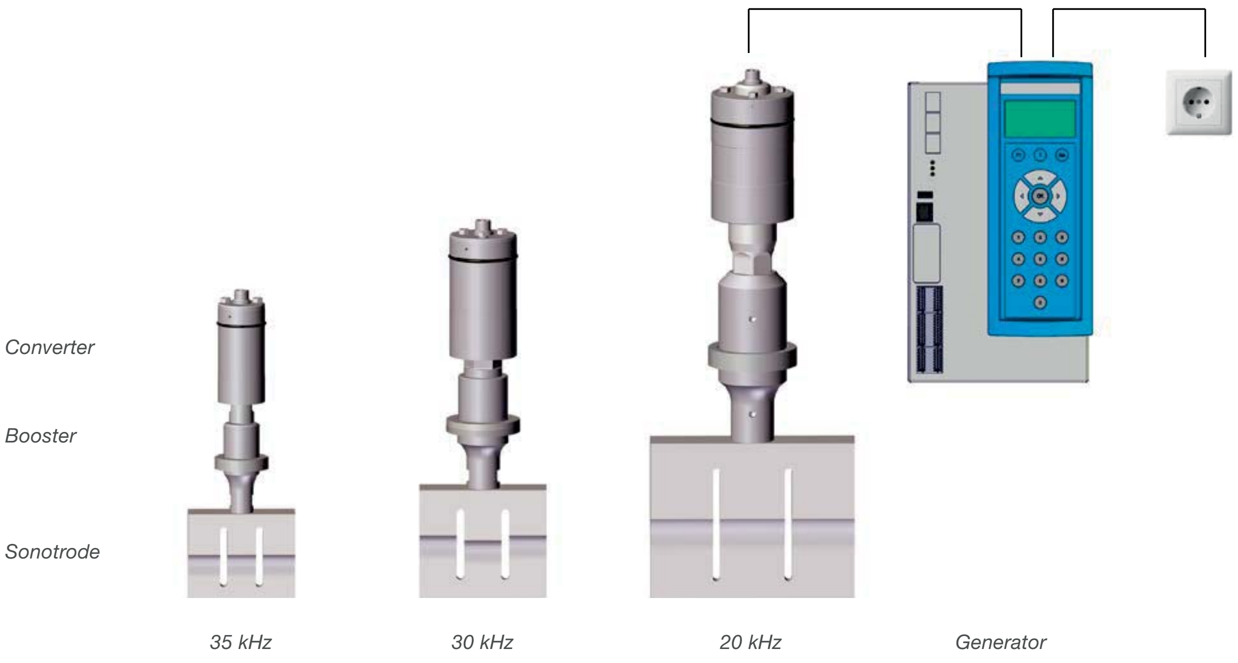
Due to high processing speeds and reproducible weld results, the technology is mostly used for high-volume production in the automotive, electronic, medical, packaging, hygiene, filter, and general technical industries.

Good weld results in terms of strength, tightness and visual appearance can only be achieved if the part material and design is suited for the ultrasonic process.

In order to attain consistently good welding results, it is important that the design of the parts to be joined is "ultrasonically correct" from the beginning. This avoids problems in component production already during the preliminary stages. Also the design of the injection mold and extrusion tools needs to take welding related considerations into account. Making changes to tools later on in the process can become very expensive and may frequently lead to compromises due to time pressure. Designs suitable for ultrasonic welding require knowledge not only of joining processes and technologies, but also material properties. The latter are essential for joining part designs.

Generation of ultrasonic vibrations

The ultrasonic generator converts the supply voltage into a high frequency voltage of between 20 and 35 kHz which is converted into mechanical vibrations in the converter using the piezoelectric effect. The weld tool, referred to as sonotrode, travels down onto the component and transfers the vibrations into the joining area. At an ultrasonic frequency of 20 kHz, for example, this means 20,000 movements per second. The resulting friction heat melts the material directly at the contact points of both components. Due to low energy consumption, the parts undergo very little thermal stress. The weld tools hardly heat up at all. The welded parts can be processed immediately, meaning that ultrasonic systems (or ultrasonic modules) can also be easily integrated into automation lines.

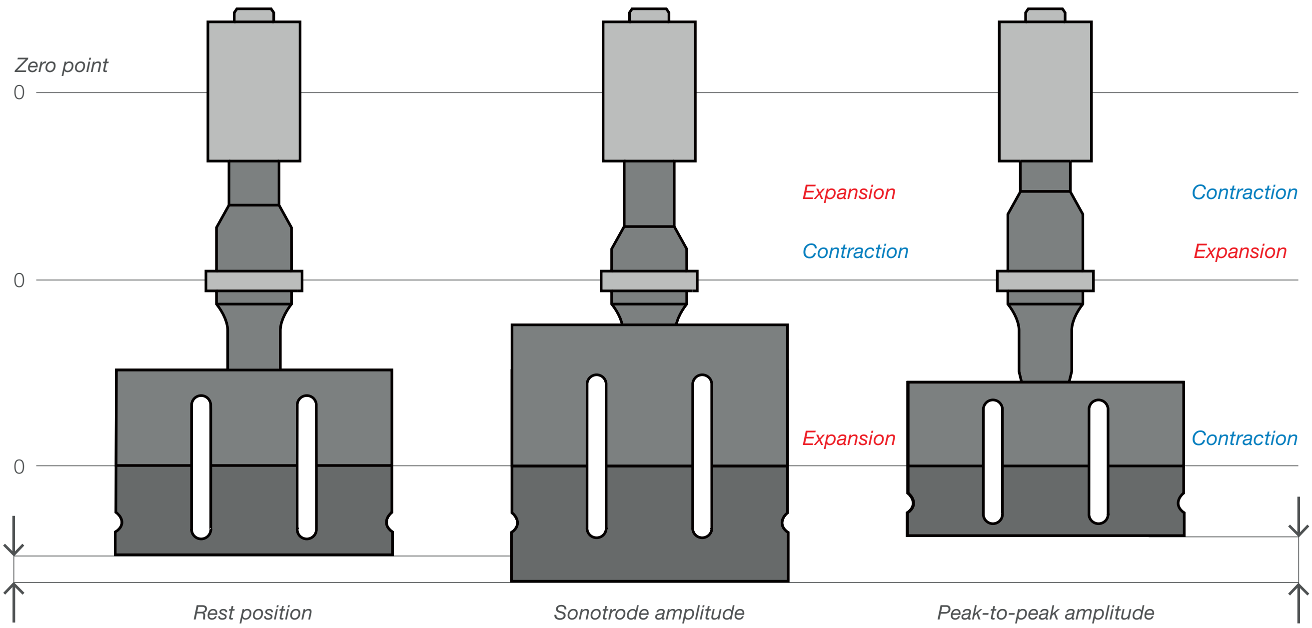


Ultrasonic welding technology.
Joined in seconds.

Procedure

During the ultrasonic weld process, mechanical vibrations of an ultrasonic frequency are transferred into the materials to be welded, at a specific amplitude, force, and duration. Molecular and boundary layer friction generates heat which increases the damping coefficient of the material. The plastic begins to melt at the energy director (definition s. p. 8). Since the damping factor of the plasticized material increases, a larger proportion of the vibration energy is converted into heat. This reaction is accelerated by itself. Once ultrasonic exposure has ended, a short cool-down phase under joining pressure is necessary to homogeneously solidify the previously plasticized material. Subsequently, the parts joined using thermal energy can be further processed right away.

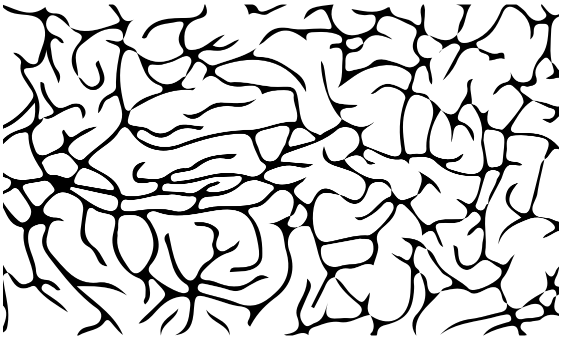
The core of the ultrasonic welding system is the stack. It is made up of the piezoelectric converter, the booster, and the sonotrode. The stack contracts and expands with the ultrasonic frequency. The resulting vibrations are longitudinal waves. The movement of the weld tool, meaning the distance between the peak position and the rest position, is referred to as amplitude – in ultrasonic welding the amplitude is between 5 and 50 µm. As comparison: The diameter of a human hair is only 100 µm. The tool movement is invisible, but can be felt and heard.



Material properties of plastics.
Influential characteristics.

Energy transmission

In principle, hard, amorphous plastics such as PC or ABS have ideal transmission properties for ultrasonic energy. The vibrations are transferred across large distances up to the joint area. In contrast, semi-crystalline plastics, such as PA or POM, have a high acoustic damping factor which greatly weakens the transferred vibrations. These materials can consequently only be welded within the near field of the sonotrode.

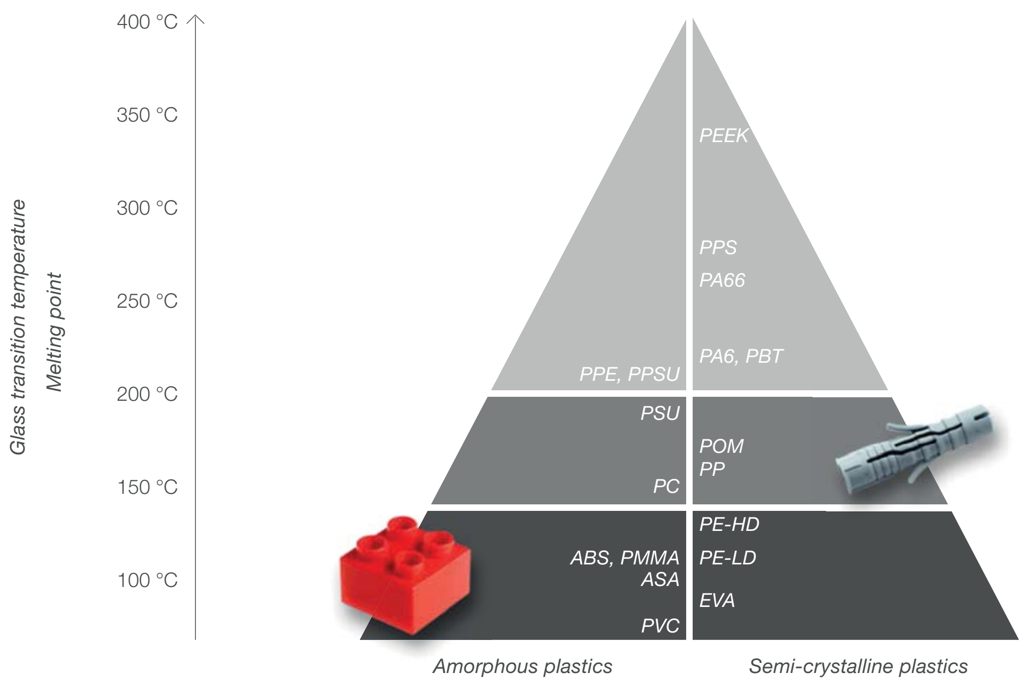


Amorphous plastics

Material properties

Both groups of materials differ with regard to the energy required. Amorphous thermoplastics have no defined melting point and generally require less energy. As the temperature increases at the weld zone, the material transitions from solid to molten. Semi-crystalline plastics require a higher amount of energy and power. Moisture content especially is of particular importance with PA semi-crystalline plastic. More moisture creates more damping and therefore lowers weldability (blistering). Glass fibers, on the other hand, have a positive effect on semi-crystalline plastics.

Semi-crystalline plastics



Precise welding parameters.
For optimal reproducibility.

Process parameters

The great benefit of ultrasonic processes is the range of possible parameters and their exact adjustment. By using a more exact parameterization you attain

- optimal joining velocity for a good weld and
- easy reproducibility of consistent results.

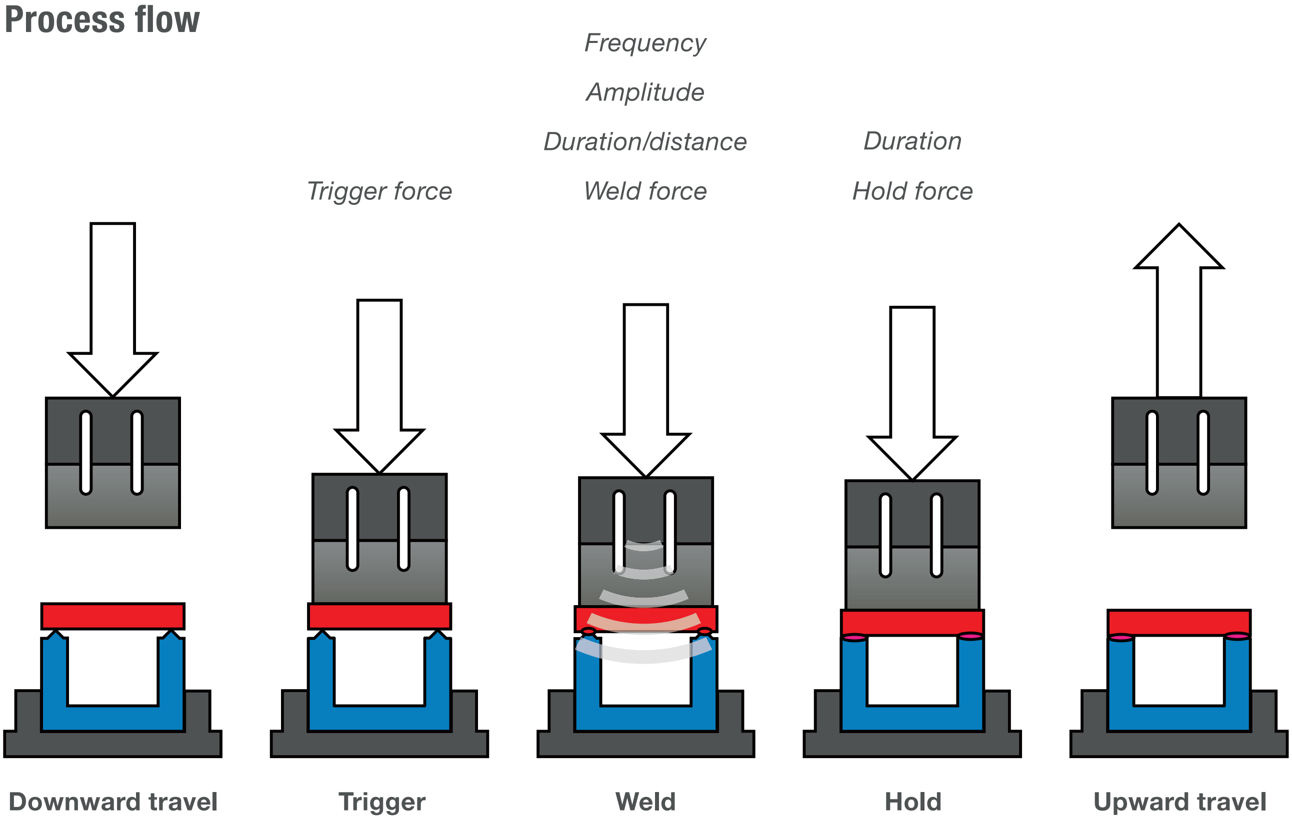
Important welding parameters:

- Frequency
- Amplitude
- Weld force
- Trigger force
- Switch-off criteria (e.g. weld distance or weld time)

The welding procedure can be graphically illustrated. The visualization on the controller user interface shows deviations in the procedure and allows for process optimization. The path of the joining velocity curve (distance over time) is a deciding indicator here.

Joining process illustration DIALOG user interface

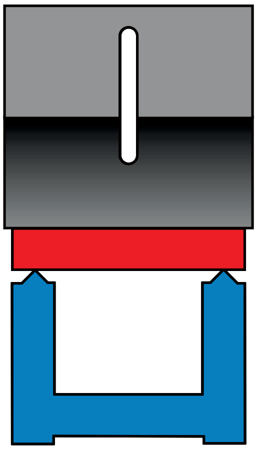
Process flow



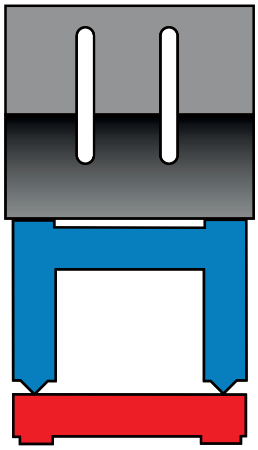
Optimized setting.
One process, many solutions.

Sonotrode/sonotrode contact

The weld tool (sonotrode) must be geometrically fitted to match the component and simultaneously be able to vibrate efficiently. This requires superb technical expertise. The sonotrode contact surface should always be as close as possible to the energy director so that the ultrasonic waves do not lose intensity as they travel through the plastic.



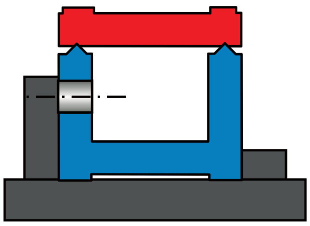
Near field welding



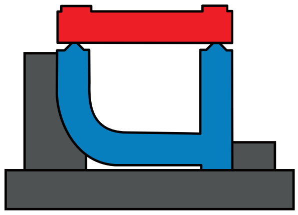
Far field welding

Fixture

The fixture is just as important as the sonotrode's geometry. It must be able to bear the forces during the weld and hold the components securely in place. Selecting the right material for the fixture ensures that the welded parts are technically and visually flawless. The weld joint should always be properly supported so that there is no deformation under load and the amplitude is efficiently transmitted to the joint. The components must be supported in such a way that they are forced to move in weld direction.



Example fixture 1

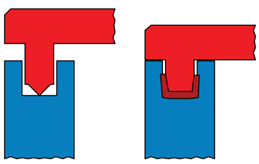


Example fixture 2

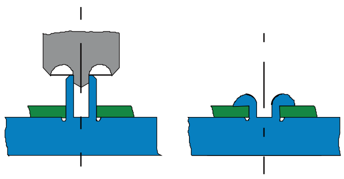
Joining variants

To facilitate the process, there are four different joining variants:

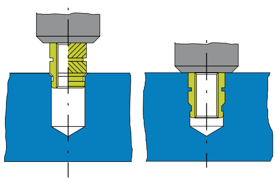
- Classic welding of two plastic components using an energy director
- Staking a component made from a different material to a thermoplastic (reforming)
- Inserting threaded inserts into plastic components
- Embedding of non-woven fabric or incompatible materials to a thermoplastic component



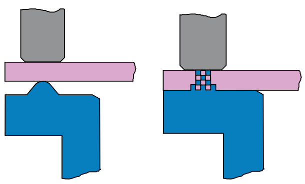
Welding



Reforming/staking



Inserting



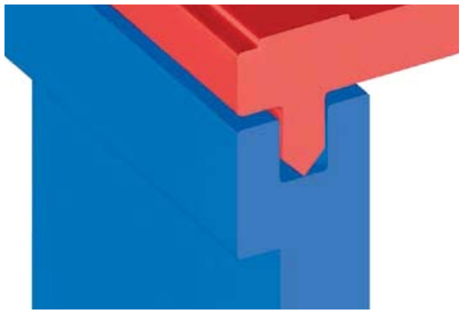
Embedding

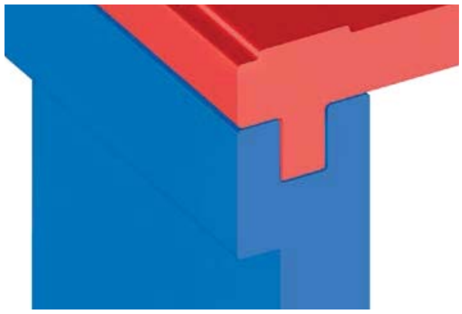
Defined melt initiation.
Concentrating on the essentials.

Energy director

The joint design for injection-molded parts consists of adapted weld geometries with points or edges in the joining area – they are called energy director. They focus the ultrasonic waves and define the melt initiation. Ultrasonic waves are transmitted through the molded components to the joining area.

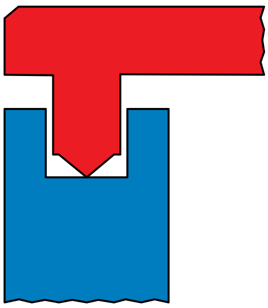
Point contact prevents planar coupling. The melt is formed directly between the components at the contact point of the energy director. The joint design is of the utmost importance for carrying out a reliable process. There are different joint designs. They are different depending on component design (wall thickness), the plastic material (amorphous/semi-crystalline) as well as different requirements (high strength, hermetic seal as well as particularly sensitive and visible surfaces).

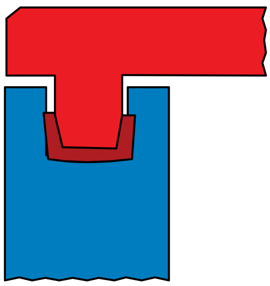




Melt encapsulation

A well encapsulated weld joint is air-tight and flash free. Strength is also increased because the melt is equally distributed across the joint. Amorphous plastics can be welded easily without encapsulation due to their highly viscous melts. If injection-molding technology reaches its limits in terms of accommodating joint designs, then a one-sided encapsulation is better than none.

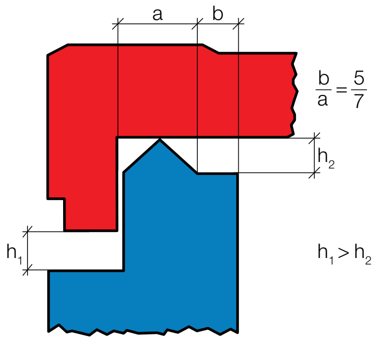




Types of joint design.
For specific requirements.

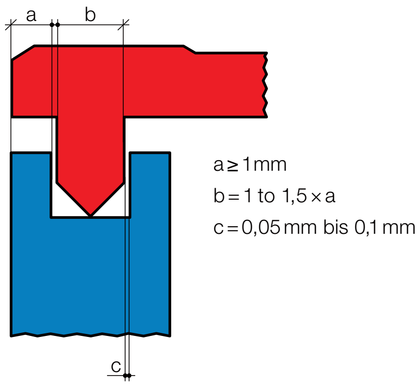
Step joint

This type of joint design is relatively easy to implement in the injection-molding tool. When amorphous plastics are used, this joint design promotes production of visibly flawless, high-strength and air-tight welds. Additional advantages are that the step joint supports self-centering of parts and absorption of increased shear and tensile forces.



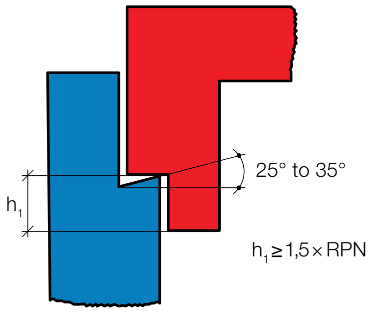
Tongue and groove joint

The greatest strength is usually attained by using a tongue and groove joint. Gap dimensions with very small clearances create a capillary effect which causes the generated melt to penetrate through the entire joint area. This joint design requires relatively thick walls and is a fundamental recommendation, provided that all prerequisites are met.



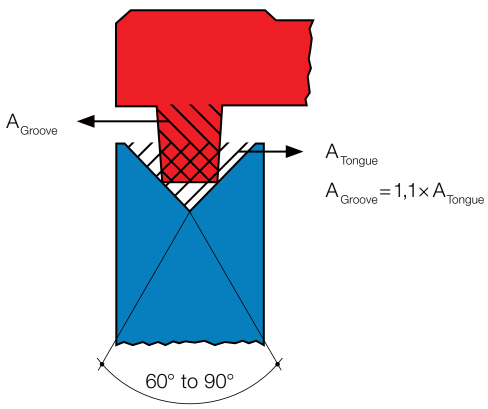
Mash joint

The mash joint has proved to be successful for semi-crystalline plastics combined with thin walls. With large joining distances this joint design typically produces air-tight and high-strength welds.



Double V joint

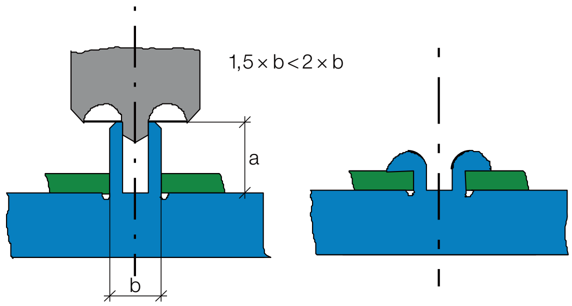
This joint is recommended for components with a wall thickness of less than 1.5 mm. Precise automatic centering of components and the resulting defined joint positioning contribute to high strength after welding. It should be noted that precise injection-molding and the correct adjustment of the joint are absolutely necessary.



Reforming using ultrasonics.
Joining element.

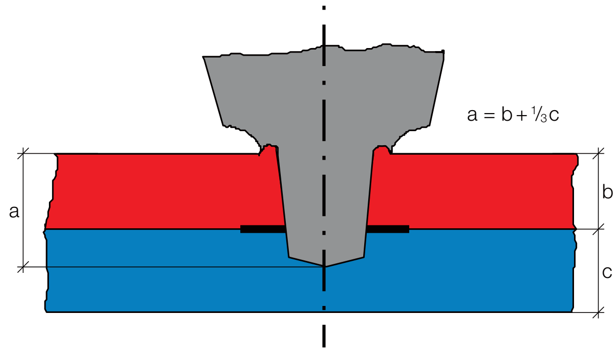
Staking

Using ultrasonics for staking allows thermoplastic molded components to be quickly and cleanly joined with metallic or other non weldable materials. There is no need for other additional joining elements. The heat resulting from the staking process can be dissipated by means of an air-cooled sonotrode. After the actual staking process, the system provides a pre-selected hold time so that the melt can fully solidify under static pressure. In this way, reset forces are blocked, which in turn ensures accurate and zero-clearance joints.



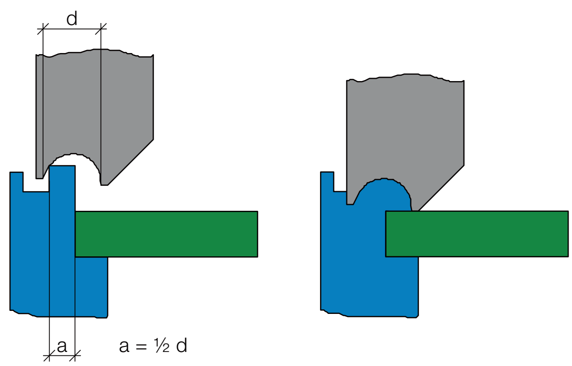
Spot welding

The molded components that are to be welded lie planar on top of one another without prepared joint points and without energy director. The point of the sonotrode penetrates through the upper plate into the lower plate and so plasticizes the plastic in both components. The resulting melt partly collects in the joint and produces a spot weld.



Swaging

It is not always possible to mold parts with the necessary staking pins. Swaging is a suitable alternative for these kinds of applications. The contact face of the sonotrode must be machined appropriately for the swaging process. With ultrasonic swaging reforming of large formats and inclusion of the entire circumference of the component is possible.



Continuous support from the beginning.
ULTRASONIC ENGINEERING.

The expert teams at Herrmann Ultraschall will support you during every phase of your project. This includes joint design discussion, component design, pre-production prototype welding in application laboratories, weld parameter definition for verification of the required component properties, training/instruction services, and after-sales services. Close cooperation with the customer and efficient product development is the primary focus.

Ultrasonic laboratory

Application consulting
- Early support for component design
- Support and direction for designing the geometry of the weld joint area
- Principle testing for feasibility

Application optimization
- Common trials and tests with the customer
- Determination and optimization of tooling profiles and process limits
- Verification of research results with the help of microscopy, tensile tests, sealing tests, burst tests, high-speed cameras, and microtome cuts
- Complete documentation of the feasibility test results

Technical project management

- Consistent implementation of customer requirements and test results in design concepts
- 3D supported collision analysis
- FEM assisted tool design
- Mechanical and electrical interface definition
- Guidance on integrating the weld process into the machine sequence

Tech-Center on-site

- Customer-oriented support for feasibility analyses
- Ultrasonic laboratories are strategically located in the major markets worldwide
- Experienced and native-speaking application specialists

Trainings and seminars

- Beginner and expert seminars
- Hands-on user training
- Trainings on site or at our local facilities
- Customer-specific trainings

After-sales service

- Optional 24-hour service hotline
- On-site service in the respective languages through our Tech-Center network
- Preventative maintenance and service measures

FIRST CLASS TECHNOLOGY. WORLDWIDE. 24 LOCATIONS IN 18 COUNTRIES.

Global Headquarters
Herrmann Ultraschalltechnik GmbH & Co. KG
Descostraße 3–11 · 76307 Karlsbad, Germany
www.herrmannultraschall.com

North America Headquarters
Herrmann Ultrasonics, Inc.
1261 Hardt Circle · Bartlett, IL 60103, USA
www.herrmannultrasonics.com

China Headquarters
Herrmann Ultrasonics (Taicang) Co. Ltd.
Build 20-B, No. 111, North Dongting Road, Taicang,
Jiangsu Province, China · **www.herrmannultrasonic.cn**

Japan Headquarters
Herrmann Ultrasonic Japan Corporation
KOIL 503-1, 148-2 Kashiwanoha Campus, 178-4 Wakashiba,
Kashiwa City, Chiba 277-8519 · **www.herrmannultrasonic.co.jp**

Herrmann Ultraschall

86512 02/19 ENG 500 Subject to technical changes.