



MECASONiC[®]
Plastic Welding Solutions



Ultrasonic welding technology.
For thermoplastic materials.

Basics of Plastics

What is Ultrasonic Welding?

Ultrasonic plastic welding is the joining or reforming of thermoplastics through the use of heat generated from high-frequency mechanical motion. It is accomplished by converting high-frequency electrical energy into high-frequency mechanical motion. That mechanical motion, along with applied force, creates frictional heat at the plastic components' mating surfaces (joint area) so the plastic material will melt and form a molecular bond between the parts. The following drawings illustrate the basic principle of ultrasonic welding.

Plastics assembly is a fast, clean, efficient, and repeatable process that consumes very little energy. No solvents, adhesives, mechanical fasteners, or other consumables are required, and finished assemblies are strong and clean.

The basic principle of ultrasonic welding

Step 1 - Parts in fixture



The two thermoplastic parts to be assembled are placed together, one on top of the other, in a supportive nest called a fixture.

Step 2 - Horn contact



A titanium or aluminum component called a horn is brought into contact with the upper plastic part.

Step 3 - Pressure applied



A controlled pressure is applied to the parts, clamping them together against the fixture.



Step 4 - Weld time



The horn is vibrated vertically 20,000 (20 kHz) or 40,000 (40 kHz) times per second, at distances measured in microns, for a predetermined amount of time called weld time. Through careful part design, this vibratory mechanical energy is directed to limited points of contact between the two parts.

The mechanical vibrations are transmitted through the thermoplastic materials to the joint interface to create frictional heat. When the temperature at the joint interface reaches the melting point, plastic melts and flows, and the vibration is stopped. This allows the melted plastic to begin cooling.

Step 5 - Hold time



The clamping force is maintained for a predetermined amount of time to allow the parts to fuse as the melted plastic cools and solidifies. This is known as hold time

Step 6 - Horn retracts



Once the melted plastic has solidified, the clamping force is removed and the horn is retracted. The two plastic parts are now joined as if molded together and are removed from the fixture as one part.

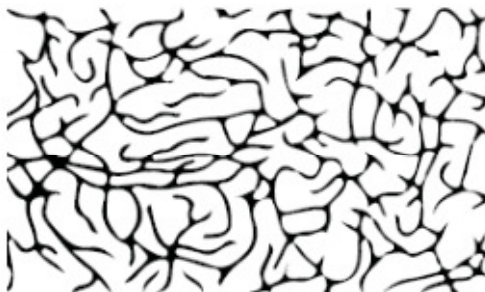


Material properties of plastics.

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.



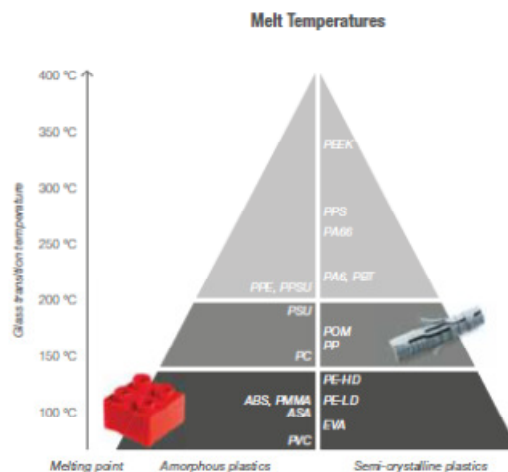
Amorphous plastics



Semi-crystalline plastics

Material properties

Both groups of materials differ with regards 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.





Joined in seconds

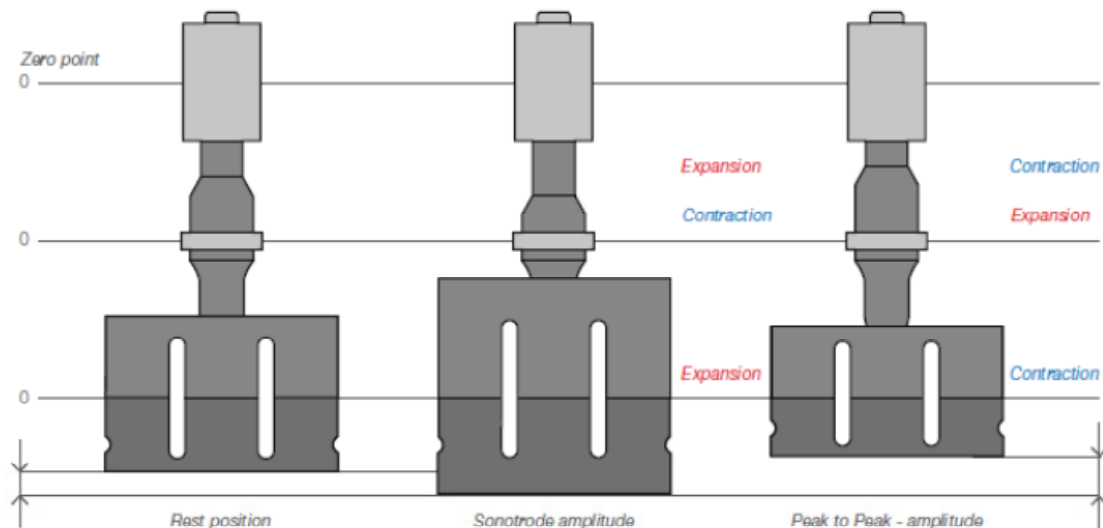
Procedure

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 directed.

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 vibration 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 at a lower frequency



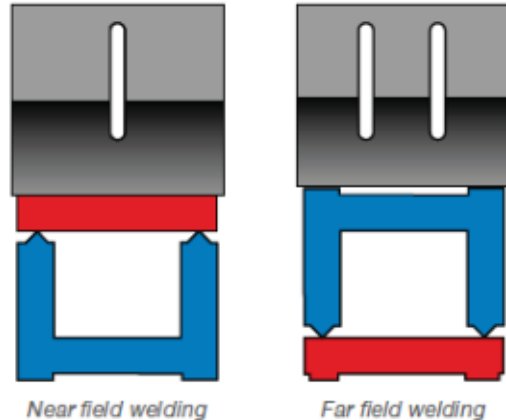


Optimized setting.

One process, many solutions.

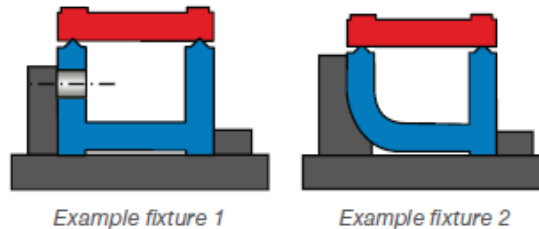
Sonotrode/part contact

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.



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.



Joining variants

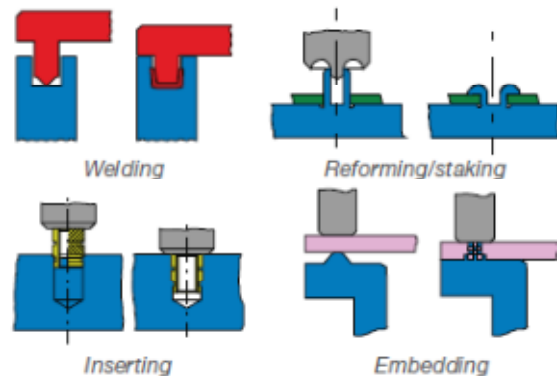
To facilitate the process, there are four different joining variants:

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





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.

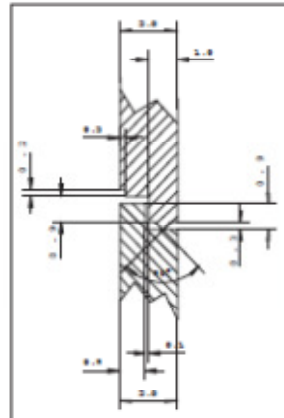


Types of joint design.

For specific requirements.

Step joint

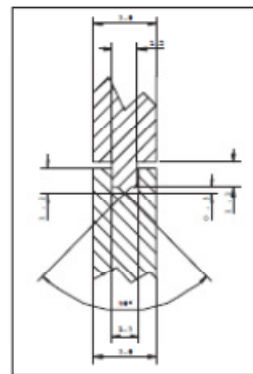
This type of joint design is relatively easy to implement in the injection-molding tool. When amorphous plastics are used, this joint design promotes production of visibly flawless, high-strength and air-tight welds. Additional advantages are that the step joint supports self-centering of parts and absorption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



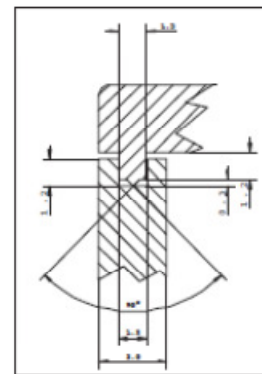
Energy Director 2

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.



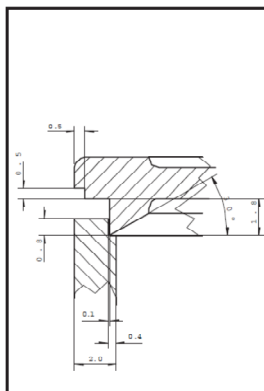
Energy Director 1



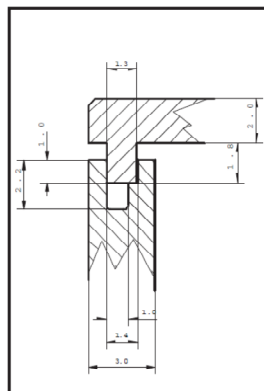
Energy Director 1.1

Share joint

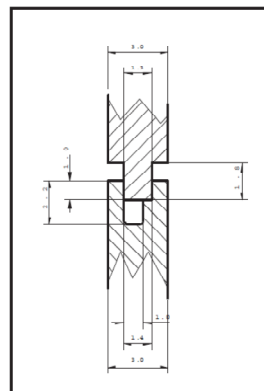
The mash joint has proved to be successful for semi-crystalline plastics combined with thin walls. With large joining distances this joint design typically produces air-tight and high-strength welds.



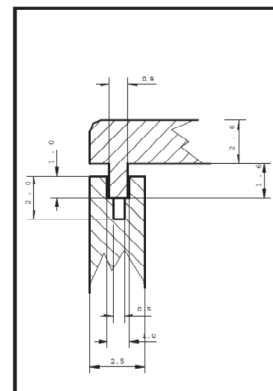
Shear joint 2



Shear joint 3



Shear joint 3.1



Shear joint 4

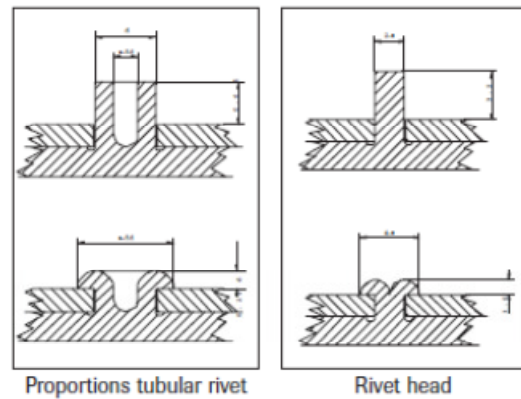


Forming using ultrasonics.

Joining element.

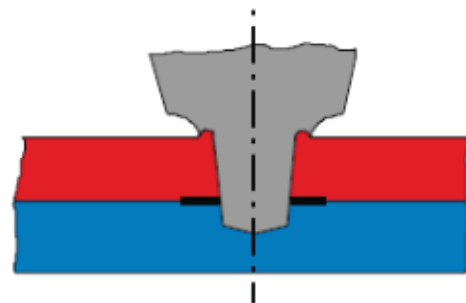
Staking

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.



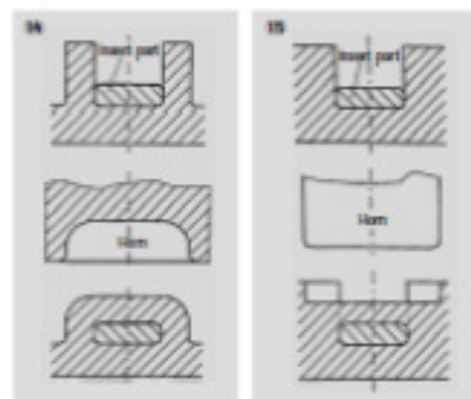
Spot welding

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.



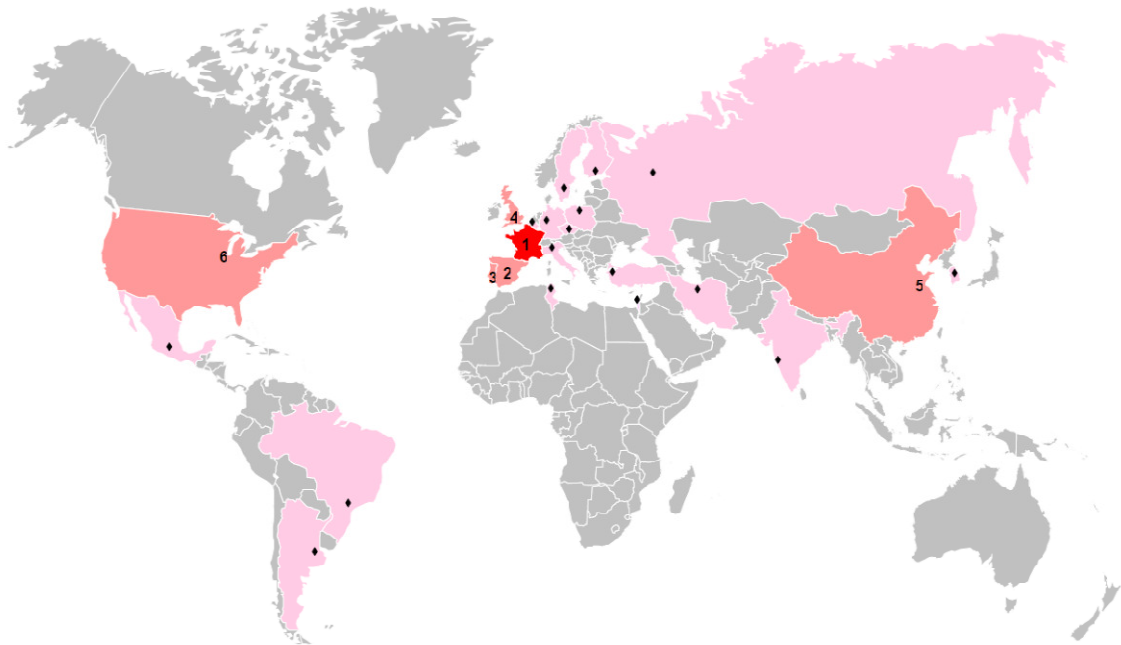


MECASONIC[®]
Plastic Welding Solutions

Continuous support.

Consulting and services from the ultrasonic specialists.

This includes understanding of customer requirements, joint design discussion, component optimization, pre-production prototype welding in application laboratories, weld parameter definition for verification of the required component properties, training/instruction services and after-sales services. Efficiently developing products together is the primary focus.



www.tells.com.ar
ricardo.oliveto@tells.com.ar
+54 11 4762-3605

Construction Guidelines

Inserting

A method known from earlier days of working with Duroplast, for bonding metal and plastic parts together is pressure coating or extrusion coating of metal inserts. The process is also used

in thermoplastic injection moulding. If the physical properties of the thermoplastics are considered

when processing and for their longterm behaviour, the result is often unsatisfactory from both an economic and a quality point of view.

- . the metal parts must be pre-heated,
- . loading the parts into the injection mould tool is very costly, whether by hand or by robot,
- . extended – and in the case of manual loading – irregular cycle-times for the injection moulding adversely affect the quality of the plastic parts,
- . the injection moulds are subject to extra wear and tear in the area of the insert loading,
- . the manufacturing tolerances of the loading parts must be within unrealistic narrow limits,
- . extrusion-coated metal inserts hinder contraction of the plastic when solidifying and cooling off.

This always results in very high tangential stresses, which often lead to formation of cracks. As a rule one tries to absorb these stresses with excessive wall strengths surrounding the inserted metal part. Such accumulations of material are unhelpful for achieving reasonable cooling times

for injection moulding.

Plastics with a high stress-strain ratio, such as for example Standard Polystyrene, are particularly

susceptible to stress fractures. All other thermoplastics too, though, can fail in their longterm behaviour under the influence of weathering or chemicals which trigger off stress fractures.

One reason for using ultrasonic inserting, which should not be ignored, is the considerable saving in energy.

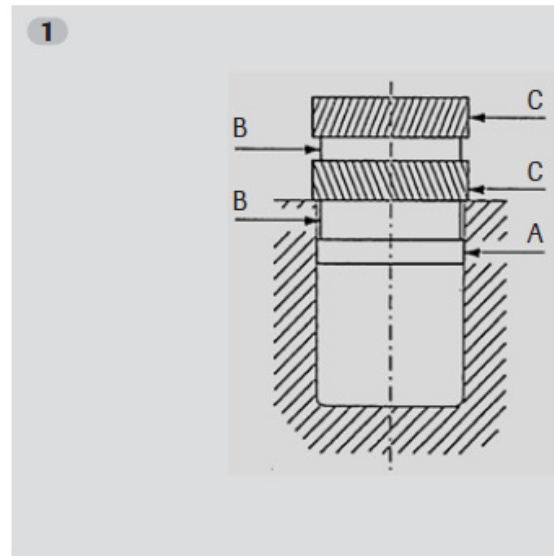
For the reasons already stated, an experienced designer will abandon injection moulding of metal inserts, in favour of technically better solutions achieved by ultrasonic inserting.



Design 1-4-

In principle, construction of an ultrasonic produced metal insert always contains the three elements described below:

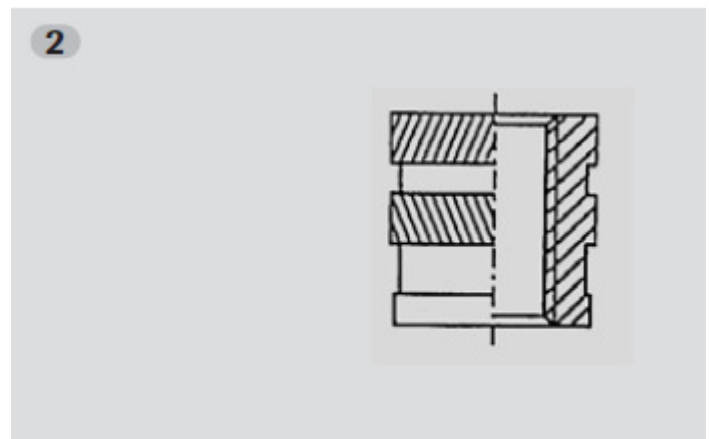
Reference diameter (A), which has the task of positioning the metal part precisely in the hole of the plastic part. The height of this zone must be sized large enough so that in this area the plastic part does not melt under the effect of the ultrasonics. This would result in movement away from the inserting axis. **Undercut (B)**. One or several notches, into which the molten plastic flows, to fix the insert in the axial direction. In this way high pull out forces are achieved. **Knurling (C)** or lengthways grooves take care of the torsional hold on the insert. Sharp edges encourage stress fractures and must at all costs be avoided.



The three elements of an ultrasonic metal insert

The standard range of an ultrasonic insert manufacture in general covers three types:

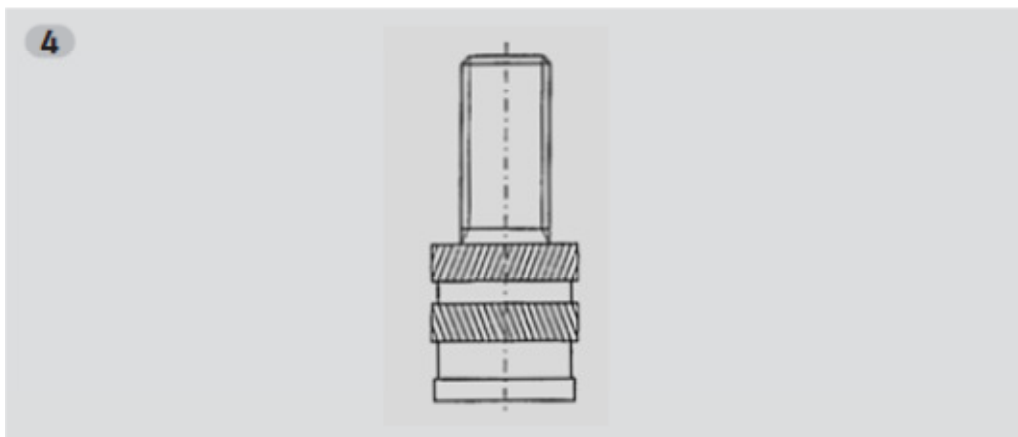
- . standard threaded insert
- . threaded insert with flange
- . insert with set screw



Standard threaded insert



Threaded insert with flange



Insert with set screw

Inserting Procedure 5-8-

In most cases the sonotrode acts directly on the metal part.

The part to be inserted is to be considered as an extension of the sonotrode, i.e. it is excited by the sonotrode into vibration with practically equal frequency and amplitude. In this way the heat energy between the surface of the part to be inserted and the surface of the plastic part becomes molten.

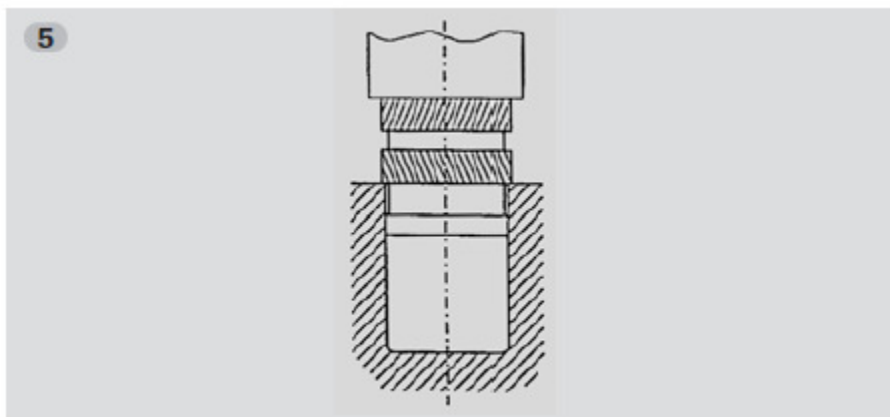
The insert sinks into the molten plastic under the combination of the amplitude and force applied by the ultrasonic system. The molten plastic flows into the profile of the insert and quickly solidifies when the ultrasonics are switched off. The volume of affected plastic should be equal to or greater than the volume of the profile in the insert. Blind holes should be about 2 mm deeper than the insert so that any surplus molten plastic is forced down into the hole. To avoid unnecessarily high pull out forces being applied to the threaded inserts, they should stand slightly above the surface of the plastic. In this way the pull out forces on screwing down are supported on the top surface of the insert and not on the plastic part.



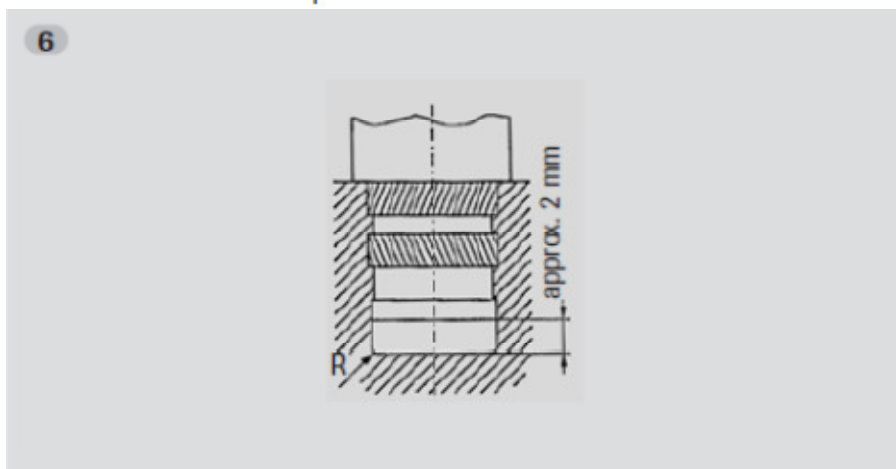
MECASONiC[®]

Plastic Welding Solutions

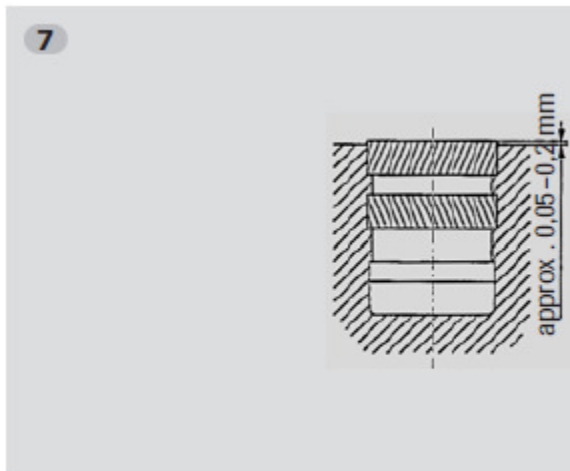
This requirement can be adhered to very easily by using inserts with a flange, and taking appropriate measurements. Also the tendency to protruding flash is significantly less because the flange forms a barrier against the rising molten material. If shafts, axles or other unfavourably shaped parts have to be inserted, it is advisable to locate the metal part inside the fixture, and allow the ultrasonic energy to act upon the plastic part. The points in the **Construction Guidelines for Ultrasonic Welding** described under near and far field welding must also be taken into account. Marking must be expected on the coupling surface. By using a protective foil between the sonotrode and the plastic part, this can be avoided.



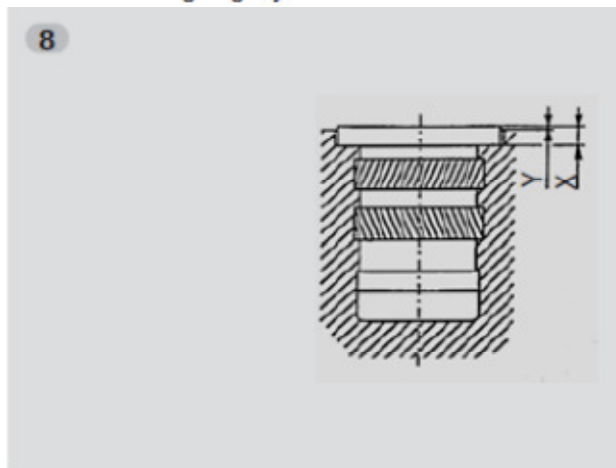
The insert is inserted and precentred over the reference diameter.



The insert is pushed in by ultrasonics and firmly encased in the molten plastic.



Insert Protruding Slightly



Insert with Flange. Dimension X determines residue Y.

Notes

Sonotrodes are subject to a high rate of wear and tear by the metal-to-metal contact when inserting is done. For this reason the sonotrode tips are either treated with a coating of hard material or manufactured from hardened steel. Any repair work on worn sonotrodes should in principle be left to the manufacturer. Abrasion of metal must be expected at the inserting points. To avoid damaging threads when inserting is taking place, they should have a suitable counter-bore. Information regarding the dimensions of the counter-bore hole can be obtained from the ultrasonic insert manufacturer's corresponding documentation. We will gladly supply you with the address of these companies on request.

Thermoplastic joints can also be produced by ultrasonic inserting. Inserts made of thermoplastics with higher melting points and of lower deformability than the surrounding material can be processed very well. The options extend to joints made from the same material. Here, however, special measures are needed for design.



MECASONIC®

Plastic Welding Solutions

Noise Protection 9

The excitement of a metal part by ultrasonics generally leads to development of a high noise level. With 20 KHz systems the frequency level of this noise is within the audible range.

The strength may reach levels which can damage hearing.

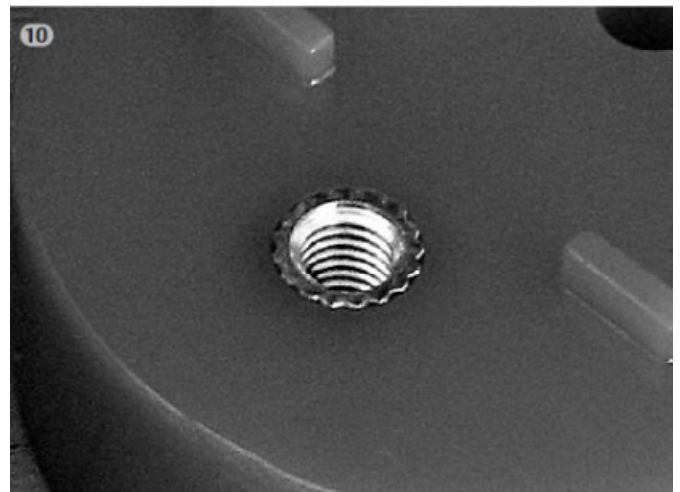
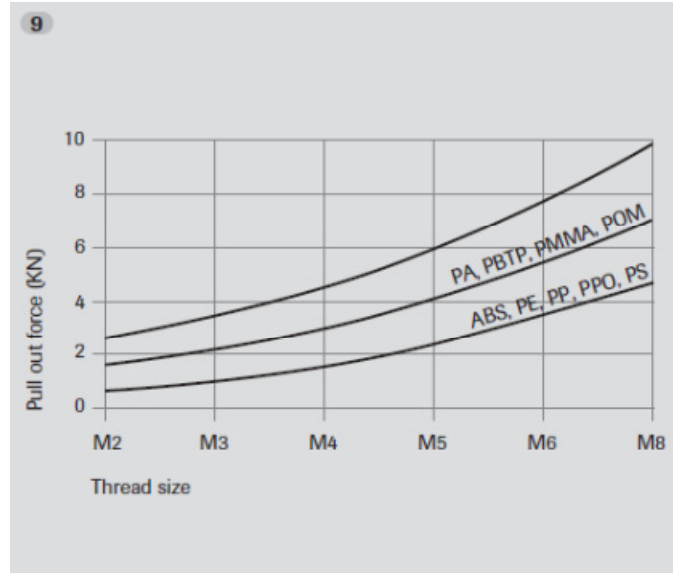
The use of hearing protection devices is strongly recommended.

The neatest solution is provided by acoustic booths, which incorporate the complete ultrasonic welding machine. Such booths are of course a part of the MECASONIC product range.

The table at the side shows the standard values for the pull out forces of inserts. When filled materials are used (glass fibres, minerals, etc.), the values are generally speaking higher still. They are significantly influenced by the processing conditions, and may deviate upwards or downwards accordingly.

An exceptional application:10

Six metal threaded inserts are inserted in a working cycle.



Construction Guidelines

Ultrasonic-Fusion Forming

In addition to traditional ultrasonic welding, fusion forming by means of ultrasonic offers a very wide range of possible applications:

- . riveting
- . flanging
- . embedding

These processes considerably extend the use of ultrasonic. They offer the possibility of formlocked combining of thermoplastic synthetics with other materials – metals, glass or dissimilar plastics. Unlike welding, in the case of fusion forming only one plastic part is locally plasticized and shaped in its viscous state. In this way effective use is made of the heat energy between the horn surface and the surface of the plastic part.

Forming by ultrasonic has important advantages over other techniques. Because the forming takes place in the melting phase, only negligible stresses arise in the shaped parts – provided the machinery is correctly adjusted. The problem of stress relaxation is practically non-existent.

Fixed connections with no play in them are achieved, coming up to very exacting demands, even in their longterm behaviour.

The wide spectrum of possible applications is shown at MECASONIC by the supply of the most varied

equipment and machinery. It ranges from hand welding appliances for simple riveting or flanging work, through standard welding presses, up to multi-head systems, producing a working cycle of dozens of shaping points, and operating on various different levels.



Riveting 1-3-

The horn transfers the mechanical oscillation energy to the rivet spigot. It is the riveting tool while at the same time being worked on the face side to the desired rivet headshape. This recess corresponds to the volume of the shaped plastic. Particular attention must be paid to the wear on horn tips, especially when working with abrasive materials. Plastics with mineral fillers or glass fibres require the use of suitable horn materials. Hardened tool steels of hardnesses above

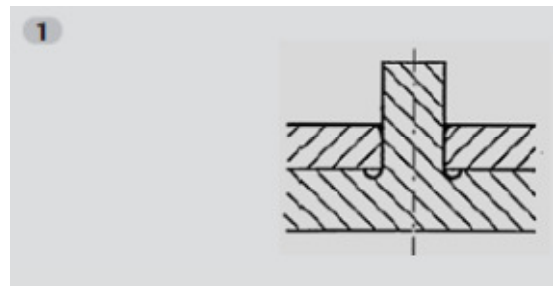
60 HRC, or a suitable coating are recommended. Thin metal parts can be excited by ultrasonic vibrations and there is a tendency for the parts to climb up against the horn. A clean bond is not guaranteed. Clamping down devices will help. The vibrations can also lead to the break up of

exposed parts. Such problems are solved by using sound-compensating materials, possibly combined with clamps designed for the purpose. If metal parts are fixed with several rivet heads, all rivet heads should be shaped in one working cycle. If rivet joints are made individually, the sound energy is conducted through the metal part to the already shaped rivet heads and

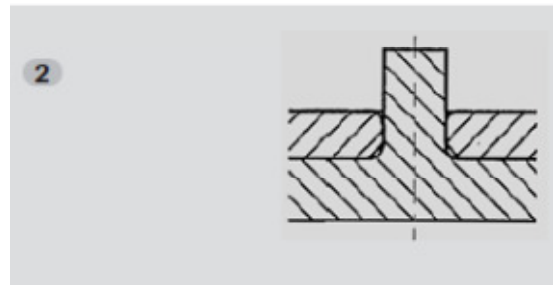
can lead to breakage. The horn must not touch the part to be attached. The plasticized material must solidify under pressure during the cooling time. This procedure can be compared with the stress and cooling time for injection moulding. If the horn lies on the upper part, the pressure on the rivet head is reduced. The result is a non-homogeneous structure with resultant loss of strength.

When metal parts are being riveted, this problem is solved very neatly in the form of a contact breaker. A suitably equipped absorption tool, connected electrically to the controls, causes cut off of the ultrasonic energy if the horn touches the metal part. A welcome secondary phenomenon with this system is that component tolerances are automatically compensated for. **Structure** The general shape of a rivet joint is known from the machine

construction. The fixing of the rivet pin should in all circumstances be provided with a ringshaped undercut, with a radius or at least with a bevel. In either case the part to be riveted on must of course be recessed. The same applies to the upper edge of the hole of the part being riveted on. If cost considerations and manufacturing capabilities allow, a radius or at least a bevel should be made here. These measures prevent notch effect and stress concentrations, which can lead to breakages even when shaping the rivet head.



Rivet pin with undercut



Rivet pin with radius



Rivet pin with bevel



Head shapes 4-11 –

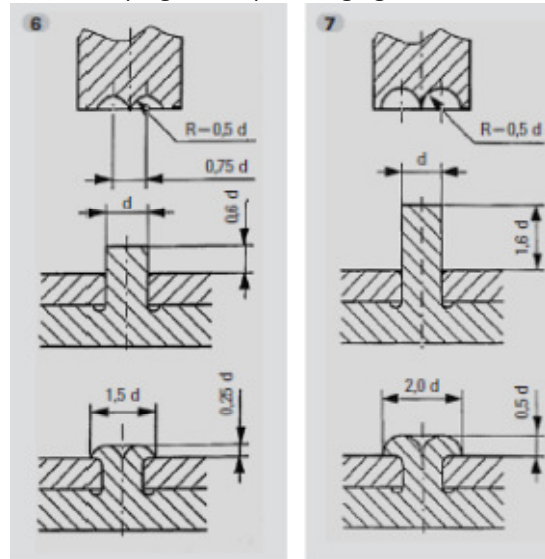
The simplest head shape, as in illustrations A and B, is used chiefly for rivet pins up to approx. $d = 4$ mm. Partially crystalline thermoplastics can in certain circumstances be difficult to work in these forms, because no particular care is taken over melting of the material. A proven, modified shape helps here. The horn has a central tip. The ultrasonic energy is thereby heavily concentrated and greatly assists melting of the material. As a result short welding times and good strength values are achieved. Shapes C and D are suitable for all thermoplastics and rivet spigots where $d =$ approx. 2 – 8 mm.

Head shape E shows an alternative to the central spike. Here melting of the material is assisted by suitable shaping of the spigot. It is important for this tip to be sharp-edged or shaped with a maximum radius of 0.2 mm. This shape is favourable for working with glass fibre reinforced materials.

Multiple rivet joints in one plane with spigot diameters up to about 4 mm can also be produced with large area, plane horns. Positional inaccuracies and measurement tolerances have no effect or are insignificant. As head shapes F and G are not defined, these applications are limited to places which are not visible on the finished product. For partially crystalline thermoplastics and larger spigots, steps must be taken to assist with the melting. A rhombic shaping (Kourl pattern) of the horns has proved very successful. Quite understandably, these two variants do not meet any special requirements for strength. They are used in preference for the fixing of metal parts in electrical engineering. For the larger spigot diameters, from about 6 mm upwards, the use of hollow spigots as in illustration H is recommended. Accumulations of material and therefore sink marks on injection moulded parts can thus be avoided. The quantity of material to be shaped is reduced, which is

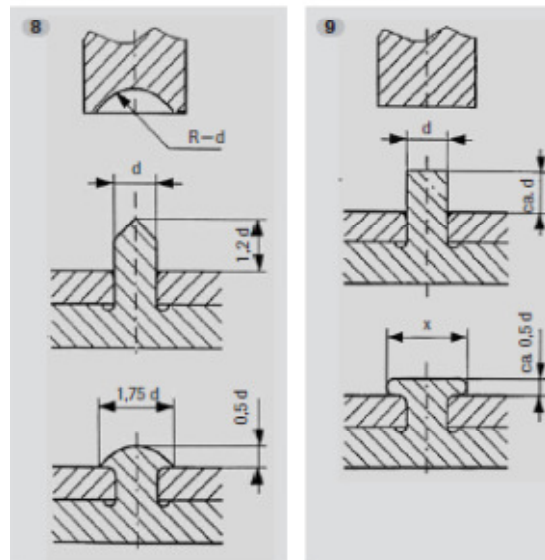
beneficial in terms of the welding time and the energy requirement.

The suggested standardization represents approximate values. These can of course be varied and adapted to individual requirements. The shape of the hollow rivet brings us to a further shaping technique: flanging.



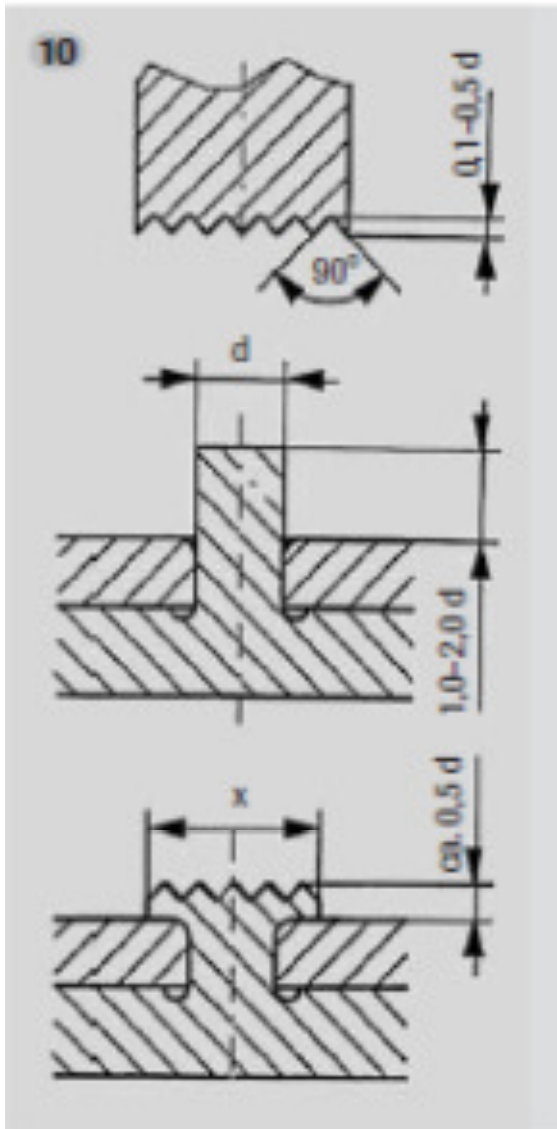
Head shape C

Head shape D

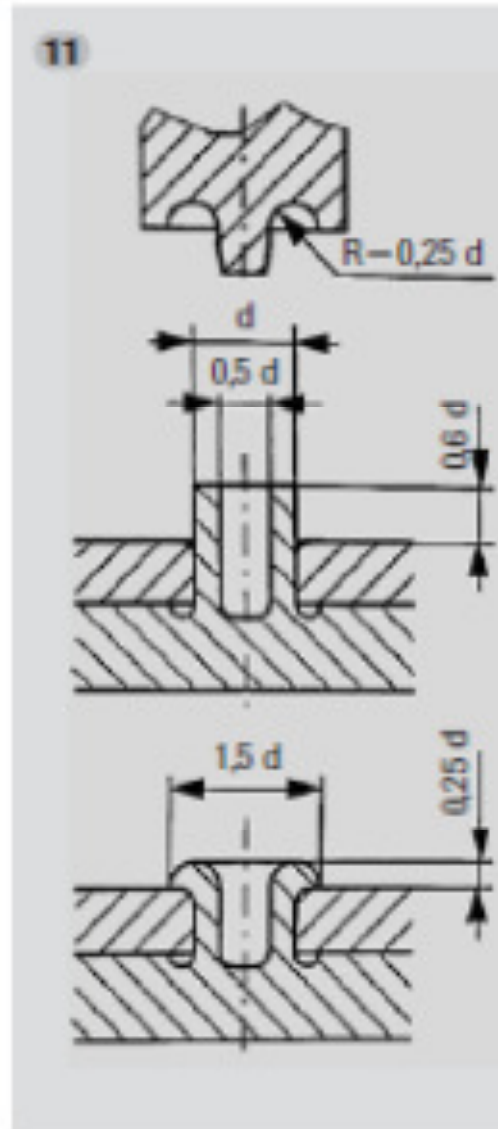


Head shape E

Head shape F. Measurement x is precisely defined!



Head shape G. Measurement x is not precisely defined!



Head shape H



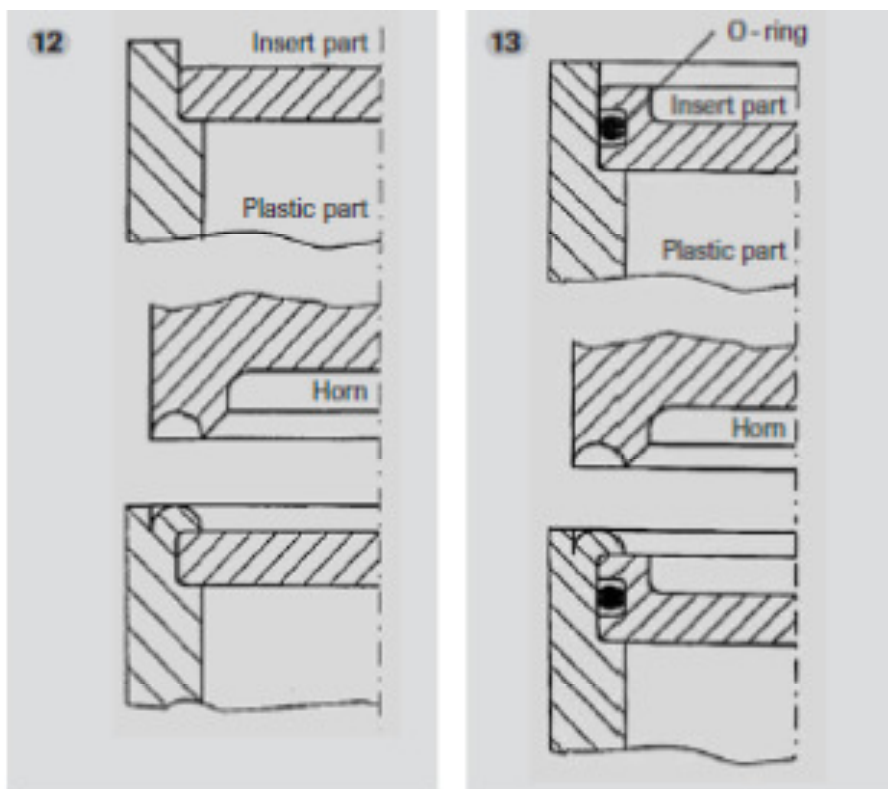
Flanging 12-13–

The flanging technique is known from metal-working. The most important characteristic in the case of ultrasonic flanging is that the material is plasticized by the ultrasonic energy and shaped in the viscous melting phase.

The advantages deriving from this were mentioned in the introduction. A typical application is shown in Illustration 12. The designer has a relatively free choice in shaping jointed flange connections,

though the parts being shaped must exceed the volume calculation. Even if such joints meet very high specifications, they can never be airtight because of the unequal thermal expansion of both parts. If airtightness is essential, a separate sealing element must be inserted.

Illustration 13 shows an airtight flanging joint where an O-ring is used. When soft materials are being welded, unacceptable welding ridges often occur. Here flanging offers an alternative to traditional welding.



Typical flanging connection.
Radii prevent notch effects!

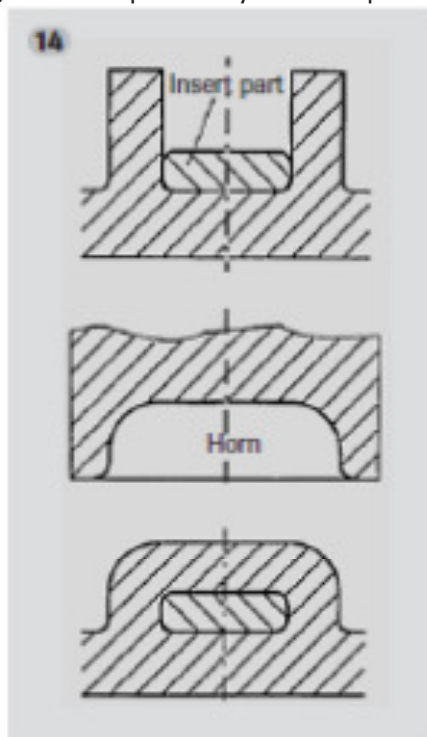
Airtight flange-connection with
use of O-ring.



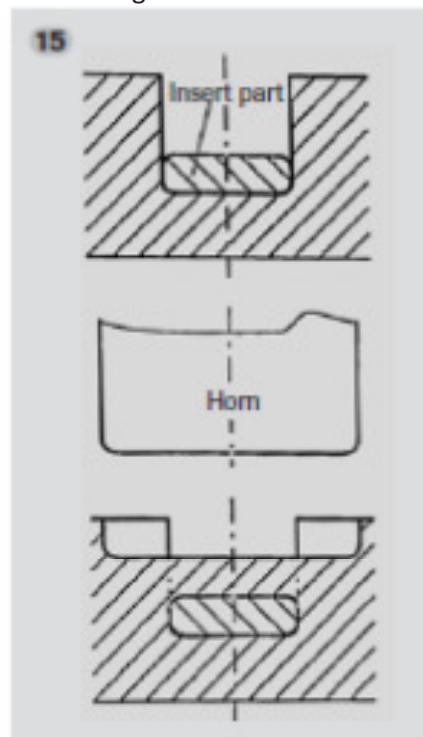
Embedding 14-16 –

Ultrasonic embedding is a very efficient but little used method of joining different form-locking parts to each other. Wall thicknesses and ribs on the synthetic part are plasticized by the horn and pressed into recesses, undercuts and holes. In this way electrical contact elements, for example, can be bedded into plastic housings, plastic parts can be fixed radially and axially on to steel shafts etc.

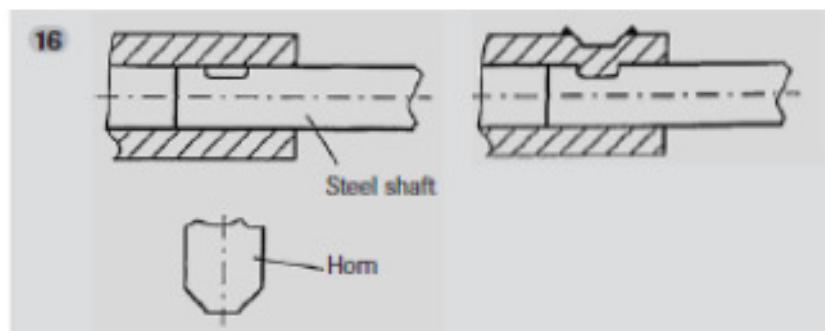
For applications where the sonotrode is immersed into the plastic part, the formation of ridges, as shown in Illustration 16, is generally speaking unavoidable. Otherwise, there are practically no limits placed on the design.



Embedding - shaping of injection moulded ribs.



Embedding - shaping by immersion of the horn.

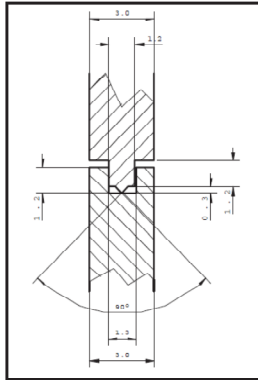


Embedding - fixing of a steel shaft in a plastic part.

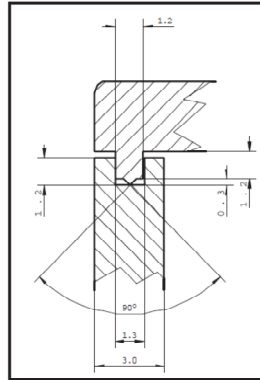


Construction Guidelines

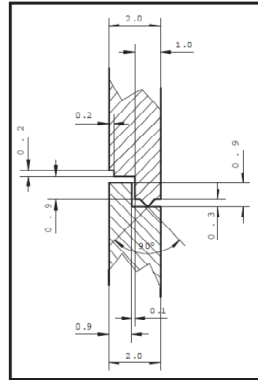
Welding Join for Ultrasonic Welding



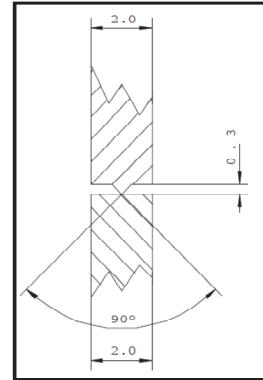
Energy Director 1



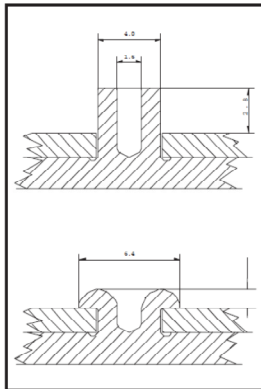
Energy Director 1.1



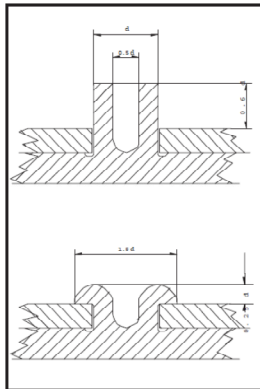
Energy Director 2



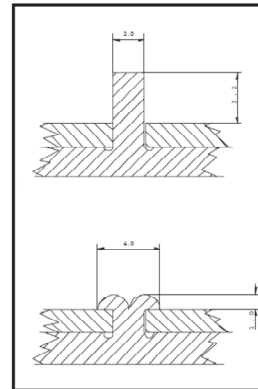
Energy Director 3



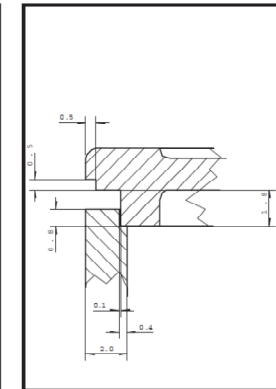
Tubular rivet 1



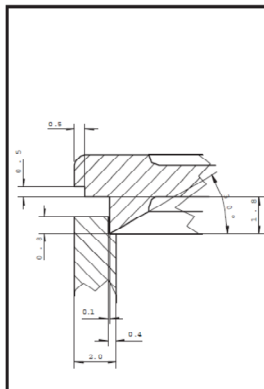
Proportions tubular rivet



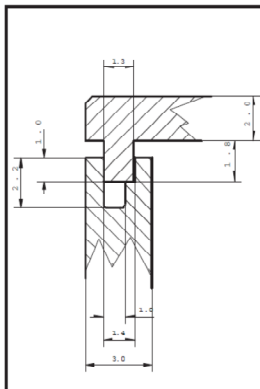
Rivet head



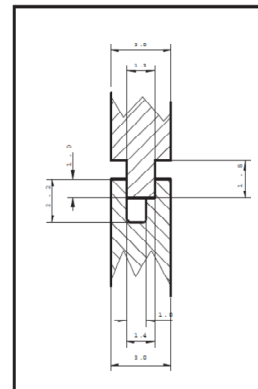
Shear joint 1



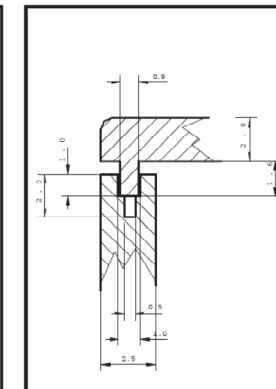
Shear joint 2



Shear joint 3



Shear joint 3.1



Shear joint 4



MECASONiC[®]
Plastic Welding Solutions

THANK YOU

TELLS ARGENTINA

Tel.: +54 11 4762-3605

E-mail: ricardo.oliveto@tells.com.ar

Web: www.tells.com.ar

Curapaligue 6565 – Carapachay
Buenos Aires – Argentina (ZIP: 1605)