CALCULATIONS · DESIGN · APPLICATIONS B.3.7

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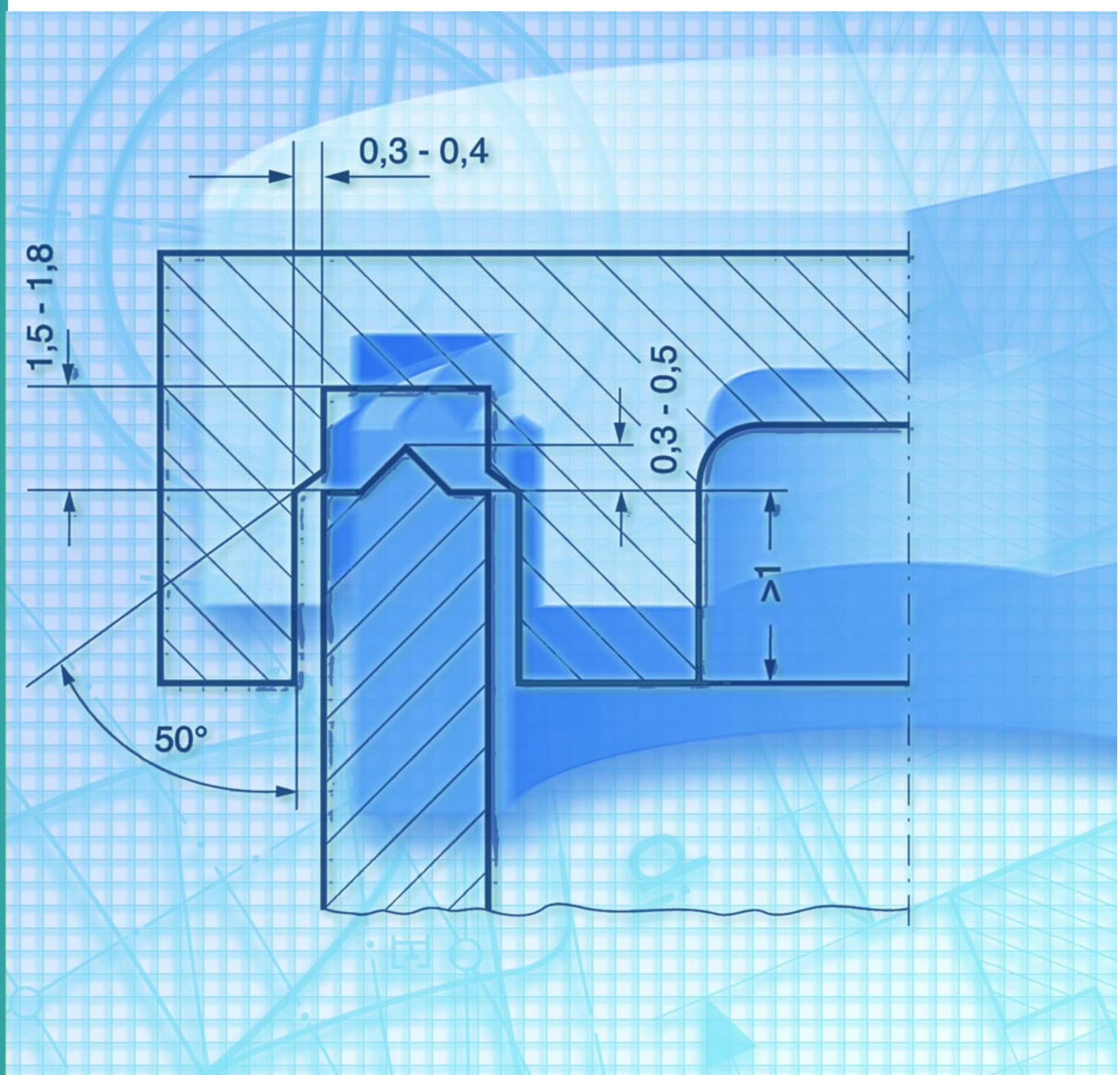
Ultrasonic welding and assembly of engineering plastics



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Ticona GmbH
Information Service
Tel. +49 (0) 180-584 2662 (Germany)
+49 (0) 69-305 16299 (Europe)
Fax +49 (0) 180-202 1202 (Germany and Europe)
e-mail infoservice@ticona.de
Internet www.ticona.com

®Hostaform
Acetal copolymer (POM)

®Hostacom
Reinforced polypropylene (PP)

®Celanex
Polybutylene terephthalate (PBT)

®Hostalen GUR
Ultrahigh molecular
weight polyethylene (PE-UHMW)

®Fortron
Polyphenylene sulphide (PPS)

®Vectra
Liquid crystal polymers (LCP)

® = registered trademark

Contents

1. Introduction

Homogeneous jointing of injection moulded or extrusion blow moulded thermoplastic components by ultrasonic welding is a cost-effective technique which has proved particularly suitable for long runs because of the very short welding cycles.

Ultrasonic welding is an ideal process for jointing cigarette lighter tanks, valve bodies and small containers, assembling parts for electrical equipment and for use in the automotive and household appliance industries. With ultrasonic welding, high-strength, liquid- and gas-tight joints can be produced.

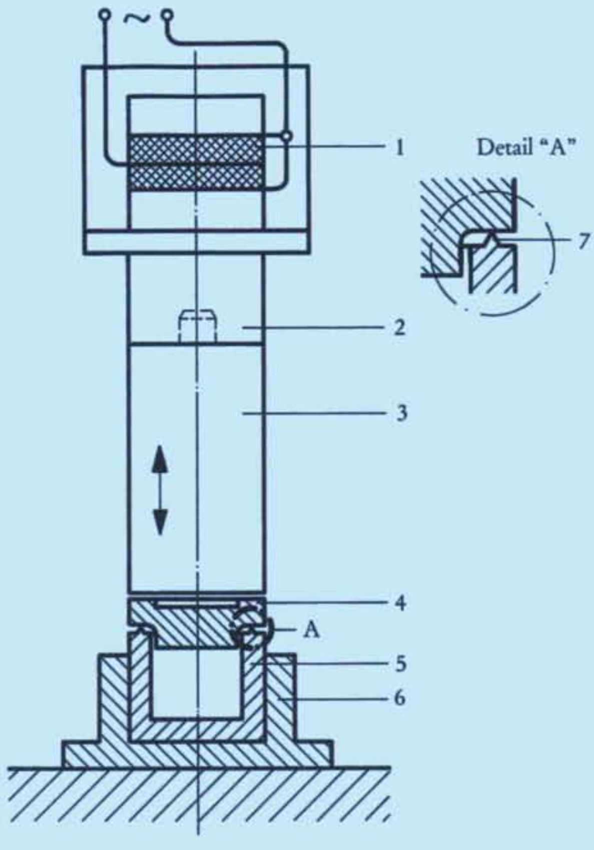
The technology has been developed to the stage where on standard equipment (e.g. up to a maximum generator output of 4 kW), welds up to about 120 mm in length can be produced. Special equipment with combined vibrating systems make it possible to weld even greater lengths.

The Hoechst engineering plastics ®Hostaform, ®Celanex and ®Hostacom and the performance polymers ®Fortron and ®Vectra have been used successfully in the manufacture of ultrasonically welded components for many years. It should be noted that the most suitable type of weld and welding method depend not only on the material but also on the design of the finished part and on the requirements it has to meet. Trial results relate exclusively to the given test specimen geometry and machine conditions. Even slight deviations can lead to different results. It is therefore almost impossible to draw general conclusions. For critical applications we recommend contacting us first.

2. Design and operation of an ultrasonic welding unit

The principle of ultrasonic welding involves converting (vibrating) energy into heat energy which melts the plastic at the joint surfaces. In an ultrasonic converter, high-frequency alternating current (20 – 50 kHz) is transformed into mechanical vibration which are transmitted via an ultrasonic horn*) into an energy director on one of the joint surfaces (fig. 1, detail A, and fig. 2). There the vibrating energy is concentrated in the joint and the joint surfaces are heated up directly to melting temperature.

Fig. 1: Diagram showing principle of an ultrasonic welding unit (piezoelectric operation)



1 Ultrasonic converter
2 Adaptor (amplitude transformer)
3 Ultrasonic horn
} resonance unit (1–3)
4 Top part
5 Bottom part
6 Jig for the bottom part
7 Energy director
↕ Travel

*) Note: In view of the high stresses involved, the ultrasonic horn is made of titanium or high strength aluminium alloys.

The parts being welded are pressed together to obtain the required welding pressure (horn travel ↕, see fig. 1, can be mechanically restricted). The contact pressure is infinitely variable.

Various equipment parameters influence the quality of the weld:

- vibration amplitude,
- contact pressure,
- welding time,
- welding distance
- hold time (cooling time)

The vibration amplitude can be altered within certain limits to suit the material and joint design by using adaptors of different sizes (amplitude transformation), see 2 in fig. 1.

The resonance unit of an ultrasonic system consists of the ultrasonic converter, the adaptor and the horn.

3. *Ultrasonic welding of Hoechst engineering plastics*

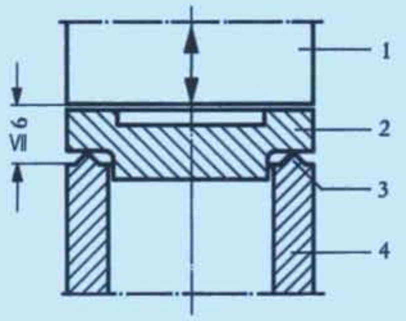
3.1 Requirements for optimum ultrasonic welds

Correct joint design is essential for optimum welding (see section 5). The joint must be adequate for the function of the weld.

It should be noted that

- the joint surfaces should normally be positioned less than 6 mm from the horn tip (fig. 2). In ultrasonic welding of Hostaform mouldings, the distance can be > 6 mm, i.e. at long range; due to Hostacom's high damping capacity, the distance between the horn and welding seam should be < 3 mm.
- the vibratory energy should be concentrated locally and if possible should only be effective locally (function of an energy director),

Fig. 2: Positioning of joint surfaces at close range ($\leqq$ 6 mm)



1 Horn
2 Top part
3 Energy director
4 Bottom part

- the parting line should be designed to facilitate the welding operation and not to impair the functioning of the component (figs. 3 and 4).
- the parts to be welded should be dimensionally stable, i.e. the walls which receive the ultrasonic energy should be of adequate thickness (e.g. to prevent the diaphragm effect, fig. 4, i.e. sympathetic vibration of areas not involved in the welding operation ↓),
- corners, edges and transitions should be adequately radiused (to prevent notch effect),
- welds should as far as possible be arranged in a single plane (contact surface) at right angles to the horn axis (fig. 3)

Fig. 3: Design of the parting line

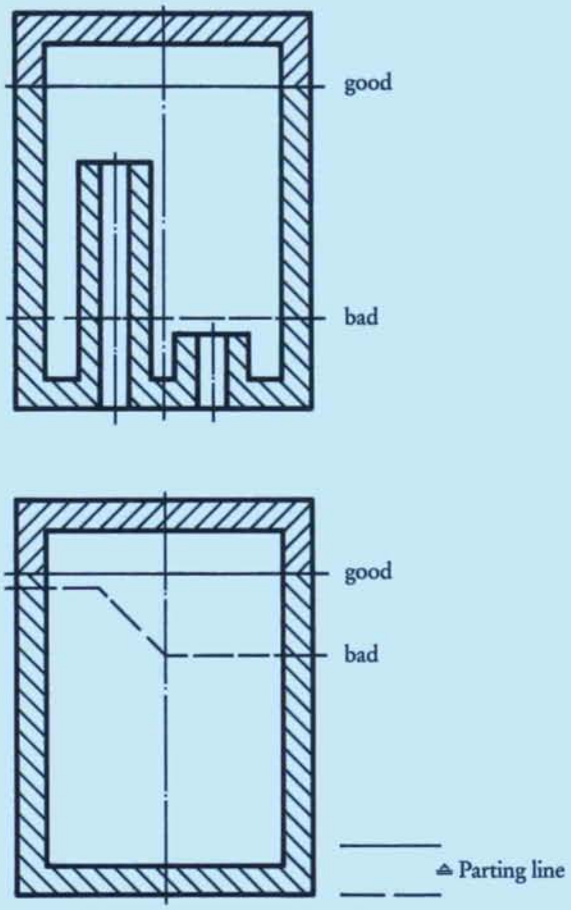
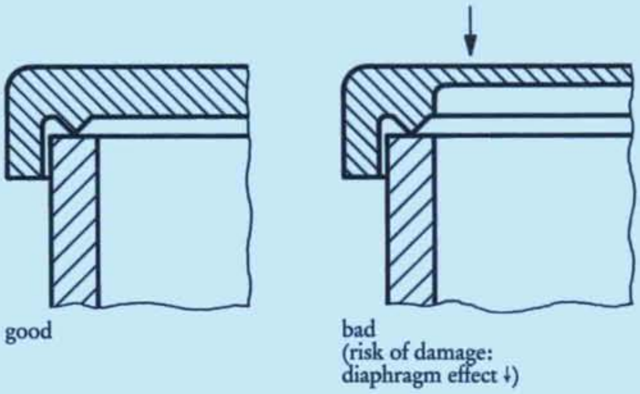


Fig. 4: Wall thickness design



- the horn contact area should be flat and adequately large because with too small an area the ultrasonic energy flow will be impeded (fig. 5),
- the parts to be joined should fit together with a suitable clearance, i.e. they should not pinch but on the other hand the clearance should not be too great (fig. 6); precision injection moulding is recommended,

Fig. 5: Design of contact area "a"

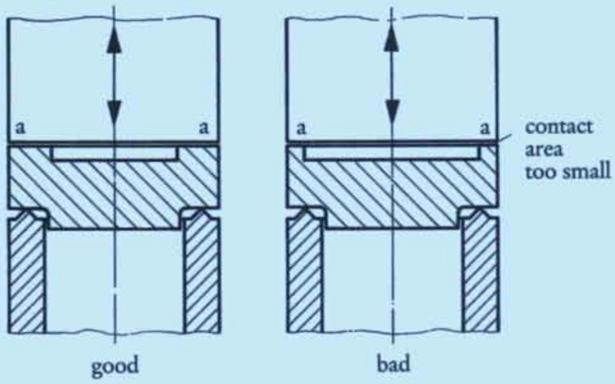
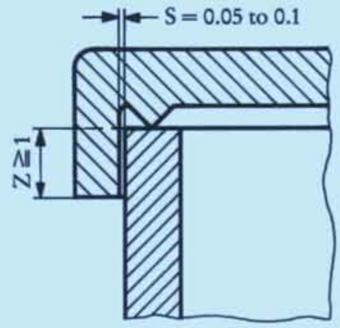


Fig. 6: Clearance S required for the joint parts and minimum alignment overlap Z



- the two parts should be perfectly aligned so that they remain in position when vibratory energy is applied. The alignment overlap should not be less than 1 mm (fig. 6).
- projecting pins, ribs, tabs etc. are prone to sympathetic vibration during ultrasonic welding and may therefore melt and be damaged. This can be countered by using larger radii, additional supports or elastic pads,
- the contact surface of the horn leaves permanent marks on high-gloss mouldings. This problem can largely be avoided by interposing LDPE sheets between the horn and part.

3.2 Factors affecting welding properties

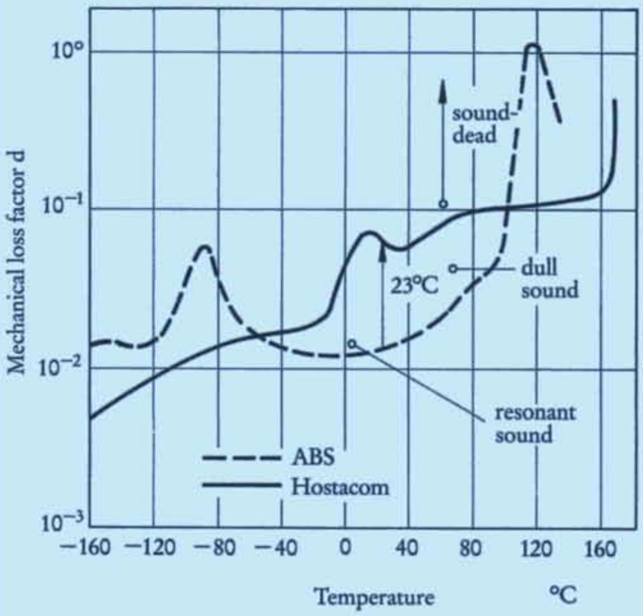
To find the right solution to welding problems, a number of important factors have to be taken into consideration. These concern material quality, the method used to make the joint, welding equipment and welding conditions.

3.2.1 *Effect of the moulding compound*

As compared with amorphous plastics (PS, ABS, PC, PMMA etc.) partially crystalline thermoplastics require more energy to plasticize (melt) the joint faces. This is basically due to their greater heat of fusion and generally higher melting point or range. Furthermore, energy propagation may be impeded in most partially crystalline thermoplastics by their high damping capacity.

This generally means longer welding times and in some cases a higher generator output. Fig. 7 shows the mechanical loss factor curve (which describes damping capacity) as a function of temperature for Hostacom and ABS.

Fig. 7: Mechanical loss factor curve as a function of temperature for Hostacom (reinforced PP) and ABS (torsion pendulum test according to DIN 53445)



Provided these properties and requirements are given due consideration, components produced from partially crystalline thermoplastics can be ultrasonically welded, particularly by the close-range method (see section 2).

Suitability for welding and energy transmission losses can be influenced by additives such as processing aids, pigments, lubricants, reinforcing materials and elastomer additions.

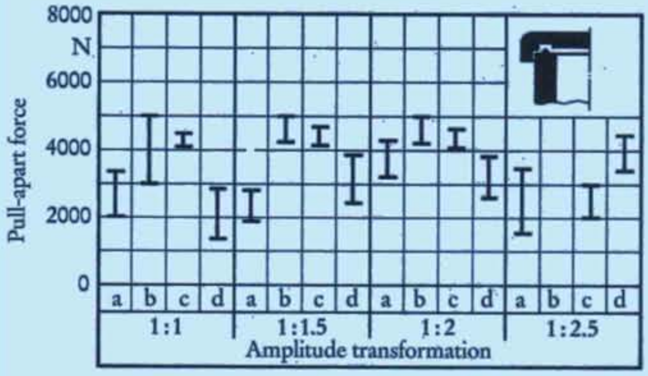
The effect of these additives on welding properties has been studied with test pieces. The results obtained apply for the specified test conditions.

Deviating results may be obtained with mouldings of different geometrical shape and welding conditions chosen accordingly.

3.2.1.1 *Effect of melt viscosity*

Hoechst engineering plastics are produced with various degrees of polymerization. The grades therefore differ in molecular weight and this factor coupled with melt viscosity has an effect on welding properties. Fig. 8 shows this using the example of Hostaform. Given the same welding data, welding time, contact pressure and hold time, the strength of ultrasonically welded joints varies according to the Hostaform basic grade.

Fig. 8: Effect of the melt viscosity of Hostaform basic grades on the strength of welded joints



a Hostaform C 27021
b Hostaform C 13021, C 13031, C 52021
c Hostaform C 9021
d Hostaform C 2521, T 1020
I ≙ range of scatter

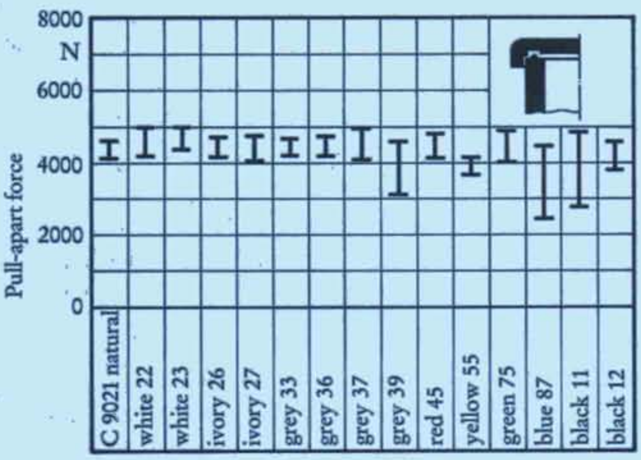
These variations in the strength of welded joints according to grade can, however, be compensated by careful selection of welding conditions, i.e. by optimization of

- vibration amplitude (use of different-sized adaptors or amplitude transformers, see fig. 1),
- contact pressure,
- welding time,
- welding distance.

3.2.1.2 *Effect of pigments*

The effect of different pigments was studied with Hostaform C 9021. From fig. 9 it can be seen that – given the same welding conditions – all the pigmented formulations tested may be expected to provide approximately the same level of joint strength.

Fig. 9: Effect of different pigments in Hostaform C 9021 on the strength of welded joints



I ≙ range of scatter

The large range of scatter observed with grey 39 and the dark shades blue and black can be reduced by adjusting amplitude, for example. In especially critical cases, the strength level can be raised by cutting down the pigment content. This can be achieved by adding natural granules. The effect of special shades should be checked in preliminary trials.

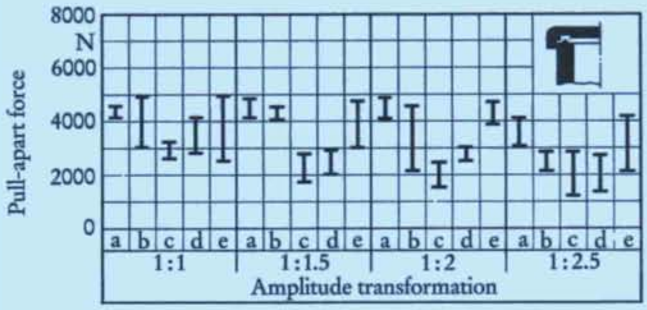
3.2.1.3 Effect of reinforcing materials and elastomer additions

Modification of Hoechst engineering plastics leads to differences in the strength properties of ultrasonic welds, depending on the type of additive and/or reinforcing material used. Fig. 10 shows this using the example of modified Hostaform grades as compared with the basic grade C 9021; fig. 11 shows it with Hostacom and Hostalen PP.

The glass fibres in Hostaform C 9021 GV 1/30 and the ®Hostaflon (PTFE) content in Hostaform C 9021 TF reduce the strength of welded joints under comparable conditions. This loss in strength may be countered by increasing the area of the joint surfaces.

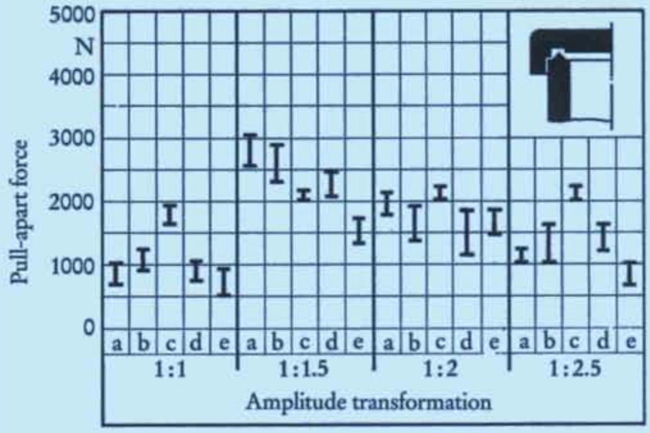
Experience has shown that reinforced products require different welding conditions from those used for the basic material, i.e. longer welding times and in some cases smaller amplitudes and accordingly slightly higher contact pressures.

Fig. 10: Strength of welded joints in modified Hostaform grades



a Hostaform C 9021
b Hostaform C 9021 K
c Hostaform C 9021 TF
d Hostaform C 9021 GV 1/30
e Hostaform C 9021 M
I ≙ range of scatter

Fig. 11: Strength of welded joints in Hostacom and Hostalen PP grades



a Hostalen PPN 1060, PPU and PPW grades
b Hostacom G2 N01 (with 20% glass fibres)
c Hostacom G3 N01 (with 30% glass fibres, chem. linked)
d Hostacom M2 N01 (with 20% mineral)
e Hostacom M4 N01 (with 40% mineral)
I ≙ range of scatter

Thermoplastics impact-modified with elastomer additives are more difficult to weld than the unmodified basic grades. Suitability for welding depends on the elastomer content. In any case, other welding methods such as hot plate welding and vibration welding should be considered.

The joint strength of impact modified grades is slightly lower. This reduction may be countered by increasing the area of the joint and/or by higher energy input (longer welding time).

As far as weld geometry is concerned, the same points apply as for the non-reinforced material.

3.2.2 *Effect of moulded part design*

The parts to be welded must be dimensionally accurate and as far as possible free from internal stresses.

To achieve this, the rules of precision injection moulding should be observed. Recommended processing conditions are given in the relevant Hoechst product brochures (see 10. Literature).

To ensure high quality mouldings, the following points are important:

- correct location and cross-section of the gate for the particular material and moulding,
- optimum processing conditions, in particular the right melt and mould temperatures,
- optimum mould temperature control,
- avoid multi-cavity production of identical articles,
- take into account post-shrinkage to ensure dimensionally accurate mouldings,
- do not weld parts immediately after injection moulding; a delay of at least 24 hours is recommended.

3.2.3 *Welding equipment and welding conditions*

Correct selection of welding conditions is of great importance for weld quality. It is vital for the welding equipment to operate reliably and for welding parameters to be consistent with the jointing task. The quality of the welding tool and jig is equally important.

3.2.3.1 *Requirements for the welding equipment*

The welding equipment has to meet a number of requirements:

- high repeatability of results,
- sensitive control,
- sufficiently high output reserve,
- contact pressure, welding time and hold time must be infinitely variable,
- time- and stroke-dependent control should be possible,
- the possibility of choosing between time-, stroke- and energy-control operating modes extends the area of application.

3.2.3.2 *Effect of welding conditions*

Optimum welding results can only be obtained if the welding parameters amplitude, contact pressure, welding time and hold time are suitable for the material and joint. In this context it should be noted that:

- The ultrasonic energy introduced (welding heat) and the contact pressure should be carefully balanced to ensure that there is sufficient melt flow in the welding zone for welding but to avoid squeezing more melt than necessary out of the welding zone.
- The risk of thermal degradation of the moulding must be absolutely avoided, if necessary by reducing welding time.
- Prolonged welding times, excessive contact pressure or unfavourable positioning of the joint can lead to damaged mouldings. This may not be apparent immediately after welding but can cause failure at a later stage during service (creep effect).

4. *Procedure for optimizing welding conditions*

Selection of welding conditions is governed by the type of plastic, the geometry of the component, the position and design of the joint and not least by the equipment available. As a rule, welding conditions must be optimized in preliminary trials. Optimization often has to be carried out in several stages. Corrections to the moulding or joint surfaces are costly and time-consuming. It is therefore advisable not to harden the injection moulds at this stage to make it easier to effect any corrections. Adjustment of welding equipment parameters, on the other hand, causes fewer problems.

Stages in the optimization of welding conditions:

Stage 1: Selecting the amplitude

The vibration amplitude has to be matched to the particular material and welding problem. This is most easily achieved by carrying out preliminary trials with different amplitude transformers (see. fig. 1). For welding Hoechst engineering plastics, amplitudes of 10 to 30 μm are normally used.

Stage 2: Selecting the contact pressure

The contact pressure has to be matched to the amplitude. It should be such that energy transmission is not impeded.

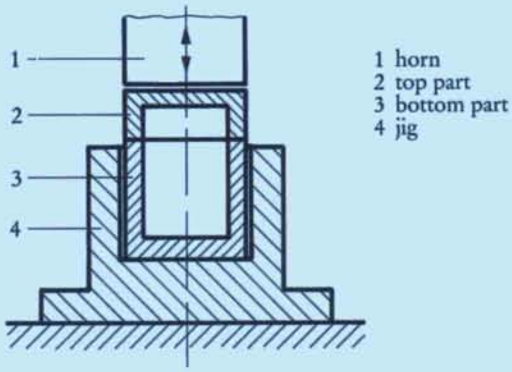
General rule:
High amplitude – low contact pressure
low amplitude – high contact pressure.

Stage 3: Welding time (ultrasonic exposure time)

Only a few preliminary trials are required to determine welding time. The criterion is the time taken by the top part to penetrate the required depth into the bottom part. Generally speaking, the welding time is less than 1 second. In practice, welding time is increasingly being stroke-controlled to improve reliability.

Note: Prolonged welding times – which may result in damage to the component – are often necessary if the generator output is not sufficient and/or the bottom part vibrates in sympathy. In many cases, this problem can be remedied by supporting the bottom part if possible right up to joint height (using a jig to hold the bottom part, see fig. 12). Split jigs are often used for this purpose.

Fig. 12: Correct design of jig to hold the bottom part (principle)



Stage 4: Hold time

The hold time (cooling time) is normally between 0.5 and 2 s. It should be established in preliminary trials. In critical applications, the following additional measures are worth considering:

- start the horn vibrating before it is applied to the top part,
- apply slight pressure as the horn starts to vibrate,
- elastic jig mounts,
- use clamps and damping devices with thin-walled components (to reduce diaphragm effect, see also fig. 4).

The sum of the welding time and hold times gives the welding cycle time (see also section 9.6). This is normally 1 to 3 s. To this must be added the time for placing and removing the joint parts. If these operations are carried out manually, experience has shown that the total cycle time is increased by about 5 to 10 seconds. The high cost effectiveness of ultrasonic welding is therefore fully realized on automatic machines where cycle times of 5 seconds are rarely exceeded. The choice of the most suitable machine is a matter for discussion with the machinery manufacturer. Welding machines with adequate output reserve and welding data control are an advantage. They make production more reliable.

5. *Designing the joint*

In ultrasonic welding, the joints may have various designs depending on the function of the weld. The surfaces must be provided with energy directors. The shape and size of the energy directors may be freely selected within certain limits, i.e. several alternative designs of joint are often possible in the same situation.

The following basic designs are possible:

- joints with conical and knob-shaped energy directors,
- joints with roof-shaped energy directors,
- pinch welds (edge contact).

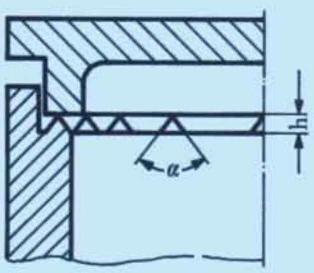
5.1 *Different joint designs*

5.1.1 *Joints with conical and knob-shaped energy directors*

Energy directors of this type (fig. 13) are used for joining components with relatively flat joint surfaces. They are not suitable for sealing welds.

Fig. 13: Conical energy directors

α = 60 to 90° **h = 0.5 to 1.0 mm**



5.1.2 *Joints with roof-shaped energy directors*

Joints with roof-shaped energy directors (fig. 14) can be used for nearly all component dimensions. The energy director has an angle α of 60 to 90°; the height h can be varied between 0.3 and 1 mm (in special cases up to 2 mm) according to requirements.

A symmetrically positioned energy director is preferable to an asymmetrically positioned director. It should contact the opposing joint surface as near as possible to the centre. In special cases, several small energy directors may be used instead of one large director. They may be offset and of different heights.

Figs. 15 to 19 show some successful joint designs with roof-shaped energy directors. Their dimensions may be altered within certain limits. Special shapes are also possible.

Fig. 14: Roof-shaped energy director

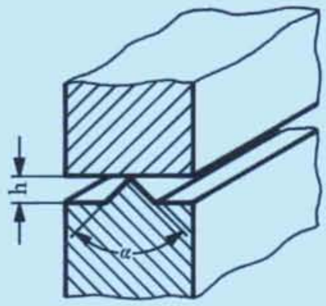


Fig. 15: Top part with inside alignment piece. The weld is concealed on the inside but melt can escape towards the outside

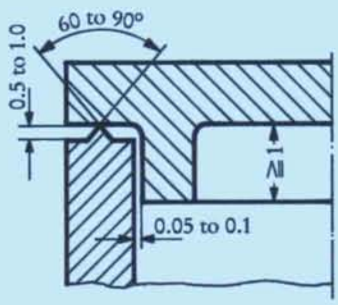


Fig. 16: Top part with outside alignment piece. The weld is concealed on the outside but melt can escape towards the inside

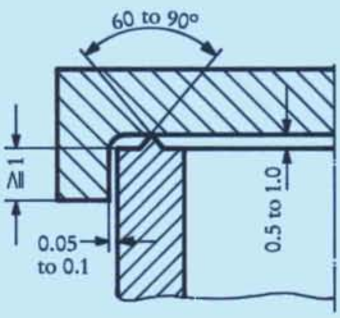
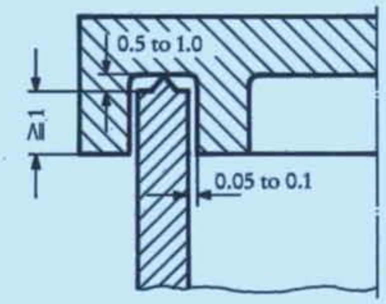


Fig. 17: Top part with alignment pieces on both sides. Because of the high dimensional accuracy required, should preferably only be used for relatively small parts.



5.1.2.1 Weld design for larger components

Fig. 18: With this joint design relatively large components can be welded. The horn is placed on the edge of the top part. The edge of the bottom part is supported by the jig. An alignment piece on the top part or bottom part can conceal the weld on either the inside or the outside. This weld design is very suitable for Hostacom (reinforced PP).

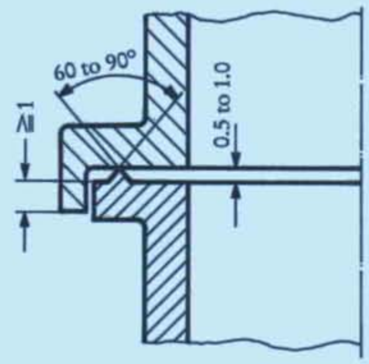
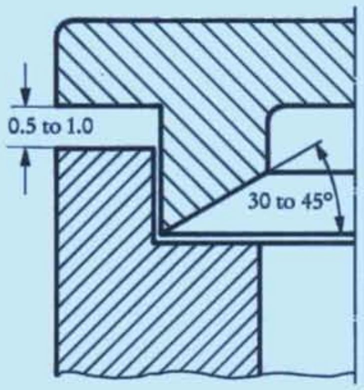


Fig. 19: Top part with inside alignment piece and asymmetrical energy director. This design is particularly suitable for welding hard, amorphous and partially crystalline plastics.



5.1.3 Joint designs for pinch welds

Pinch welds are preferred for seal welding hard, partially crystalline plastics. The parts must be made to close tolerances and fit together with very little clearance. The side walls of the bottom part should be supported up to weld height (figs. 20 to 23).

Some successful joint designs for pinch welds are shown in figs. 21 to 23.

Fig. 20: Principle of joint design for pinch welds

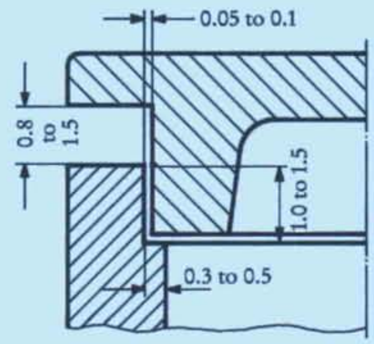
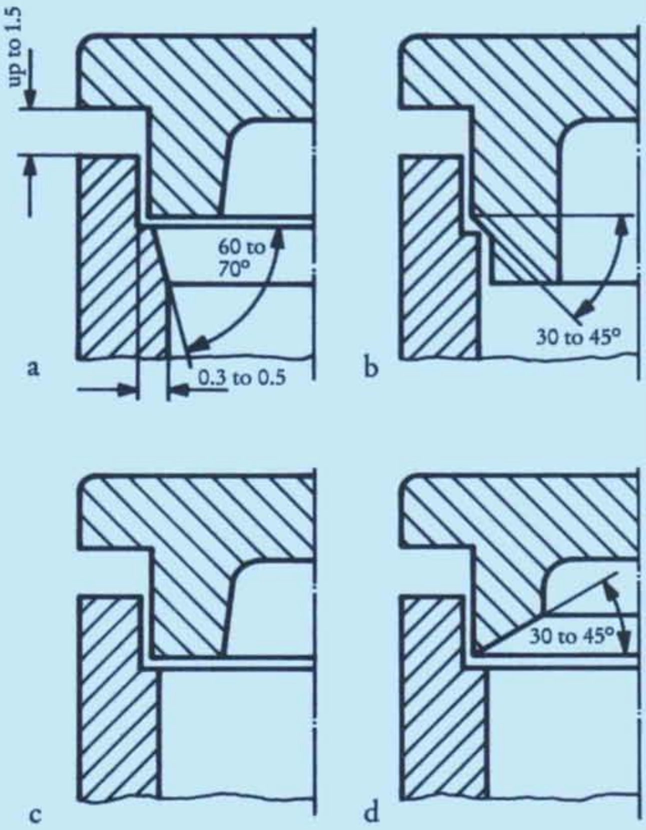
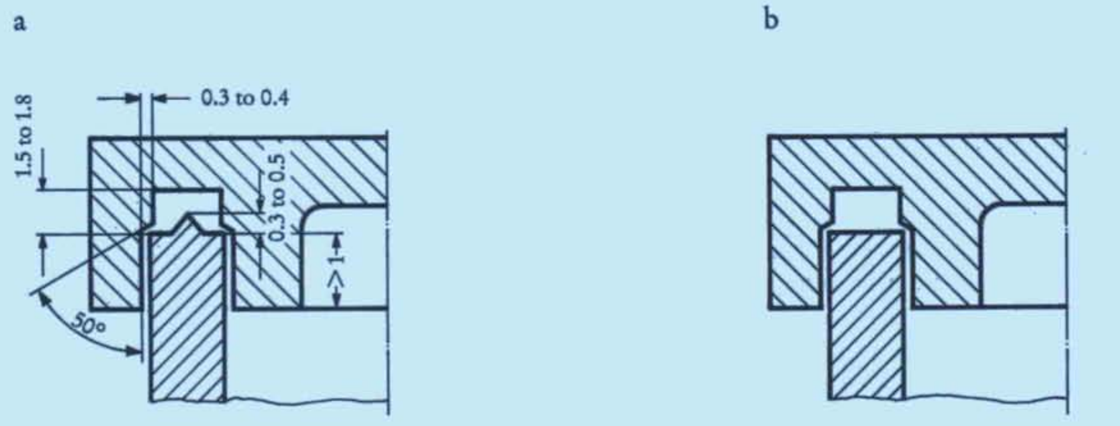


Fig. 21: Joint designs for single pinch welds



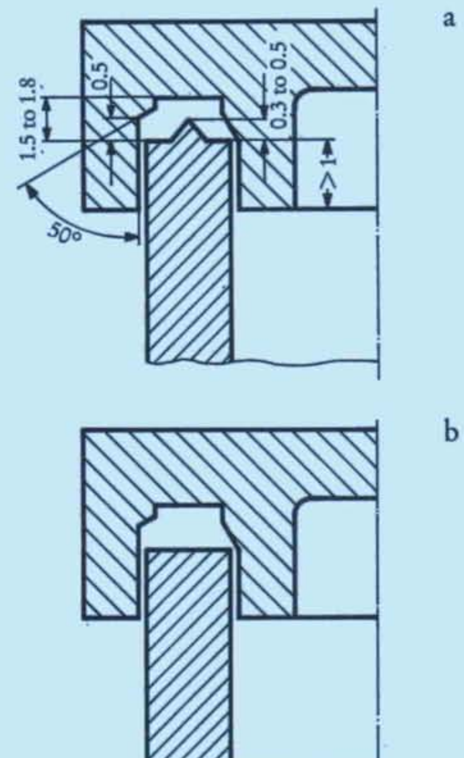
5.1.3.1 Double pinch weld with symmetrical joint surfaces

Fig. 22: Joint designs for double pinch welds (a) with and (b) without an energy director on the bottom part. Because of the high dimensional accuracy required, should preferably be used only for parts made to close dimensional tolerances.



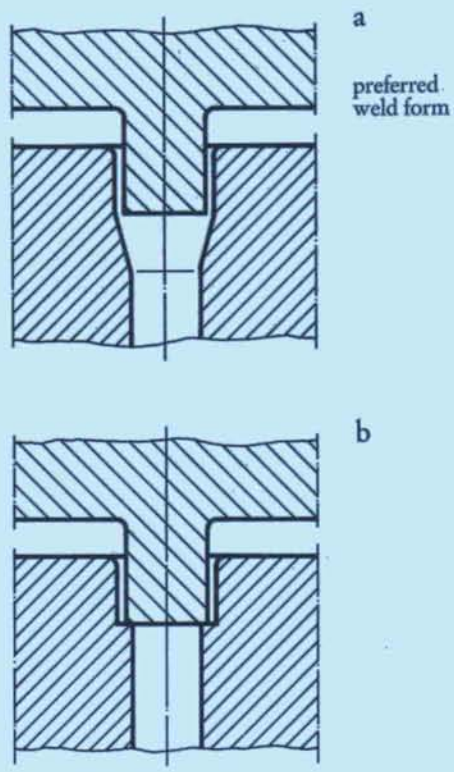
5.1.3.2 Double pinch weld with asymmetrical joint surfaces

Fig. 23: Joint designs for double pinch welds (a) with and (b) without an energy director on the bottom part. The second pinch weld is only formed after the top part has slightly settled down on the bottom part. Because of the high dimensional accuracy required, should be used only for relatively small parts.



The "mortise and tenon" weld (fig. 24) is used for joints which have to be strong but need not be sealed. Much the same criteria apply in designing this weld as with the other types of weld discussed. In special cases sealing welds can be obtained by incorporating elastic sealing elements.

Fig. 24: Joint designs for mortise and tenon weld



6. Notes on ultrasonic welding of moulded parts made from Hoechst engineering plastics

6.1 ®Hostaform (POM)

Hostaform mouldings can be welded at close range and – provided suitable geometric requirements are met, i.e. low loss energy transfer to the joint surface – at long range too. The attainable joint strength satisfies most practical requirements. Good welding results are obtained when the joint parts are rigidly designed and the horn is applied perpendicularly above the joint surface. A point to watch is the rapid plasticization (transition from solid to melt) of the joint zone when the ultrasonic horn is applied. The risk of melt beeing squeezed out of the joint can be countered by low contact pressure. Hostaform can be successfully welded at amplitudes between 20 and 40 μm.

For sealing welds, single and double pinch welds according to figs. 20 to 23 can be selected. When welding parts with larger dimensions (from about 60 mm diameter upwards), joint surfaces with roof-shaped energy directors or joint designs in accordance with fig. 18 are preferred.

The minimum height of the energy director should be 0.3 mm. As a rule, the height of the energy director should be 1/5 to 1/10 of the base wall thickness.

The alternating strains introduced into the moulding by the horn can in unfavourable circumstances lead to the melt separating from the solid. Even if this occurs very rarely and usually only at isolated points it nevertheless reduces joint strength and impairs sealing welds. Melt separation such as this tends to occur where free sinking of one part into the other is restricted at some point. It is therefore important at the planning stage to prevent these problems through suitable design of the joint contours. At the same time, the sink-in depth should be suitably limited through the provision of horn travel control.

Figs. 25 and 26 show two examples of how the risk of melt separation can be countered by suitable design of the joint contours, i.e. free sinking-in must be ensured.

Fig. 25: Minimum gap after welding in a pinch weld

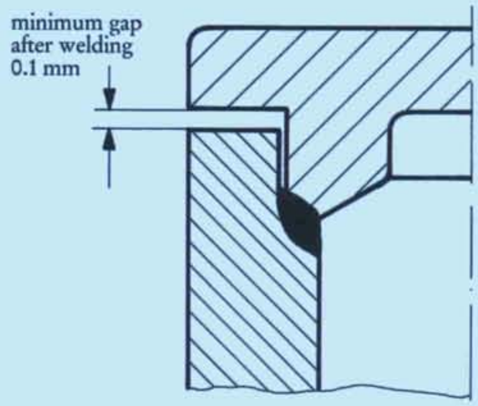
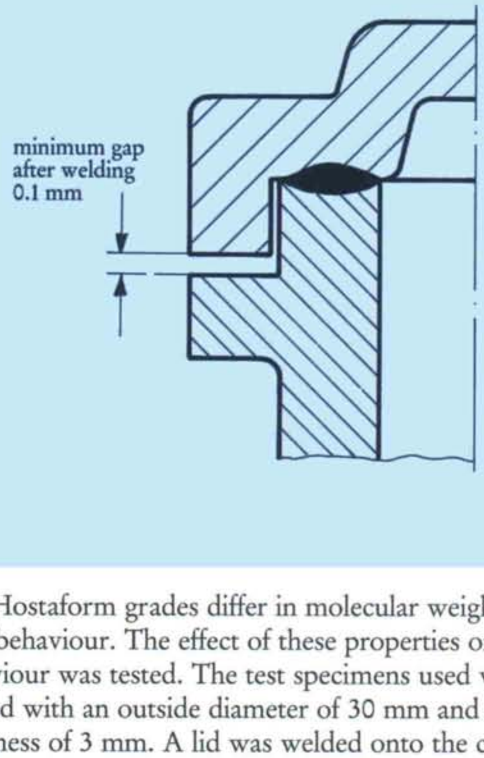


Fig. 26: Minimum gap after welding in a butt weld

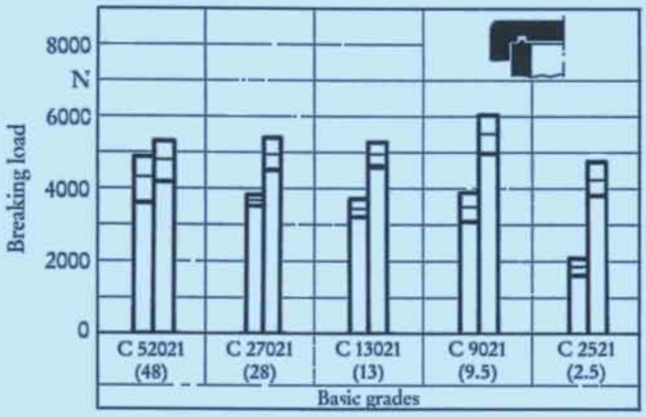


The Hostaform grades differ in molecular weight and flow behaviour. The effect of these properties on welding behaviour was tested. The test specimens used were can-shaped with an outside diameter of 30 mm and a wall thickness of 3 mm. A lid was welded onto the can with the joint designed as a double pinch weld (the can and lid were made from the same material).

Figs. 27 shows breaking loads determined on specimens produced from the Hostaform basic grades (melt index range studied MFR 190/2.16 : 2.5 to 48 g/10 min). Only cans and lids made from the same Hostaform grade were welded together. When welding moulded parts made from different Hostaform grades, lower weld quality can be expected. The suitability of such welds for the application should be tested in each particular case.

Fig. 27 shows that the strength of welded joints depends significantly on welding time. The higher values (right-hand bar) were obtained with the longer welding time (increase from 0.6 to 1.0 s).

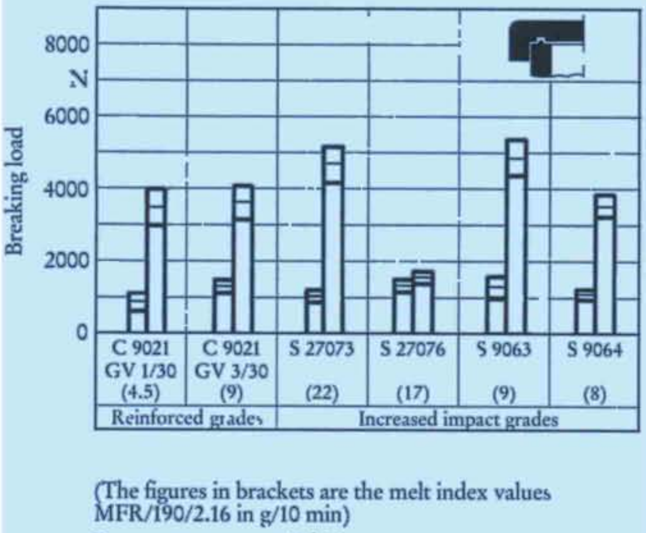
Fig. 27: Effect of the melt viscosity of Hostaform basic grades on the strength of welded joints



(The figures in brackets are the melt index values MFR/190/2.16 in g/10 min)

Frequency	20 kHz
Amplitude	30 μm
Welding pressure	1.8 bar
Welding time	0.6 sec (left bar) 1.0 sec (right bar)
Weld design	double pinch weld
Generator output	700 W

Fig. 28: Effect of additives in modified Hostaform grades on welded joint strength



(The figures in brackets are the melt index values MFR/190/2.16 in g/10 min)

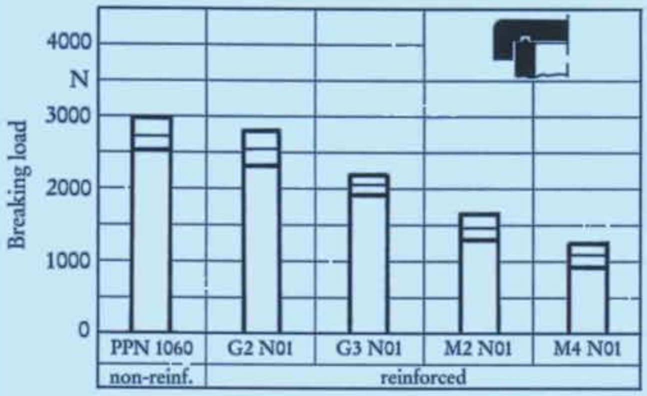
Frequency	20 kHz
Amplitude	30 μm
Welding pressure	1.8 bar
Welding time	0.6 sec (left bar) 1.0 sec (right bar)
Weld design	double pinch weld
Generator output	700 W

Studies of test specimens made from reinforced and impact modified Hostaform grades show generally satisfactory welding behaviour except for Hostaform S 27076. The breaking load values attained with 1 sec. welding times roughly correspond to those for the basic grades, fig. 28. Prolongation of welding time leads to a considerable increase in breaking load. The strength loss in the case of Hostaform S 27076 is due to the higher elastomer content.

6.2 ®Hostacom (reinforced PP)

Hostacom and Hostalen PP grades can only be welded at close range because of their high damping capacity. Studies showed that with the materials indicated in fig. 29 homogeneous welds can be obtained. Joint strength as compared with the parent material depends on the type and amount of reinforcing material used. Fig. 29 shows how these influences affect joint strength.

Fig. 29: Joint strength of ultrasonically welded test specimens made from Hostalen PPN 1060 and Hostacom grades

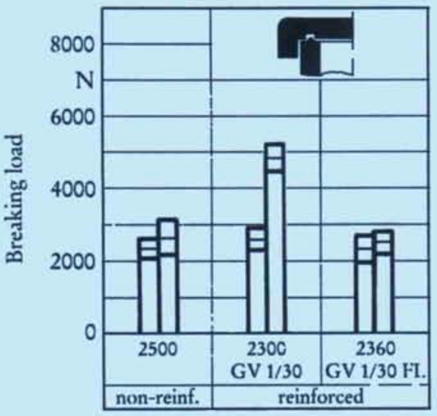


Frequency	20 kHz
Amplitude	30 μm
Welding pressure	1.8 bar
Welding time	1.0 sec
Weld design	double pinch weld
Generator output	700 W

6.3 ®*Celanex (PBT)*

The breaking load values attainable with specimens made from Celanex are shown in fig. 30. Even long-range welds (up to 25 mm distance between horn and joint surfaces) give serviceable results.

Fig. 30: Joint strength of ultrasonically welded test specimens made from various Celanex grades



Frequency	20 kHz
Amplitude	30 μm
Welding pressure	1.8 bar
Welding time	0.6 sec (left bar)
	1.0 sec (right bar)
Weld design	double pinch weld
Generator output	700 W

Celanex, like Hostaform, plasticizes (changes from solid to melt) rapidly when the ultrasonic horn is applied. Here again there is a risk of melt being squeezed from the joint at excessive contact pressures.

7. *Ultrasonic assembly of performance polymers*

The Hoechst performance polymers Fortron (PPS) and Vectra (LCP) can generally be joined by ultrasonic assembly methods such as welding, riveting, flanging and staking. Metal inserts can be ultrasonically embedded. In most cases, the guidelines and notes relating to ultrasonic welding of the engineering plastics described are also applicable to the performance polymers. It should be remembered however that high filler contents can cause damage to moldings during transmission of ultrasonic energy. In such cases, it is advisable to check whether the problem can be effectively remedied by higher frequencies or smaller amplitudes.

In critical cases, close cooperation between the user, equipment manufacturer and material producer is essential.

7.1 ®*Fortron (PPS)*

Fortron is suitable for both near- and far-field ultrasonic welding. However, because of the relatively brittle-hard behaviour of the material, it should be borne in mind that the alternating strains which have to be absorbed by the joint parts can lead to localized damage. To avoid this, special precautions need to be taken in terms of correct component design for the material and weld and correspondingly optimized equipment settings. Since these measures have to be specially adapted to the component, we recommend early contact with the equipment manufacturer and material supplier.

Additions of reinforcing material up to 40% still permit good welding results. Under mechanical load, fracture usually occurs outside the weld. With higher proportions of reinforcing material, however, weldability deteriorates.

Tapered pinch welds with a welding distance of over 1 mm can if necessary be made gas-tight.

7.2 ®Vectra (LCP)

The welding behaviour of Vectra is uniquely influenced by its characteristic material properties and molecular orientation in the joint parts. Particularly good results are obtained if the weld runs in the direction of orientation. As trials on models have shown, these requirements can best be met by pinch welds with slightly tapered joint surfaces (angle of inclination 10 to 15°).

Ultrasonically welded Vectra moldings are gas-tight.

Good energy transmission is obtained in near-field welding. With far-field welding, thicker walls are generally recommended for energy transmission.

8. Other ultrasonic assembly methods

Ultrasonics can be used to plasticize and re-form mouldings. This possibility is used in riveting, flanging and staking. The advantage of ultrasonic methods as compared with re-forming with a hot die is that the ultrasonic horn remains cold and so can also assume the function of the cooling die.

8.1 Riveting

In riveting, the vibration energy at the rivet shaft end is converted into heat. The plasticization initiated in this way is allowed to continue until the rivet head is formed. The ultrasonic horn assumes the function of the riveting die and is produced in the desired shape of the rivet head. Single and multiple riveting can be carried out in one operation.

The riveting time (welding time) depends on the material and the rivet shaft diameter. It ranges between 0.5 and 2 sec. In many cases, it is advisable to work with clamps. The following points should be borne in mind when riveting:

- the projecting end of the rivet shaft should be of sufficient volume for the proposed rivet head,
- the ultrasonic horn should be lowered slowly,
- contact pressure should be lower and amplitude generally higher than in ultrasonic welding,
- the horn should be held in position until the rivet head freezes,
- the end of the horn may be subject to wear (especially in the case of glass fibre reinforced plastics).

The rivet pin is in most cases an integral part of the moulding. The point where it joints the main body of the moulding should be radiused as generously as possible to prevent plasticization or breakage. Shaft design according to fig. 31 H have proved successful. The part to be riveted to the plastic is provided with a slightly oversized receiving hole for the rivet shaft (clearance fit). The rivet pin projection length and rivet head design depend on

- the material being riveted,
- the required strength,
- the rivet shaft dimension,
- the dimensional tolerance (in multiple riveting).

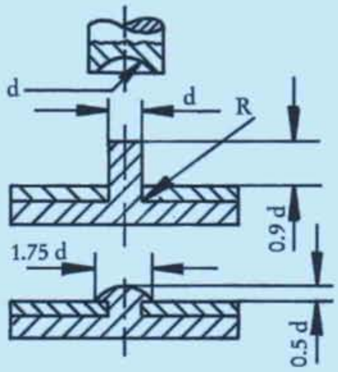
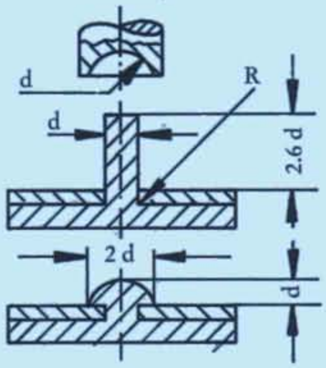
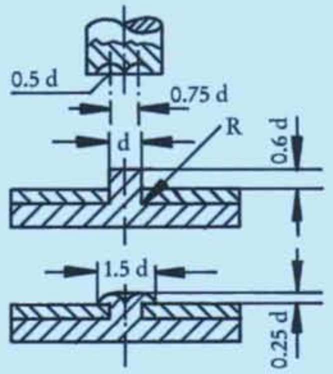
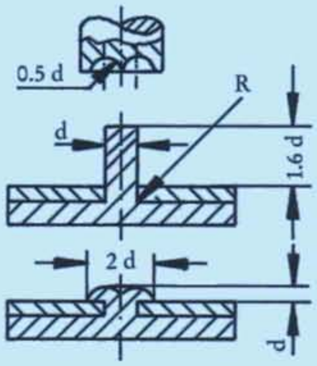
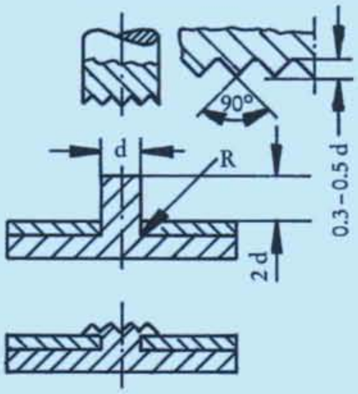
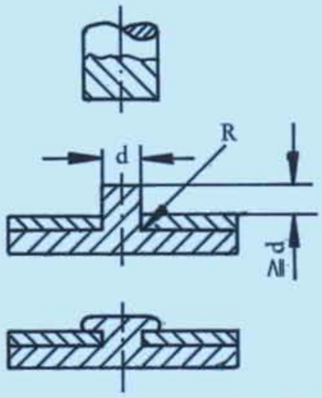
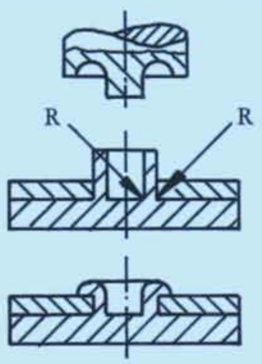
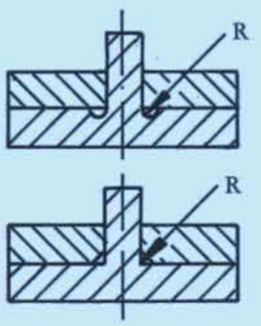
Fig. 31: Recommended rivet pin diameters and rivet head designs				
Diagram showing horn design, workpiece and rivet head	Head design	Diagram showing horn design, workpiece and rivet head	Head design	Rivet pin diameter
	A		B	$d > 1-5$
	C		D	$d > 2$
	E		F	$d > 0.5$
	G		H	

Fig. 31 shows some frequently used rivet head designs. Rivet head designs A and B are preferably employed for thin rivet pins up to about 3 mm diameter. Head designs C and D have proved particularly successful. In these designs, the contact surface between the horn and rivet pin is through the central tip which must be applied centrally and initially represents a very small area. The ultrasonic energy is introduced through this area. Head design D is preferred because of the good strength values it gives. In design E, the horn face is knurled. This design has proved successful for single, and particularly, for multiple riveting. It enables positional inaccuracies between the horn and rivet pin and dimensional tolerances in the spacing between a number of rivets to be accommodated. If large rivet pin diameters are required, it is advisable to use hollow pins, fig. 31 design G or several thin pins to avoid sink marks when injection moulding the parts.

In riveting glass fibre reinforced thermoplastics, a higher ultrasonic output is required than for the non-reinforced material.

Since the rivet horns are subject to relatively severe wear with glass reinforced plastics, the horn surface must be of wear resistant design (e.g. carbide tipped).

In special cases, it might be advisable to check whether hot riveting would give better results.

In riveting mouldings made from Hostaform and Celanex, it is important not only to optimize rivet head design but to select riveting conditions very carefully. Designs C, D and E, fig. 31, should preferably be used. Good results are also obtained with head designs C and E (fig. 31) when riveting the ultrahigh molecular weight material Hostalen GUR. The following conditions are recommended:

- high generator output,
- high amplitude,
- contact pressure commensurate with amplitude,
- low horn descent speed,
- welding time commensurate with the volume of material to be plasticized (time required to convert the projecting rivet pin to a rivet head),
- long hold time (≧ 2 s).

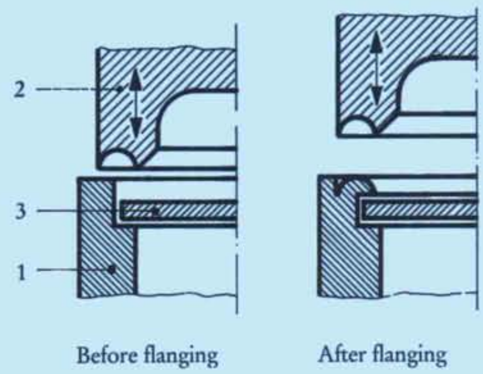
8.2 *Flanging*

As in metal processing, mouldings made from engineering plastics can be flanged. In this way, plastic components can be joined to each other and to components made from other materials. The horn must be appropriately profiled for the task in hand to plasticize and re-form edges, pins projections or other fixing aids.

Ultrasonic flanging is very economic. Processing times are comparable with the normal cycles for ultrasonic welding of mouldings. When flanging over glass components, the horn should not touch the glass part.

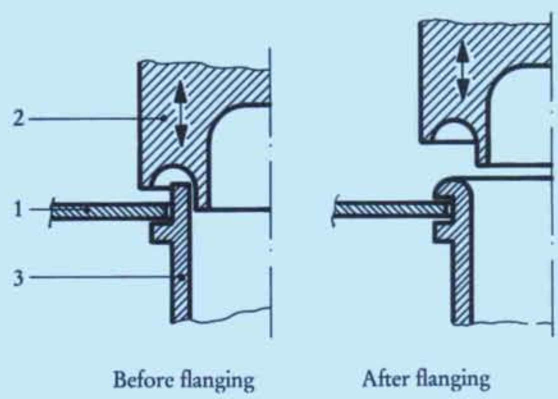
Figs. 32 and 33 show examples of inside and outside flanging.

Fig. 32: Inside flanging, fixing a metal plate in a plastic housing



1 Plastic housing
2 Ultrasonic horn
3 Metal plate to be fixed

Fig. 33: Outside flanging, fixing a plastic pipe stub into a container base

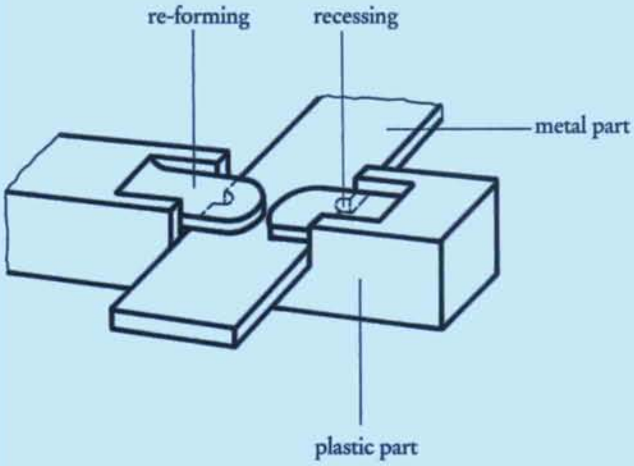


1 Metal base
2 Ultrasonic horn
3 Pipe stub to be attached

8.3 *Staking*

Staking can be carried out relatively easily by the ultrasonic technique. Staking is a jointing method similar to flanging or riveting in which the plasticized material is forced into recesses, undercuts or holes so creating a non-detachable joint, fig. 34.

Fig. 34: Securing parts together by staking



8.4 *Insertion of metal parts*

Threaded inserts, set screws or other metal parts can be embedded in specially provided holes or recesses with the aid of ultrasonics. Depending on the design of the metal parts, high anti-rotation and pull-out resistance can be achieved.

Fig. 35 shows some examples.

With this jointing technique, the following points should be observed.

Straight insertion of the metal part can be ensured by providing a guide hole which is about 0.1 to 0.2 mm larger in diameter than the metal part. The metal inserts must be guided. The boss should have a radius of $R > 0.2$ mm at the junction with the main body of the plastic part, fig. 35.

The receiving hole must be slightly smaller than the metal inserts, table 1.

When tapered metal parts are to be embedded in cylindrical receiving holes, the metal part should be sunk about halfway into the receiving hole. The undersizing of the receiving hole should be sufficient to provide a volume of plasticized material at least equivalent to the volume of the undercuts or knurling in the metal part.

In the case of blind holes, the receiving hole must be at least 2 to 3 mm deeper than the insertion depth of the material part in order to accommodate the displaced molten plastic.

The wall thickness of the boss should be at least 2 mm. During insertion, the amplitude should be as low as possible to avoid damaging either the metal insert or the plastic wall.

It is an advantage to start the horn vibrating before applying it to the part or to introduce the ultrasonic energy immediately after applying very slight contact pressure. The horn descent rate should be slow. Ultrasonic application should only be continued until the metal part is fully inserted. During insertion, metal abrasion can be expected.

Fig. 35: Plastic parts with integrally moulded boss to receive metal parts

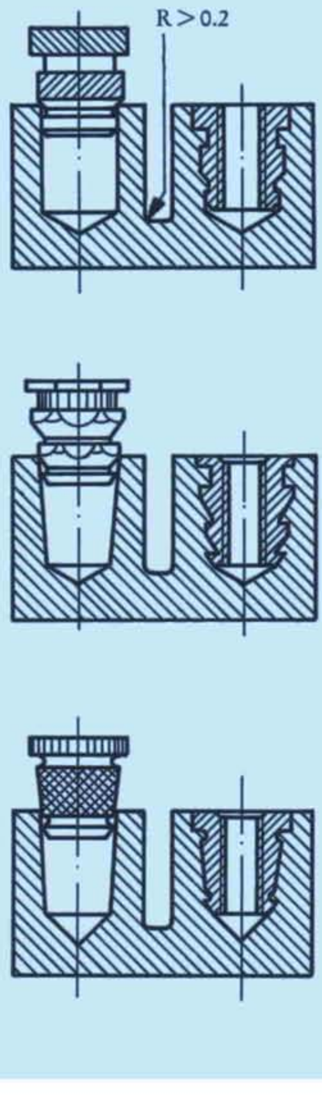
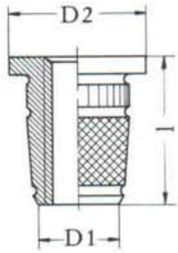
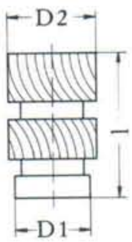
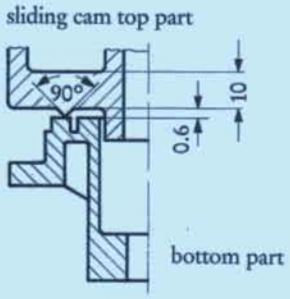


Table 1: Recommended receiving hole diameters for threaded inserts 1 and 2 (dimensions in mm)

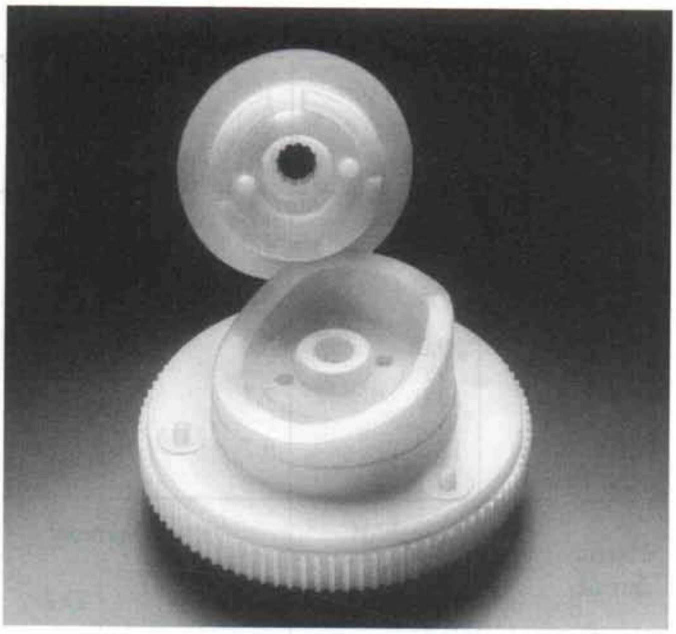
Metric thread	Length of bushing l	Diameter D 1	Diameter D 2	Receiving hole diameter (guide values)	Threaded insert 1
M3	5.5	4.0	4.7	4.3	
M4	7.5	5.2	6.15	5.65	
M5	9.0	6.4	7.35	6.85	
M6	10.0	7.7	8.75	8.25	
M8	12.0	9.7	11.3	10.8	
Metric thread	**Length of bushing l**	**Diameter D 1**	**Diameter D 2**	**Receiving hole diameter (guide values)**	**Threaded insert 2**
M3	5.8	3.9	4.7	4.0	
M4	8.2	5.5	6.3	5.6	
M5	9.5	6.3	7.1	6.4	
M6	12.7	7.9	8.7	8.0	
M8	12.7	9.5	10.2	9.6	

9. Examples of applications

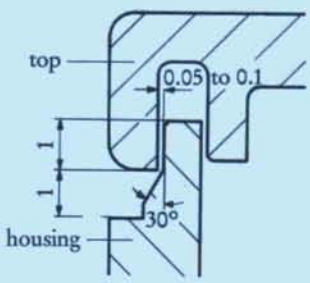
9.1 Sewing machine control part



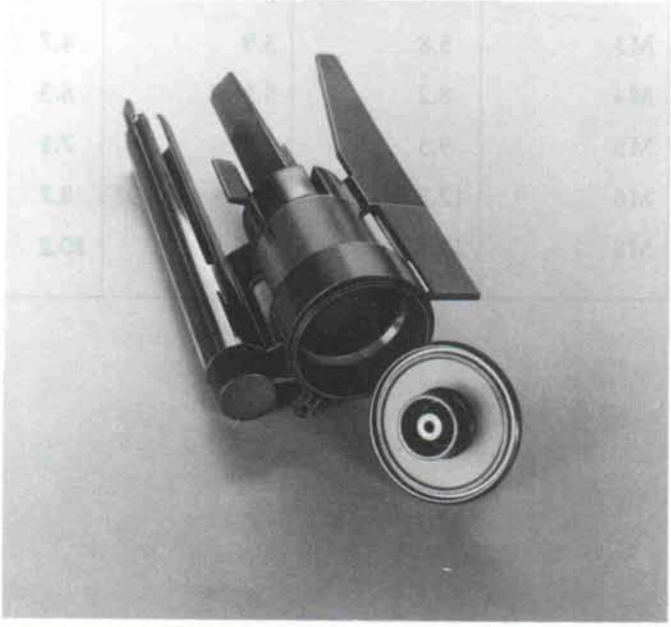
This part made of Hostaform C 13021 is difficult to weld. Correct horn/part contact was obtained with a suitably contoured horn.



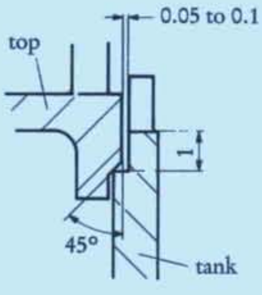
9.2 Time control mechanism for a toaster



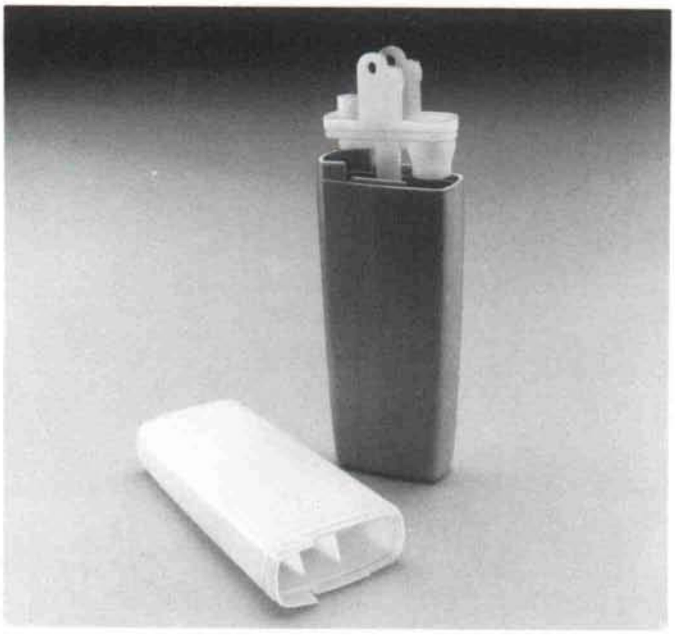
This time control mechanism enables toasting time to be set exactly every time to suit individual taste. The housing and top are injection moulded from Hostaform C 13021. The top is welded to the housing to form an air-tight seal.



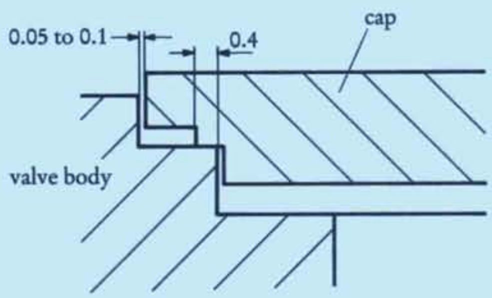
9.3 Disposable cigarette lighter



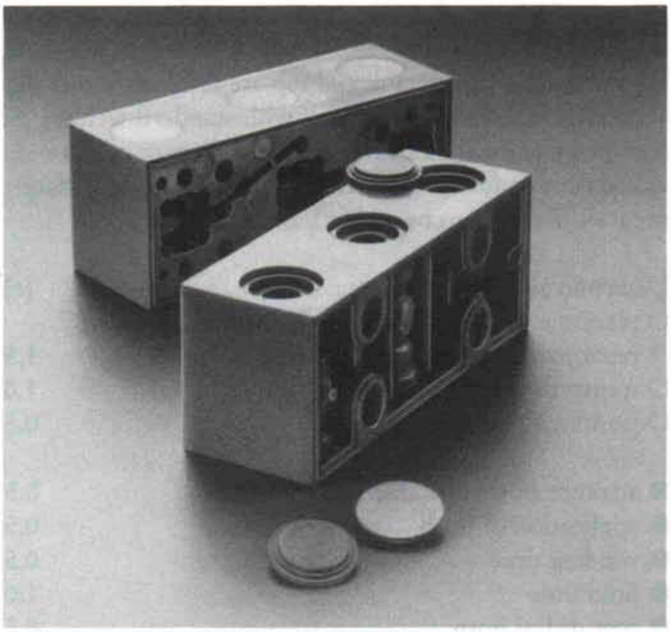
This lighter comprises a tank with welded-on top. The components are under internal pressure stress. They are made from Hostaform C 27021.



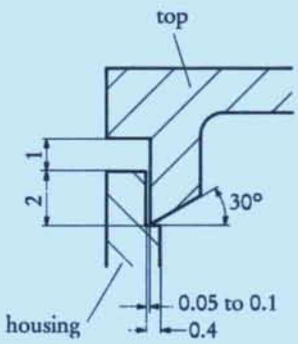
9.4 Pneumatic control element



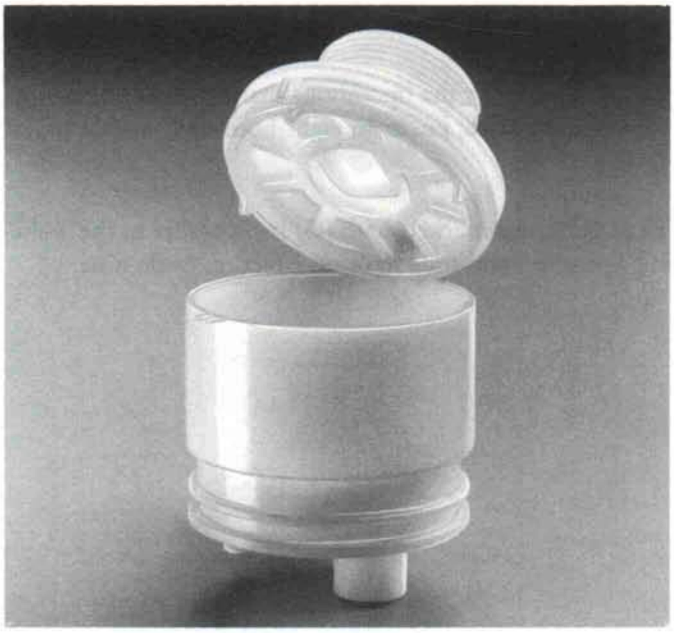
These pneumatic control elements made from Hostaform C 9021 are used to control pressure, quantity and direction. In each valve body there are several valve pistons which move in a cylindrical bore. After assembly, the bores are sealed with disc-like caps by ultrasonic welding.



9.5 Mixer tap regulator



These injection moulded Hostaform C 13021 regulators are used in single-lever-operated mixer taps. After insertion of ceramic sealing washers, the top and housing are welded together to form a liquid-tight seal.



9.6 *Example of welding cycle time calculation*

A gas cigarette lighter tank and top are to be ultrasonically welded. A rotary table machine with standard welding equipment is available. The jig is the split type and is closed pneumatically. The whole process, including placement of the parts to be welded, is automated.

Determination of cycle time:	[s]
○ placement of the tank in the jig, including pneumatic jig closure	1.5
○ transport of the top	1.0
○ positioning of the top	0.5
● advance of rotary table machine	0.5
● application of horn	0.5
● welding time	0.5
● hold time	1.0
● removal of horn	0.5
○ ejection of welded part < 0.5	

The total time for the operations marked with (●) = 3.0 s = cycle time, i.e. in an eight-hour day, output is 9600.

The operations marked with (○) run parallel to the welding operation and thus have no effect on cycle time.

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Product brochure "Hoechst Plastics, ®Hostacom (reinforced PP)", H 703.

Product brochure "Hoechst Plastics, ®Celanex, ®Vandar, ®Impet", B 243.

Product brochure "®Fortron (PPS)", B 240.

Product brochure "®Vectra (LCP)", B 241.

ZVEI brochure: "Ultrasonic assembly of thermoplastic mouldings and semi-finished products",
ZVEI, Stresemannallee 19
D-60596 Frankfurt a. M.

DVS Data Sheets: 2216 part 1 – 5

Useful addresses:

Branson, Ultraschall GmbH,
Waldstraße 53 – 55, D-63128 Dietzenbach

Herrmann Ultraschalltechnik,
Descostraße, D-76307 Karlsbad-Ittersbach

KLN – Ultraschall – GmbH,
Siegfriedstraße 124, D-64646 Heppenheim

KVT Bielefeld, Gesellschaft für
Kunststoff-Verbindungstechnik mbH,
Werkering 6, D-33609 Bielefeld

Rinco Ultrasonics,
CH-8590 Romanshorn/Schweiz

Telsonic Ultraschallgeräte GmbH,
Gartenstraße 17, D-88212 Ravensburg

Telsonic AG,
Industriestraße, CH-9552 Bronschhofen/Schweiz

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In this technical information brochure, Hoechst aims to provide useful information for designers who want to exploit the properties of engineering polymers such as ®Hostaform. In addition, our staff will be glad to advise you on materials, design and processing.

This information is based on our present state of knowledge and is intended to provide general notes on our products and their uses. It should not therefore be construed as guaranteeing specific properties of the products described or their suitability for a particular application. Any existing industrial property rights must be observed. The quality of our products is guaranteed under our General Conditions of Sale.

Applications involving the use of the Hoechst materials ®Hostaform, ®Celanex, ®Hostalen GUR, ®Fortron and ®Vectra are developments or products of the plastics processing industry. Hoechst as supplier of the starting material will be pleased to give the names of processors of plastics for technical applications.

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Ticona

Hostaform®, Celcon®
polyoxymethylene copolymer (POM)

Celanex®
thermoplastic polyester (PBT)

Impet®
thermoplastic polyester (PET)

Vandar®
thermoplastic polyester alloys

Riteflex®
thermoplastic polyester elastomer (TPE-E)

Vectra®
liquid crystal polymer (LCP)

Fortron®
polyphenylene sulfide (PPS)

Celstran®, Compel®
long fiber reinforced thermoplastics (LFRT)

GUR®
ultra-high molecular weight polyethylene (PE-UHMW)

Europe
Ticona GmbH
Information Service
Tel.: +49 (0) 180-5 84 26 62 (Germany)
+49 (0) 69-30 51 62 99 (Europe)
Fax: +49 (0) 180-2 02 12 02
eMail: infoservice@ticona.de
Internet: www.ticona.com

Americas
Ticona LLC
Product Information Service
Tel.: +1-800-833-4882
Fax: +1-908-598-4306
eMail: prodinfo@ticona.com
Internet: www.ticona.com

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A business of Celanese AG