BRANSON

Ultrasonic Plastic Joining

Part Design for Ultrasonic Welding

Ultrasonic energy has been used to join thermoplastics for over 35 years. Ultrasonic welding of thermoplastic materials is by far the most common form of ultrasonic assembly, and is used extensively in all major industries including: automotive, appliance, electronic, toy, packaging, textile, and medical. It offers advantages in speed, economy, and efficiency, and is frequently chosen when parts are too complex or expensive to be molded in one piece.

This bulletin provides guidelines to aid the designer during the initial concept stage of a new product design, ensuring optimum production results. The dimensions given in the designs should be used as *guidelines only,* since the specifics of your application may require variations. If you have questions or need assistance in designing your parts, contact your local Branson representative, Branson Regional Technical Center, or the Application Laboratory at Branson's headquarters in Danbury, Connecticut.

Primary Factors Influencing Joint Design

All of the following basic questions must be answered prior to the design stage to gain a total understanding of what the weld joint must do:

- What type of material(s) is to be used?
- What is the overall part size and configuration?
- What are the final requirements of the part?
  - Is a structural bond desired? If so, what loads does it need to resist?
  - Is a hermetic seal required? If so, to what pressure?
  - Does the assembly require a visually attractive appearance?
  - Is flash or particulate objectionable inside and/or outside?
  - Any other requirements?

Three Major Joint Design Characteristics

In order to obtain acceptable, repeatable welded joints, three general design guidelines must be followed:

1. **The initial contact area between the mating surfaces should be small** to concentrate and decrease the total energy (and thus the time) needed to start and complete melting. Minimizing the time the vibrating horn remains in contact with the part also reduces the potential for scuffing, and since less material is moved, less flash is generated.
2. **A means for aligning** the mating parts should be provided. Features such as pins and sockets, steps, or tongues and grooves, should be used for alignment rather than the vibrating horn and/or fixture, to ensure proper, repeatable alignment and to avoid marking.
3. **Horn contact directly over the joint area** should be accommodated in order to transmit the mechanical energy to the joint area, while reducing the propensity for part marking.

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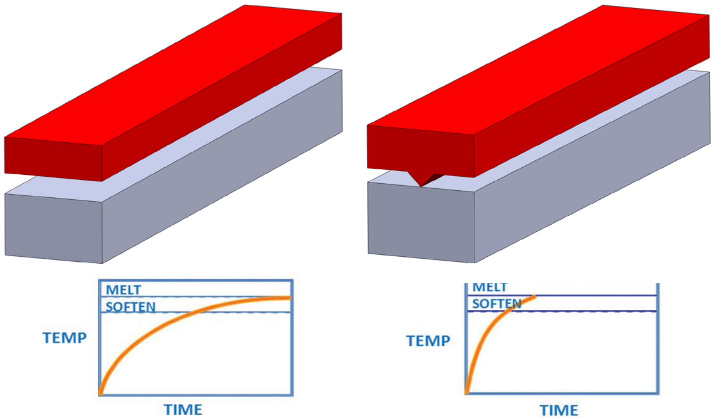
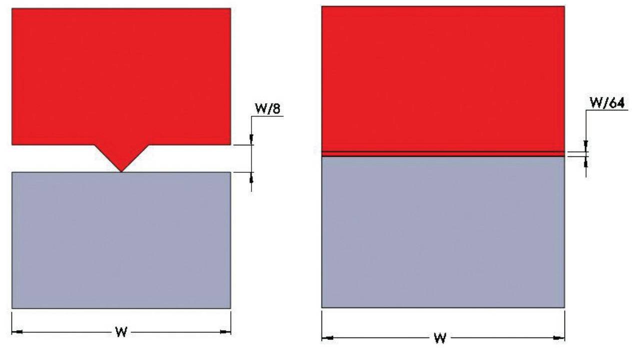
Part Design Ultrasonic Welding



Butt Joint   Butt Joint with Energy Director

Figure 1. Time-Temperature Curves:
Butt Joint vs. Energy Director Design



Before   After

Figure 2. Basic Energy Director
Design Formula

Two Major Types of Joint Design

There are two major types of joint design: the **energy director** and the **shear joint.** All other joint variations can be classified under these general categories or as hybrids combining aspects of both.

Energy Director — The energy director is typically a raised triangular bead of material molded on one of the joint surfaces. The primary function of the energy director is to concentrate the energy to rapidly initiate the softening and melting of the joining surface. The diagrams in Figure 1 show time-temperature curves for a butt joint and the more ideal joint incorporating an energy director. The energy director permits rapid welding while achieving maximum strength; material within the director generally flows throughout the joint area. The energy director is the most commonly-used design for amorphous materials, although it is also used for semi-crystalline materials.

Butt Joint with Energy Director —The basic design formula for the energy director design is illustrated in Figure 2. It is very important to remember that the size and location of the energy director on the joint interface are dependent upon:

- Material(s).
- Requirements of the application.
- Part size.

The peak of the energy director should be as sharp as possible; energy directors that are round or flat at their peak will not flow as efficiently.

In the case of semi-crystalline resins (e.g., acetal, nylon) with an energy director, the maximum joint strength is generally obtained only from the width of the base of the energy director.

Although the energy director can be located on either half of the part, it is generally included on the part contacted by the horn. In special situations (as in combinations of different materials), the general practice is to place the energy director on the part with the material that has the highest melt temperature and stiffness.

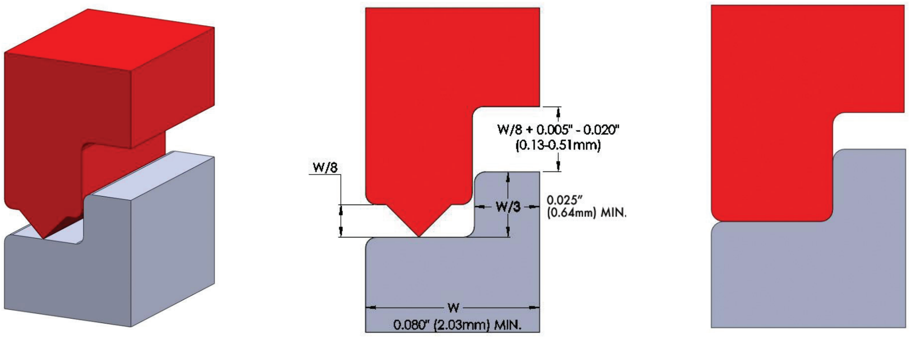
The energy director design requires a means of alignment such as pins and sockets, aligning ribs, or tongue and groove designs. Ejector pins should not be placed in the weld area.

***NOTE:** Typically a 90° included angle is used for amorphous resins, while a 60° included angle is used for semi-crystalline resins. The included angle may vary depending on materials, fillers, part geometry, or requirements. For recommendations regarding your specific application, please contact your local sales engineer or regional office.

Variations of the Energy Director Joint

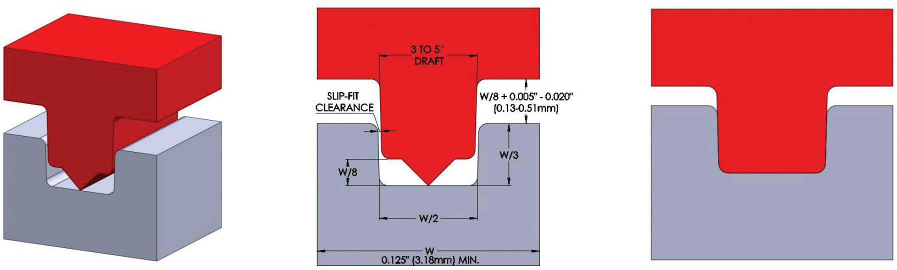
The basic energy director design can be incorporated into joint configurations other than the butt joint to gain additional benefits. Examples of joint design variations utilizing an energy director include the following alternatives:

Step Joint — The step joint is used for alignment and for applications where excess melt or flash on one exposed surface is objectionable (Figure 3). Note that 0.005 to 0.020 inch (0.127 – 0.508 mm) has been added to the gap surrounding the perimeter of the part. This adds a feature called a “witness line” to the design.



Before | After

Figure 3. Step Joint



Before | After

Figure 4. Tongue and Groove Joint Design

Branson/Moldtech Texture Designation	**Pattern Depth**
Branson 300/11040	0.003”
Branson 450/11050	0.0045”
Branson 600/11050-6	0.006”

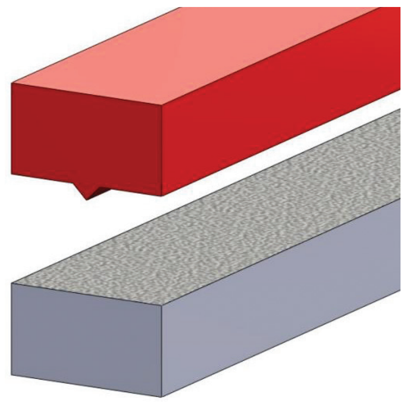


Figure 5. Textured Surface

**This design is covered by Branson Patent No. 4,618,516. License to utilize this design is granted via the purchase of Branson equipment.

When welding is completed, the witness line around the periphery of the part, will create a more appealing appearance, since part-to-part variations will be less noticeable. If the gap were completely closed, it is likely that flash would be formed in some outside areas, with slight gaps in others; whereas with the witness line, minor variations in the parts are less likely to be noticed.

The design of the energy director uses the same basic design thought process used in the butt joint energy director (i.e., material, requirements, part size). Note that a minimum wall thickness of 0.080 inch (2.00 mm) is recommended for this design.

Tongue and Groove — This joint design helps to contain flash, both internally and externally, while providing alignment between the parts (Figure 4). Containment of the material within the groove aids in the achievement of a hermetic seal. The need to maintain clearance on both sides of the tongue, however, makes this more difficult to mold.

Textured Surface** — This feature is exclusively used in conjunction with an energy director. Molding a textured surface on the mating part tends to improve the overall weld quality and strength by enhancing frictional characteristics and melt control (Figure 5).

Usually the texture is 0.003 to 0.006 inch deep (0.076 to 0.152 mm), and is varied based on the height of the energy director. In most cases, the advantages include increased weld strength, reduced flash or particulate, reduced weld times, or lower amplitude requirements. (Branson TechnoLog TL-4 provides details on this concept.)

Criss-Cross —This design incorporates energy directors on both mating sections that are perpendicular to each other, and provides minimum initial contact at the interface while allowing a potentially larger volume of material involvement. This can result in increased strength in the weld (Figure 6). Each energy director should be dimensioned at approximately 60% of the size that would be used in a standard single energy director design, with an included angle of 60° versus the standard 90°.

If an air- or liquid-tight seal is required, it is recommended that the corresponding energy directors be continuous, like a saw tooth (Figure 7). The corresponding saw-tooth energy directors must be located on the part that will be contacted by the horn. Note that this design generates a very high material flow; therefore, containing flash should be addressed in part design (e.g., use a tongue and groove or step design).

In order to achieve a hermetic seal with this design, it is important that there is no gap between each of the energy directors in the saw tooth. For round parts, the energy director should be designed as shown on the Figure 8, with height and included angle according to the desired dimension on the ID, with the included angle of the energy director increased on the OD to close the gap between the bases of the energy directors.

Energy Director Perpendicular to the Wall — Used to gain resistance to peeling forces and to reduce flash (Figure 9). This design should be used when only a structural seal is required.

Interrupted — Used to reduce the overall area and subsequent energy or power level required, or to minimize part marking. Use only where structural (non-hermetic) seals are needed (Figure 10).

Chisel Energy Director — Typically used when nominal wall thickness is 0.060 inch (1.524 mm) or less (Figure 11). If a standard energy director is used, it will be too small (less

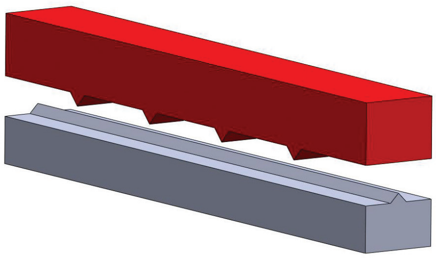


Figure 6. Criss-Cross Energy Director

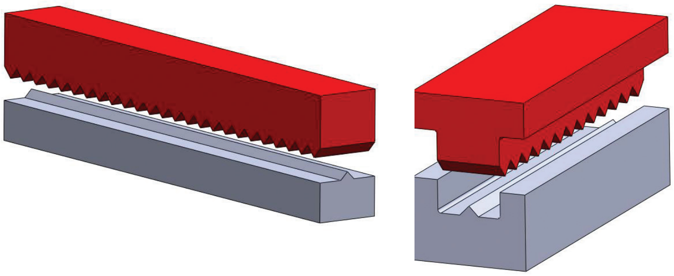


Figure 7. Criss-Cross Design for Air- or Liquid-Tight Seals

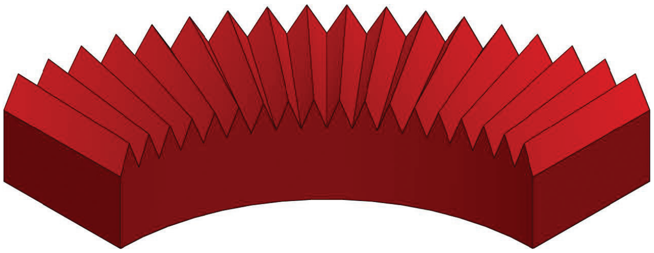


Figure 8. Criss-Cross Design on round parts

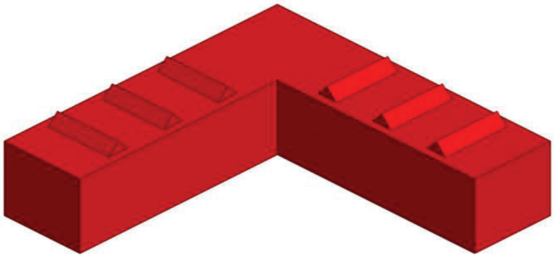


Figure 9. Energy Director Perpendicular to the Wall

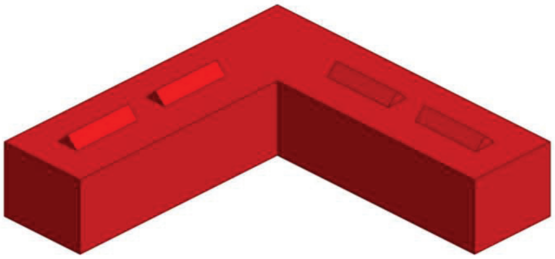
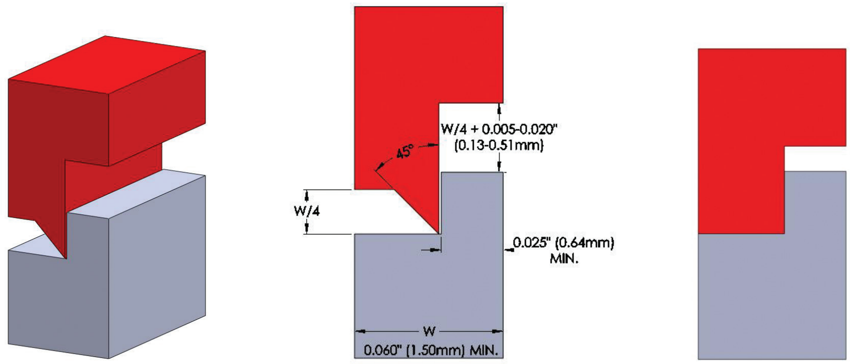


Figure 10. Interrupted Energy Director



Before

After

Figure 11. Chisel Energy Director

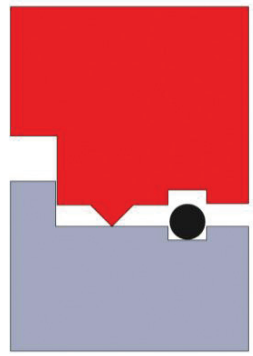
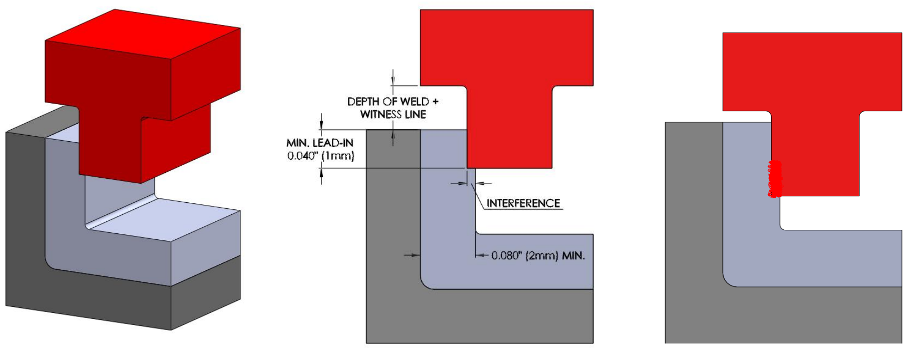


Figure 12. Joint Design with O-Ring for Hermetic Seal



Before

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Figure 13. Shear Joint Design

than 0.010 inch/0.254 mm tall), thus resulting in lower weld strengths. The knife edge can be 0.015 inch to 0.020 inch (0.381 to 0.508 mm) tall and should utilize a 45° angle. Another benefit of the chisel energy director is that it can be placed at the inside edge of a step and assure that it will not slip off the narrow welding ledge. Also, it can be used to direct the flow of molten material away from an opening (i.e around the perimeter of a lens).

Note: As weld strength will be limited to weld width, a textured surface should always be added when using this design.

Specialized Joints — In order to achieve a hermetic seal in less easily welded resins or irregular shapes, it may be necessary to use a compressible seal or a convoluted path for melt flow. Figure 12 shows a joint design incorporating an O-ring. It is important to note that the O-ring should be compressed a maximum of 10 to 15%, only at the end of the weld. Pins and sockets (stud welding, not staking) can also be used successfully with an O-ring design. (See datasheet PW-5.)

Shear Joint — An energy director type of joint design in some cases may not produce the desired results with semi-crystalline resins such as nylon, acetal, polypropylene, polyethylene, and thermoplastic polyester. This is due to the fact that semicrystalline resins change rapidly from a solid to a molten state, and back again, over a relatively narrow temperature range. The molten material flowing from an energy director, therefore, could re-solidify before fusing with the adjoining interface. The weld strength in a semi-crystalline resin could be limited to the base width of the energy director. A **shear joint** configuration is recommended for these resins where geometry permits.

With a shear joint design, welding is accomplished by first melting the small, initial contact area and then continuing to melt with a controlled interference along the vertical walls as the parts telescope together (Refer to Figure 13). This allows a strong structural or hermetic seal to be obtained as the molten area of the interface is never allowed to come in contact with the surrounding air. For this reason, the shear joint is especially useful for semi-crystalline resins.

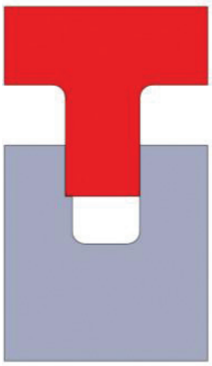

Figure 14. Tongue and Groove Variation

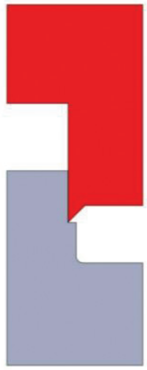

Figure 15. Shear-Joint Variation

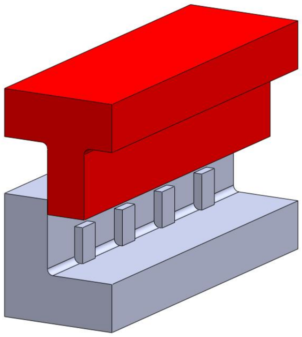

Figure 16. Interrupted Shear Joint Design

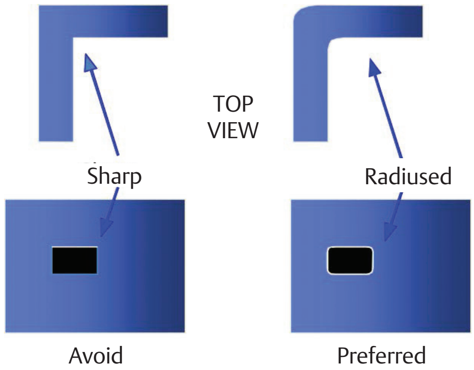

Figure 17. Radius of Corners to Reduce Stress

The strength of the welded joint is a function of the vertical dimension of meltdown of the joint (depth of weld), which can be adjusted to meet the requirements of the application. The general guideline for depth of weld is to use 0.75X the wall thickness.

In order for a shear joint to be successful, the following conditions must be met:

- The shear joint requires rigid side wall support to prevent deflection during welding. The walls of the bottom section must be supported at the joint by the holding fixture, which conforms closely to the outside configuration of the part.
- The top part should be of sufficient structural integrity to withstand internal deflection. Similarly, the minimum wall thickness of the bottom part should be 0.080 inch (2.00 mm) to prevent buckling.
- The surfaces creating the interference between the top and bottom parts should be flat and at 90° from each other.

A shear joint is not recommended:

- For parts with a maximum dimension of 3.0 inch.
- Parts with sharp corners, or irregular shapes. This is due to difficulty in holding the molding tolerances necessary to obtain consistent results.

An energy director type joint would be suggested for parts falling outside of these conditions.

For a midwall joint, the tongue and groove variation shown in Figure 14 is preferred. It is also useful for large parts. Interference on one side only is recommended.

When welding parts that need a structural weld only (hermetic or air-tight seals are not required), use the shear joint design with interrupted vertical energy directors shown in Figure 16. This design reduces the overall area and subsequent energy or power required to weld the parts. The potential for part marking is also minimized.

SHEAR JOINT GUIDELINES

The following table gives general guidelines for interference and part tolerance in relation to maximum part dimension.

Maximum Part Dimension	Interference per Side (Range)	Part Dimension Tolerance
Less than 0.75” (18 mm)	0.008” to 0.010” (0.2 to 0.254mm)	+-0.001” (+-0.025 mm)
0.75” to 1.50” (18 to 35 mm)	0.010” to 0.014” (0.254 to 0.356mm)	+-0.002” (+-0.050 mm)
1.50” to 3.0” (38 to 76mm)	0.014” to 0.018” (0.356 to 0.457mm)	+-0.003” (+-0.075 mm)

Other Design Considerations for Any Joint Design

Sharp corners localize stress. When a molded part with stress concentration is subjected to ultrasonic mechanical vibrations, damage (fracturing, melting) may occur in the high stress areas. This can be mitigated by having a generous radius (0.020 inch/0.508 mm) on corners, edges, and junctions. At a minimum, all corners or edges should be broken (Refer to Figure 17).

Hole or Voids, like ports or other openings in the part being contact by the horn can create an interruption in the transmission of the ultrasonic energy (Figure 18). Depending on the type of material (especially semi-crystalline resins) and the size of the hole, little or no welding may occur directly beneath the opening. When a hole or bend exists in the part, the resin dampens the transmission of energy, making it difficult to pass vibrations from the horn contact point to the interface of the parts to be welded, especially in shear.

Careful attention must be given to the design of parts to avoid such problem areas. Air bubbles within the plastic, due to improper venting in the mold tool, will also dampen the transmission of vibrations or cause the material to blow out in these areas.

Near-field vs. far-field welding — Near-field and far field welding refer to a joint less than 0.250 inch, or more than 0.250 inch from the horn contact surface, respectively (Figure 19).

In amorphous plastics, the random arrangement of molecules allows the vibrations to pass through easily with little attenuation. Comparatively, because of their structure, semi-crystalline resins dampen the transmission of energy, making them more difficult to weld in a far-field condition. Dampening also takes place in low-stiffness resins (low modulus). Care must be taken when designing parts to allow adequate transmission of energy to the joint area.

Appendages, tabs, or other details molded on to the interior or exterior surfaces of the molding can be affected by the mechanical vibrations, resulting in fracturing (See Figure 20).

The following are recommended to minimize or eliminate this:

- The addition of a generous radius to the area where the appendages intersect the main part.

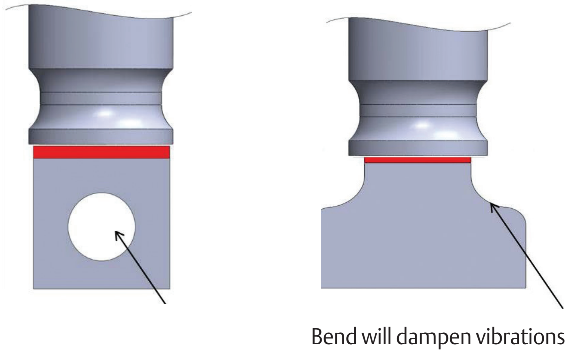

Figure 18. Interference with Energy Transmission

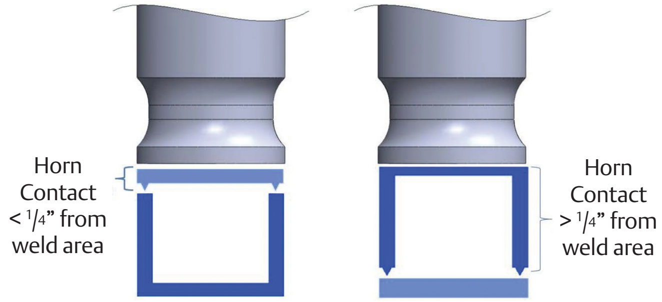

Figure 19. Near-Field and Far-Field Welding

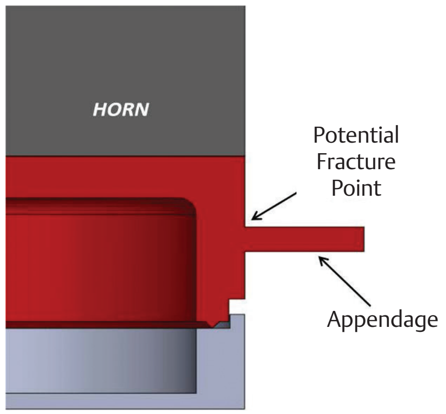

Figure 20. Part Surface Detail Design

Ultrasonic Plastic Joining

- Dampening of flexure through external means.
- Increasing the stiffness of the appendage by either increasing its thickness or adding ribs or gussets to that feature.
- Evaluation of other frequencies.

Diaphragmming — an "oil-canning" effect with related burn-through —typically occurs in flat, circular parts at thin-walled sections of the part (e.g., a living hinge) contacted by the horn (See Figure 21). This can be corrected by one or a combination of the following:

- Shorter weld time.
- Higher or lower amplitude.
- Amplitude Profiling.™
- Nodal plunger on horn.
- Thicker wall section.
- Internal support ribs.
- Evaluation of other frequencies.
- Positive air pressure from the horn nodal area to the face.
- Pulling vacuum via the fixture.
- Welding with a vented horn.

Horn contact and placement can play a major role in the successful welding of molded parts. In general, the horn should be large enough to overhang the perimeter of the parts, so it is bearing directly over the joint area (Refer to Figure 22). Doing this helps direct the mechanical energy and prevent marking of the contact surface. The surface of the horn or part can also be raised over the weld area to provide better contact, which can improve the consistency of energy transmission.

Note: The area of horn-to-part contact must be larger than the total weld area. Failure to do this could lead to surface marking.

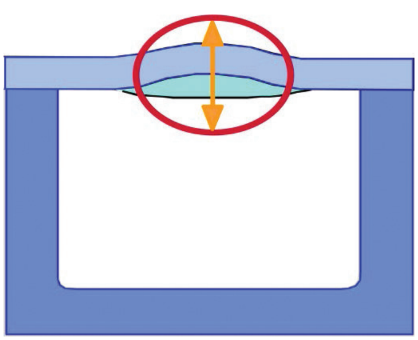

Figure 21. Diaphragmming

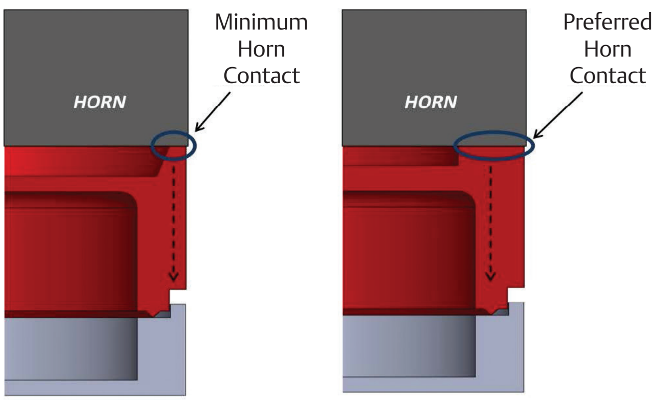

Figure 22. Proper Horn Contact and Placement

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BRANSON

Technical Information PW-1

Polymers: Characteristics and Compatibility for Ultrasonic Assembly

Weldability of Polymers

The principle of ultrasonic assembly involves the use of high-frequency mechanical vibrations transmitted through thermoplastic parts to generate a frictional heat build-up at an interface. This bulletin provides guidelines on the welding characteristics of thermoplastics as well as an understanding of how polymer structure and other factors affect the weldability of various polymers. The term "weldability" is used generically and includes the ability to stake, swage, insert, or spot weld the resin.

Polymers: Thermoset Versus Thermoplastic

A polymer is a repeating structural unit formed during a process called polymerization. There are two basic polymer families: thermoset and thermoplastic. A ***thermoset*** is a material that, once formed, undergoes an irreversible chemical change and cannot be reformed with the reintroduction of heat and pressure; therefore, thermosets cannot be ultrasonically assembled in the traditional sense. A ***thermoplastic*** material, after being formed can, with the reintroduction of heat and pressure, be remelted and reformed, undergoing only a change of state. This characteristic makes thermoplastics suitable for ultrasonic assembly.

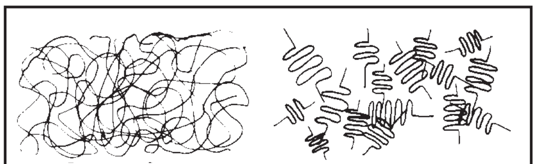
All the information contained in this information sheet and others covering ultrasonic processes is based on the use of *thermoplastic* polymers (resins).

Factors That Affect Weldability

When discussing the weldability of thermoplastics, it must be recognized that there are a number of factors that affect the ultrasonic energy requirements and, therefore, weldability of the various resins. The major factors include polymer structure, melt temperature, melt index (flow), modulus of elasticity (stiffness), and chemical makeup.

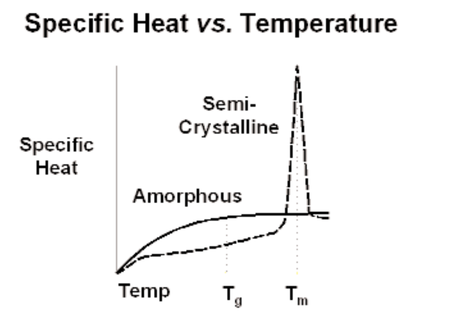
Polymer Structure

Amorphous polymers have a structure characterized by a random molecular arrangement (Figure 1a).



1a Amorphous Structure

1b Semi-crystalline Structure



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They have a broad softening temperature (T_g, glass transition temperature) range (Figure 2) that allows the material to soften gradually, melt and flow without prematurely solidifying. These polymers generally are very efficient with regard to their ability to transmit ultrasonic vibrations, and can be welded under a wide range of force/amplitude combinations.

Semi-crystalline polymers are characterized by regions of orderly molecular arrangement (Figure 1b). They have sharp melting (T_m, melt temperature) and resolidification points (Figure 2). The molecules of the polymer, when in the solid state, are spring-like and internally absorb a percentage of the high-frequency mechanical vibrations, thus making it more difficult to transmit the ultrasonic energy to the joint interface. For this reason, high amplitude is usually required. The sharp melting point is the result of a very high energy requirement (high heat of fusion) necessary to break down the semi-crystalline structure to allow material flow. Once the molten material leaves the heated area, these resins solidify rapidly with only a small reduction in temperature. These characteristics therefore warrant special consideration (i.e., higher amplitude, careful attention to joint design, horn contact, distance to the weld joint, and fixturing) to obtain successful results.

Melt Temperature

The higher the melt temperature of a polymer, the more ultrasonic energy is required for welding.

Stiffness (Modulus of Elasticity)

The stiffness of the polymer to be welded will influence its ability to transmit the ultrasonic energy to the joint interface. Generally the stiffer a material the better its transmission capability.

Welding Dissimilar Resins

A ***similar melt temperature*** between the materials to be welded is a basic requirement for successful welding of rigid parts, because a temperature difference of 40°F (22°C) can be sufficient enough to hinder weld-

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ability (even for a like resin). The lower melt temperature material melts and flows preventing generation of sufficient heat to melt the higher melt temperature material. For example, with an energy director on a part composed of high-temperature acrylic opposing a parallel surface composed of a low-temperature acrylic, the weld surface of the high-temperature part will not reach the necessary temperature to melt. The opposing surface will be in a molten state before the energy director begins to soften, and if the energy director fails to melt, bond strength will be impossible to predict.

In addition, to weld dissimilar plastics, the plastics to be welded must possess a ***like molecular structure*** (i.e., be chemically compatible) with some component of the material, usually a blend. Close examination of compatible thermoplastics reveals that like radicals are present, and the percentage of the like chemical radical will determine the molecular compatibility.

Note: Compatibility exists only among amorphous polymers or blends. Semi-crystalline polymers are weldable only to themselves.

Melt index, or flow rate, is the rate at which a material flows when it becomes molten. Different grades of the same material may have different flow rates (e.g., an injection molded nylon and an extruded nylon). Such differences may result in the melting of one component of an assembly and not the other. Thus, a melt or flow is created, but not a homogeneous bond. When selecting resins that are dissimilar or different grades of the same material, consult the resin manufacturer's specifications to acquire the melt index or flow rate. The flow rates should be fairly close (i.e., 2 to a 4) in order to achieve compatibility.

Other Variables That Influence Weldability

Moisture

Some materials are hygroscopic; that is, they absorb moisture from the atmosphere which can seriously affect weld quality. Nylon (and to a much lesser degree polyester, polycarbonate, and polysulfone) is the material most troubled by this characteristic.

If hygroscopic parts are allowed to absorb moisture, when welded the water will evaporate at 212° F (100°C), with the trapped gas creating porosity (foamy condition) and often degrading the resin at the joint interface. This results in difficulty in obtaining a hermetic seal, poor cosmetic appearance (frostiness), degradation, and reduced weld strength. For these reasons, if possible it is suggested that nylon parts be welded directly from the molding machine to insure repeatable results. If welding can't be done immediately, parts should be kept dry-as-molded by sealing them in polyethylene bags with a desiccant pouch or other suitable means directly after molding. Drying of the parts prior to welding can be done in special ovens; however, care must be taken to avoid material degradation. Keep in mind that 100% dry nylon can be very brittle. Some moisture within the material may be beneficial in eliminating an over-stress condition (which can cause cracking).

If several batches of hygroscopic parts have varying levels of moisture, the energy levels required during the welding process will have to be varied by the ultrasonic welder.

Resin Modifiers

Using additives or processing aids during preparation of a resin compound may result in properties not inherent in the base resin. These additives, which can enhance certain areas of processing, can in some cases create problems in ultrasonic welding. Parts molded with differing parameters may require minor variations in welding process parameters.

Mold release agents, often called parting agents, are applied to the surface of the mold cavity to provide a release coating which facilitates removal of the parts. External release agents, such as zinc stearate, aluminum stearate, fluorocarbons and silicones can be transferred to the joint interface and interfere with surface heat generation and fusion, inhibiting welding; silicones are generally the most detrimental. If it is absolutely necessary to use an external release agent, the paintable/printable (non-transferring) grades should be used. These grades prevent the resin from wetting the surface of the mold, with no transfer to the molded part itself, thus permitting painting and silk-screening and the least amount of interference with ultrasonic assembly. Detrimental release agents can in some cases be removed by using a solvent, such as TF Freon. Internal molded-in release agents, since they are generally uniformly dispersed internally in the resin, usually have minimal effect on the welding process.

Lubricants (internal and external) are materials that enhance the movement of the polymer against itself or against other materials. (Examples include waxes, zinc, stearate, stearic acid, esters.) Lubricants reduce intermolecular friction (melt viscosity) within the polymer and reduce melt flow friction against primary processing equipment surfaces. Since molecular friction is a basis for ultrasonically induced temperature elevation, lubricants can inhibit the ultrasonic assembly process. However, since they are generally dispersed internally, like internal mold release agents their effect is usually minimal.

Plasticizers are high-temperature boiling organic liquids or low-temperature melting solids which are added to resins to impart flexibility. They do this through their ability to reduce the intermolecular attractive forces of the polymer matrix. They can also interfere with a resin's ability to transmit vibratory energy. Attempting to transmit ultrasonic vibrations through a highly plasticized material (such as vinyl) is like transmitting energy through a sponge. Even though plasticizers are considered an internal additive, they do migrate to the surface over time, and the combination of internal as well as surface

Table 1. Characteristics

Material	Welding Near*	Welding Far*	Swaging Staking	Insertion	Spot Welding
Amorphous Polymers					
ABS	1	2	1	1	1
ABS/polycarbonate alloy	2	2	2	1	1
Acrylic	2	3	3	1	1
Butadiene-styrene	2	3	2	2	2
Phenylene-oxide based resins	2	2	2	1	1
Polycarbonate (a)	2	2	3	2	2
Polyetherimide	2	4	4	3	3
Polyethersulfone (a)	2	4	4	4	4
Polystyrene (general purpose)	1	1	4	2	3
Polystyrene (rubber modified)	2	2	1	1	1
Polysulfone (a)	2	3	3	2	3
PVC (rigid)	3	4	2	1	3
SAN-NAS-ASA	1	1	3	2	3
PBT/polycarbonate alloy	2	4	3	2	2
Semi-Crystalline Polymers (b)					
Acetal	2	3	3	2	2
Cellulosics	3	5	2	1	3
Fluoropolymers	5	5	5	5	5
Liquid crystal polymers (c)	3	4	4	4	3
Nylon (a)	2	4	3	2	2
Polyester, thermoplastic					
Polyethylene terephthalate/PET	3	4	4	3	3
Polybutylene terephthalate/PBT	3	4	4	3	3
Polyetheretherketone - PEEK (c)	3	4	4	3	3
Polyethylene	4	5	2	1	2
Polymethylpentene	4	5	2	1	2
Polyphenylene sulfide	3	4	4	2	3
Polypropylene	3	4	2	1	2

Code: 1 = Easiest, 5 = Most difficult.

The codes in Table 1 indicate ***relative ease of welding*** for the more common thermoplastics. In addition to the material factors covered in the preceding sections, ease of welding is a function of part size and geometry, joint design, energy requirements, amplitude, and fixturing.

Note: The ratings *do not* relate to the strength of the weld obtainable.

Use these tables as a *guide only,* since variations in resins, fillers, and part geometry may produce slightly different results.

Notes:

* Near-field welding refers to a joint 0.250 inch (6.35 mm) or less from the horn contact surface; far-field welding refers to a joint more than 0.250 inch (6.35 mm) from the horn contact surface. You should consider using 15 kHz equipment when welding far field with difficult-to-weld materials.

a Moisture will inhibit welds. Consider using a 2000f welder with force profiling for achieving hermetic seals.

b Semi-crystalline resins in general require higher amplitude and energy levels due to polymer structure, higher melt temperatures, and heat of fusion.

c Consider using 40 kHz for near-field welding.

Table 2. Compatibility of Thermoplastics

■ Denotes compatibility

○ Denotes compatibility in some cases (usually blends)

	ABS	ABS/polycarbonate alloy	Acrylic	Butadiene-styrene	Phenylene-oxide based resins	Polycarbonate	Polyetherimide	Polyethersulfone	Polystyrene (general purpose)	Polystyrene (rubber modified)	Polysulfone	PVC (rigid)	SAN-NAS-ASA	PBT/polycarbonate alloy	*Semi-Crystalline Polymers*	Acetal	Cellulosics	Fluoropolymers	Liquid crystal polymers	Nylon	Polyethylene terephthalate - PET	Polybutylene terephthalate - PBT	Polyetheretherketone - PEEK	Polyethylene	Polymethylpentene	Polyphenylene sulfide	Polypropylene
Amorphous Polymers																											
ABS	■	■	■			○						○	○														
ABS/polycarbonate alloy	■	■	○			■																					
Acrylic	■	○	■		○	○							○														
Butadiene-styrene				■					○																		
Phenylene-oxide based resins			○		■	○			■				○														
Polycarbonate	○	■	○		○	■	○				○			■													
Polyetherimide						○	■																				
Polyethersulfone								■																			
Polystyrene (general purpose)				○	■				■				○														
Polystyrene (rubber modified)										■																	
Polysulfone						○					■																
PVC (rigid)	○											■															
SAN-NAS-ASA	○		○		○				○				■														
PBT/polycarbonate alloy						■								■								○					
Semi-Crystalline Polymers																											
Acetal																■											
Cellulosics																	■										
Fluoropolymers																		■									
Liquid crystal polymers																			■								
Nylon																				■							
Polyethylene terephthalate - PET																					■						
Polybutylene terephthalate - PBT														○								■					
Polyetheretherketone - PEEK																							■				
Polyethylene																								■			
Polymethylpentene																									■		
Polyphenylene sulfide																										■	
Polypropylene																											■

Note: This chart depicts compatibility as a complete mixing of materials resulting in a homogeneous bond. Other combinations of materials may be used to create mechanical or partial bonds.

Consult your Branson representative if you have a combination not listed in this literature.

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lubricity make plasticized vinyl all but impossible to weld. FDA-approved plasticizers do not present as much of a problem as metallic plasticizers, but experimentation is recommended.

Impact modifiers such as rubber can affect the weldability of a material by reducing the amount of thermoplastic available at the joint interface. They can also reduce the resin's ability to transmit ultrasonic vibrations, making it necessary to increase amplitude to generate a melt.

Foaming agents also reduce a resin's ability to transmit energy. Voids in the cellular structure interrupt the energy flow, reducing the amount of energy reaching the joint area, depending on the density.

Flame retardants are added to a resin to inhibit ignition or modify the burning characteristics. They can adversely affect ultrasonic welding characteristics of the resin compound. Flame retardant chemicals are generally inorganic oxides or halogenated organic elements, and for the most part are non-weldable. Typical examples are aluminum, antimony, boron, chlorine, bromine, sulfur, nitrogen, and phosphorus. The amount of flame retardant material required to meet certain test requirements may vary from a few percent to 50% or more by weight of the total matrix, thus reducing the amount of available weldable material. This reduction must be compensated for by modifying the joint configuration to increase the amount of weldable material at the joint interface and by increasing ultrasonic energy levels.

Regrind. Scrap formed during the molding process, e.g., sprues, runners, reject parts, can usually be recycled directly back into the process after the material has been reduced to a usable size. Control over the volume and quality of regrind is necessary, as it can adversely affect the welding characteristics of the molded part. In some cases the use of 100% virgin material may be required to obtain the desired results. If regrind is to be used, the percentage should be regulated $\pm$10% for proper control.

Most colorants, either pigments or dyes, do not interfere with ultrasonic assembly; however, occasionally some pigments (white, black) can influence weldability. Titanium dioxide (TiO_2) is the main pigment used in white parts. Titanium dioxide is inorganic, chemically inert, and can act as a lubricant, and if used in high loadings (greater than 5%), it can inhibit weldability. Black parts on the other hand can be pigmented with carbon, which can also inhibit weldability. In any event, an application evaluation should be undertaken. Parts molded in different pigments may require minor variations in welding process parameters.

Resin grade can have a significant influence on weldability because of melt temperature and other property differences. An example is the difference between injection/extrusion grades and cast grades of acrylic. The cast grade has a higher molecular weight and melt temperature, is often brittle, and forms a skin that gives it greater surface hardness, all of which reduce weldability to the injection grade. A general rule of thumb is that both materials to be welded should have similar molecular weight, and melt temperatures within 40°F (22°C) of each other.

Fillers/extenders constitute a category of additives (non-metallic minerals, metallic powders, and other organic materials) added to a resin that alter the physical properties of resins. Fillers enhance the ability of some resins to transmit ultrasonic energy by imparting higher rigidity (stiffness). Common materials such as calcium carbonate, kaolin, talc, alumina trihydrate, organic filler, silica, glass spheres, wollastonite (calcium metasilicate), and micas, can increase the weldability of the resin considerably; however, it is very important to recognize that a direct ratio between the percentage of fillers and the improvement of weldability exists only within a predescribed quantitative range. Up to 20% can actually enhance weldability, due to increased stiffness, giving better transmission of vibratory energy to the joint.

Resins with a filler content up to 10% can be welded in a normal manner, without special procedures and equipment. However, with many fillers, when filler content exceeds 10% the presence of abrasive particles at the resin surface can cause horn and fixture wear. In this situation the use of hardened steel or carbide-faced (coated) titanium horns is recommended.

When filler content approaches 35%, there may be insufficient resin at the joint surface to obtain reliable hermetic seals; and when filler content exceeds 40%, tracking, or the accumulation of filler (typically fibers), can become so severe that insufficient base resin is present at the joint interface to form a consistent bond.

It should be noted that particular types of fillers can present special problems. When long fibers of glass are employed, they can collect and cluster at the gate area during molding, being forced through in lumps rather than uniformly dispersed. This agglomeration can lead to an energy director containing a much higher percentage of glass. If this were to occur, no appreciable weld strength could be achieved since the energy director would embed itself in the adjoining surface, not providing the required molten resin to cover the joint area. If this problem occurs, it can be eliminated by utilizing short-fiber glass filler.

Fibrous reinforcements of resins can, like fillers or extenders, be used to enhance or alter physical properties of the base resin. Continuous or chopped fiber strands of aramid, carbon, glass, etc., can in some cases improve the weldability of a resin; however, rules governing the use of fillers should be observed.

Further information on polymers, their characteristics, and compatibility with ultrasonic assembly may be obtained from Branson's polymer and applications data base, as well as from the suppliers of polymers.

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