Ultrasonic welding

Eastman polymers

Ultrasonic welding

Ultrasonic welding is a common method for joining plastic parts without using adhesives, solvents, or mechanical fasteners. Ultrasonic welding equipment operates on the principle of converting electrical energy to mechanical vibratory energy. This vibratory energy is transmitted to plastic parts by a specially designed horn that also applies pressure to force the parts together. The high-frequency vibration generated by the welding apparatus creates frictional heat that softens the plastic to create a bond at contact points between plastic parts.

Ultrasonic welding offers several advantages, including:

- Environmentally safe; no chemicals used
- Aesthetically pleasing joints
- Excellent product uniformity
- Rapid bonding; higher productivity
- Process adaptable to multiple tasks (inserting, swaging, etc.)
- Low energy consumption
- Computer-controlled process; suitable for statistical process control
- Provides hermetic seals

Some plastics soften and bond more easily than others, but by selecting the appropriate welding equipment and parameters, strong bonds can be obtained with most amorphous plastics. Parameters that significantly affect weld strength and appearance include vibration frequency and amplitude, horn pressure, weld time, and joint design.

Joint designs

There are multiple joint designs commonly used in the plastics industry, and the appropriate joint design should be utilized based on the application and product end use. A simple *energy-director joint* provides a small raised ridge of polymer between two flat surfaces to be joined. As the parts are pressed together by the vibrating welder horn, the ridge softens and flows over the width of the joint to create a bond. One surface to be joined may be textured or have additional detail to enhance weld quality. A crisscross design, such as shown in Figure 2, gives more material flow for stronger bonds and hermetic seals but may sacrifice some aesthetics. The tongue-and-groove and step joint designs ensure joint alignment, reduce visible flash, and promote a hermetic seal and are suggested for most applications.

Figure 1. Typical joint design*

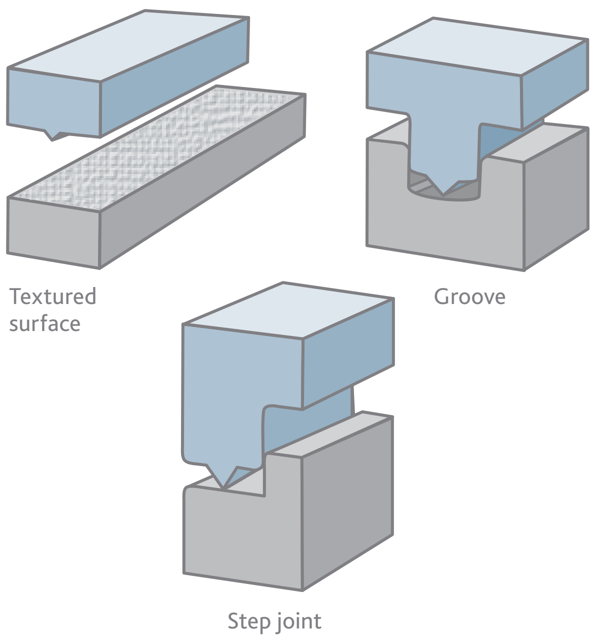
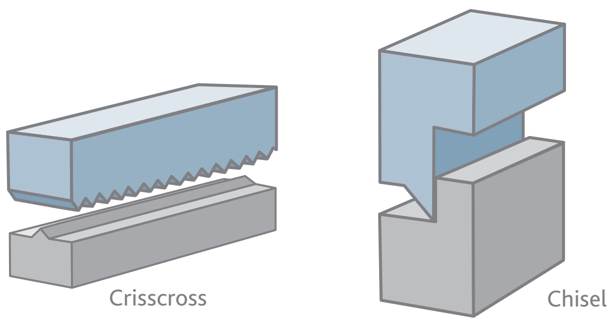


Figure 2. Additional weld joint designs*



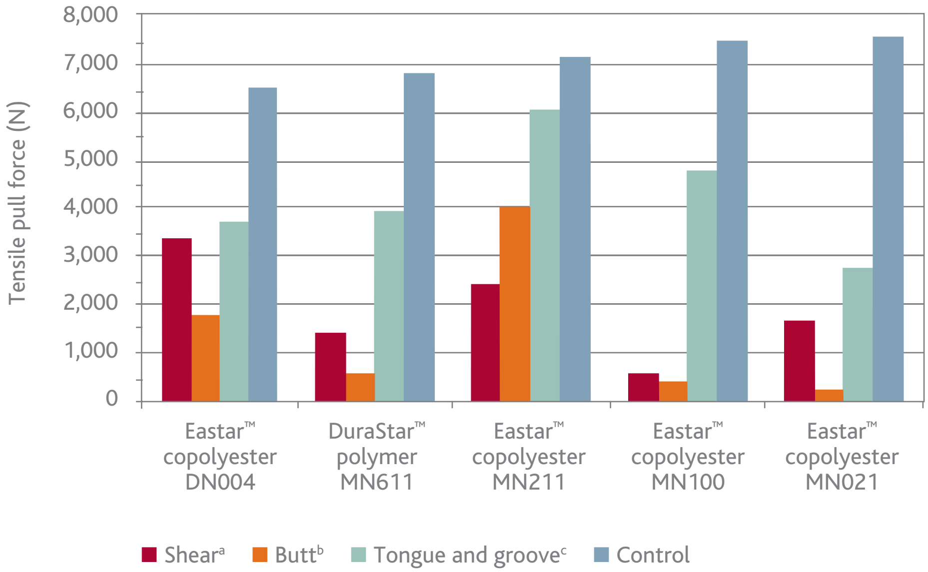
Simple energy-director joints are suggested for most parts, but in some situations, additional joint designs may be more suitable for the application. Shear joint designs are not typically recommended for amorphous materials.

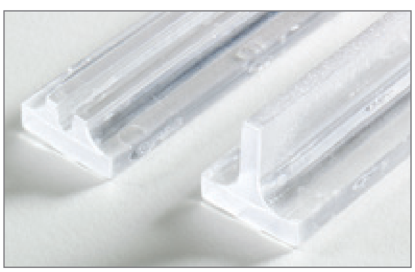
**Figures 1 and 2 obtained from Branson document PW-3*

Comparing weld joint designs

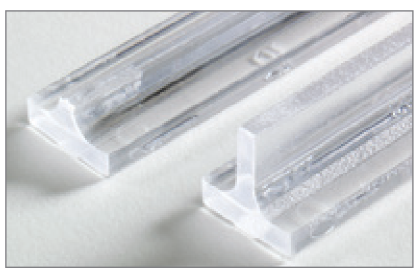
Ultrasonic welding of Eastman copolyesters was performed using standard industry specimens to form a 50.8-mm (2-in.) long, welded I beam (see ANSI AWS G1.2M/G1.2: 1999). Additional custom-designed specimens of similar overall geometry were used to evaluate tongue-and-groove and crisscross joint designs. Table 1 summarizes the ultrasonic welding setup and conditions. Weld strength was evaluated in a tensile pull test performed at a speed of 50.8 mm/min. The results of tests using three joint designs are summarized in Figure 3. The strength of a molded I beam is shown as a control sample.

Figure 3. Comparison of weld joints

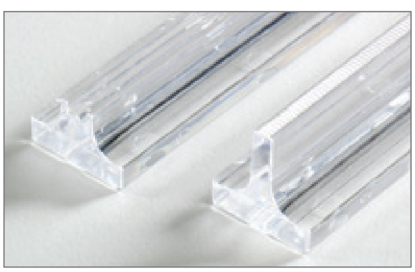




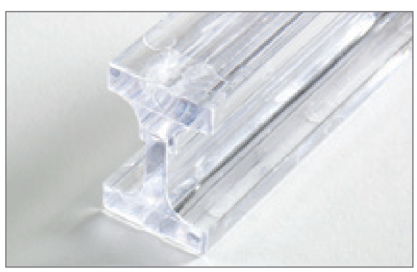
Shear[a]



Butt[b]



Tongue and groove[c]



Control[d]

[a] *Double-sided shear joint with an interference of 0.2 mm (0.008 in.) between mating parts*

[b] *A Branson 450 texture on one surface and an energy director with a height of 0.5 mm (0.020 in.) on the mating surface. See Figure 1.*

[c] *An energy director with a height of 0.36 mm (0.014 in.) on the groove surface and a crisscross pattern with a height of 0.58 mm (0.023 in.) on the tongue surface*

In general, it was found that:

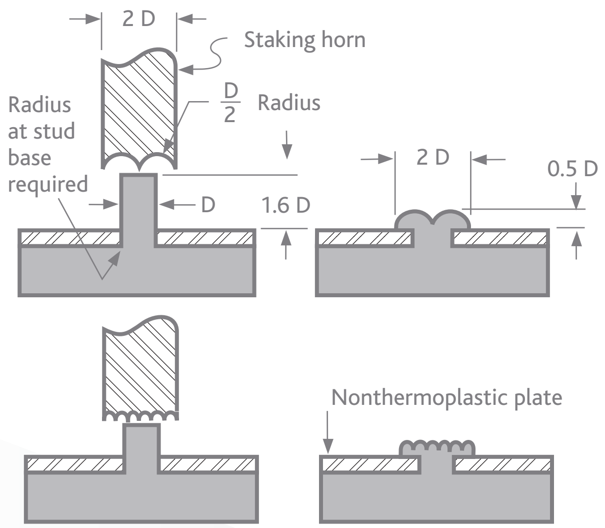
- Tongue-and-groove joints formed the strongest bonds.
- In the absence of a groove, butt joints are inherently more prone to misalignment leading to reduced weld strength.
- Increased weld strengths were formed at longer weld times and lower weld pressures resulting from improved melt formation. However, longer weld times increase the potential for horn contact damage on a part.
- Hold time after welding appears to have little to no effect on weld strength.
- Energy directors should be utilized to obtain the strongest welds.

Since actual part design may have a significant effect on performance, these results should only be used as guidelines for weld joint design. Note that these results are for tensile strength only and may not indicate weld performance in parts that experience flexing or impact. Also, weld strength can vary depending upon part design, polymer utilized, aesthetic needs, etc., and each application should be tested to determine suitability.

Ultrasonic staking

Ultrasonic staking is an assembly method in which a plastic stud is melted to capture or lock two components together (Figure 4). This method offers several advantages, including fast cycle times, good repeatability and control, tight locking, and the ability to form multiple stakes at one time.

Figure 4. Ultrasonic/heat staking methods



This method is suitable for joining parts made of Eastman plastic to other materials such as steel and dissimilar plastics. However, it may not be suitable for joining parts that are both made of Eastman materials. In such cases, there is the opportunity for the softened head of the stake to weld to the mating part and form sharp notches which concentrate stress and embrittle the joint. For best results, limit ultrasonic staking to applications in which the plastics to be joined have a melting/softening temperature difference of at least 22°C (40°F).

General welding practices suggested for Eastman polymers

Eastman offers technical support via part design review (suggested prior to manufacturing molds) and troubleshooting welding issues as needed. Your welding equipment supplier can also provide valuable assistance for equipment selection, setup, and part design. The following suggestions include some of the more important considerations for ultrasonic welding of Eastman polymers.

- Design parts with energy directors via tongue-and-groove joints or step joints for added strength and toughness.
- Provide adequate part stabilization/nest support to prevent flex and movement during welding.
- Design parts with adequate horn contact area to reduce horn marks.
- Suggest utilizing near-field welding with most polymers (less than 6.35 mm from horn contact to weld joint).
- Eliminate stress concentrators/sharp notches in part design and weld joint region.
- Properly drying and processing materials should be accomplished to improve overall part and weld strength.
- Use flat, parallel mating surfaces to optimize weld contact area.

Alternative assembly methods

If ultrasonic welding is judged to be inappropriate for the application, designers may consider alternative assembly methods, such as permanent snap fits, laser welding, spin welding, induction welding, hot-plate welding, screws, inserts, solvent bonding, or adhesives.

Conclusion

Ultrasonic welding of copolyesters can be successfully accomplished with proper joint design, material selection, and the use of proper welding parameters. Part designers must carefully select the joint design that provides the optimum performance and utility to satisfy the end-use requirements of the functional part. Because ultrasonic welding may not be appropriate for the specific part to be assembled, designers should consult their welding equipment supplier or Eastman technical representative and conduct rigorous real-life end-use testing as the product is being developed. A list of equipment suppliers follows.

Branson Ultrasonics Corporation
41 Eagle Road
Danbury, CT 06813 U.S.A.
Tel: (1) 203-796-0400

Dukane Corporation
2900 Dukane Drive
St. Charles, IL 60174 U.S.A.
Tel: (1) 630-584-2300

Sonics and Materials, Inc.
53 Church Hill Road
Newtown, CT 06470 U.S.A.
Tel: (1) 203-270-4600

Herrmann Ultrasonics, Inc.
620 Estes Avenue
Schaumberg, IL 60193 U.S.A.
Tel: (1) 847-985-7344

Ultra Sonic Seal
368 Turner Way
Aston, PA 19014 U.S.A.
Tel: (1) 610-497-5150

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