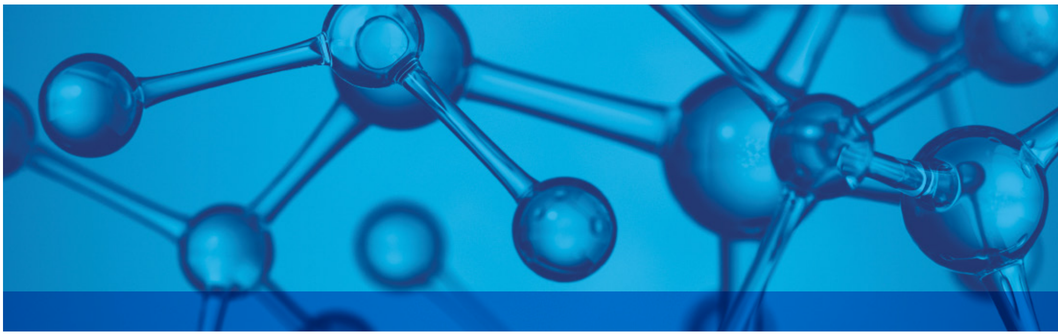

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Ultrasonic Welding Ryton® PPS Compounds

Introduction

This technical bulletin addresses frequently asked questions about joint design, welding conditions, and weld strength of Ryton® PPS. Ultrasonic technology may be used not only for welding together Ryton® PPS parts, but also for staking or insertion operations.

Ryton® PPS (polyphenylene sulfide) is a semi-crystalline thermoplastic that has a sharp, high melting temperature (285 °C, 545 °F) not really desirable for ultrasonic welding operations. However, when reinforced with glass fibers and other fillers, Ryton® PPS compounds have a high modulus conducive to transmission of ultrasonic vibrational energy. With proper joint design, the 40 % glass filled Ryton® PPS compounds (Ryton® R-4 Series and BR42B) may be readily welded, however the more highly glass and mineral filled Ryton® PPS compounds (Ryton® R-7 Series, R-10 Series, and BR111) are somewhat more difficult to weld due to their lower resin content.

Joint Design

Ryton® PPS compounds are relatively easy to weld together, however joint design is critical to the strength of the weld. It is also important to consider how the overall part design will contribute to the ultrasonic welding process.

A shear joint is generally recommended for ultrasonic welding of Ryton® PPS compounds. Although step joints have been used successfully with Ryton® R-4 Series compounds, step joints or butt joints should never be used with Ryton® R-7 Series, R-10 Series, or BR111 compounds. The more highly filled compounds apparently do not have enough mobility in the melt to flow together well in a butt-type joint. However, the shear joint generates more of a "smearing action" at the interface during the welding process, thereby incurring more mobility of the molten plastic. Tests using Ryton® R-4 have shown the shear joint to generate a weld requiring six times more force to pull apart than an ordinary butt joint with energy director (see Appendix I). Employing a shear joint can also provide for more welded surface area, and is generally considered more effective at attaining a hermetic seal. Typical joint designs for the shear and step joints, including relative dimensions, are shown in Figure 1 and Figure 2.

Figure 1. Shear joint

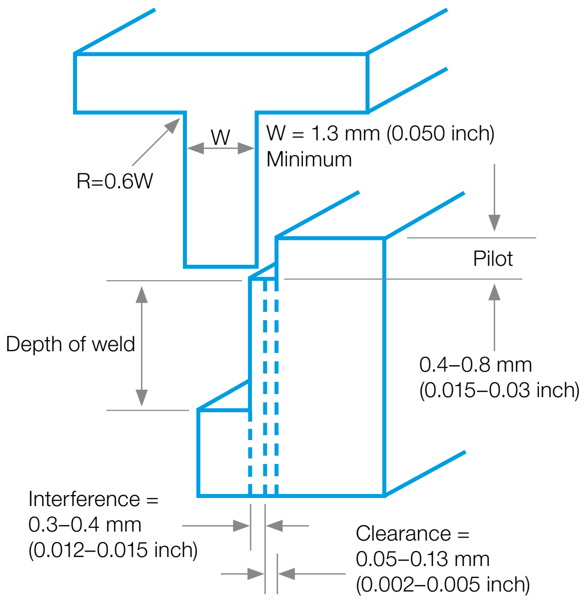
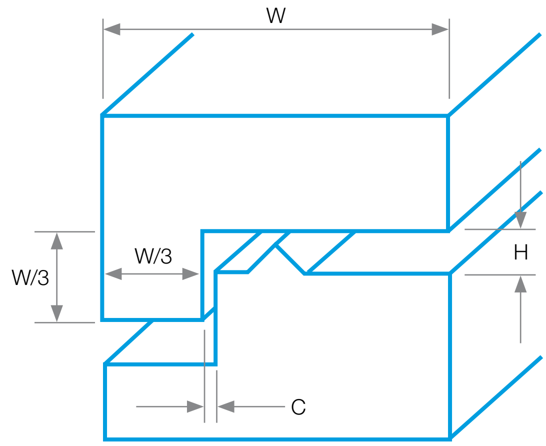


Figure 2. Step joint



C = 0.05–0.13 mm (0.002–0.005 inch)
H = 0.2–0.6 mm (0.008–0.025 inch)

A shear joint is not usually recommended for parts having a maximum dimension of 89 mm (3.5 inches) or greater, sharp 90° turns or irregular shapes, due to difficulty in achieving the molding tolerances necessary to obtain consistent results. An energy director type joint is usually recommended in such cases. However, the tight molding tolerances possible when using Ryton® PPS may extend these limitations. The depth of weld for shear joints should be about 1.25 times the wall thickness.

For near field welding of small thin-walled parts molded from Ryton® R-4 Series compounds, a butt-type joint will require lower amplitude at higher frequencies, thereby providing the advantage of less instant power and preventing destruction of the part. A sharp pointed (60° tip angle) energy director should be used, as is typical for semi-crystalline thermoplastics. The width of the base of the energy director should be 20 % to 25 % of the wall thickness, and the height of the energy director should be 0.866 times the width of the base.

When designing a part that will utilize the ultrasonic welding process, consideration must be given to reducing the loss of ultrasonic energy in unproductive modes. It is important to remember that ultrasonic waves are transmitted primarily in the direction of horn travel with an amount of energy proportional to the wall section of the part. The part to be vibrated should be the uppermost and lightest part of the assembly, and should provide a flat surface above the joint for horn contact. Special features may also be necessary to direct vibrational energy only to the area of the joint (for example, a raised lip around the edge of a lid). An adequate amount of clearance in the joint is essential to allow vibration of the parts. Corners should have a radius of 0.6 times the wall thickness to prevent part cracking during the ultrasonic welding process. Symmetrical components are easier to weld because there will be a uniform distribution of energy.

Some of the more common joint design mistakes to avoid are:

- Joints that are too tight or too close together which prevent adequate vibration
- The section transmitting the ultrasonic vibrations being too thin as it may crack under the high amplitude level
- Too large a step requiring a high instant power which may destroy the part
- An assembly in which the vibrating part is not the uppermost and lightest
- An energy director design that will prevent a homogeneous weld
- Sharp internal corners that may cause part cracking
- The presence of metal inserts that can absorb vibrations and reduce welding efficiency. In such cases inserts should be installed after welding.

Welding Recommendations

Optimum ultrasonic welding conditions are very dependent upon the assembly being welded and the welding equipment being used. While it is important to seek the advice of the manufacturer of the ultrasonic welding equipment in determining the best possible process setup, the following general comments about ultrasonic welding of Ryton® PPS compounds may help provide a starting point for developing a welding process. Adjustment of the welding parameters depends on the size and stiffness of the part, and especially the distance between the point of horn contact and the welding joint. Welding capability is limited by the capability of the plastic material to transmit the ultrasonic vibration without the part suffering damage.

Since Ryton® PPS is a semi-crystalline thermoplastic with a high melt temperature, high amplitude ultrasonic vibrations are generally required to effect adequate melting to form a weld. Because of the high modulus of Ryton® PPS compounds, the high amplitude vibrations may be transmitted fairly long distances through the part, but the greater the distance from the horn to the joint, the more amplitude will be required. Higher welding frequency may achieve more efficient welding with lower amplitudes, especially in near field welding (when the distance from the point of horn contact to the joint is less than 6 mm). But for far field welding (when the distance from the point of horn contact to the joint is more than 6 mm), the amplitude will ultimately be limited by the rigidity of the walls transmitting the vibrations. The thinner the walls, the shorter the distance ultrasonic vibrations may be transmitted, because the part will not be able to withstand the amplitude required to generate an adequate weld.

The power required for welding depends on the surface area to be welded, the geometry of the part, and the absorption of the material. High power is generally required when welding Ryton® PPS compounds because a lot of energy must be delivered very rapidly to melt the plastic at the joint before inflicting any damage on the vibrated piece.

The horn speed must be adjusted to coincide with the rate of melting and weld formation, usually a slow rate for Ryton® PPS compounds.

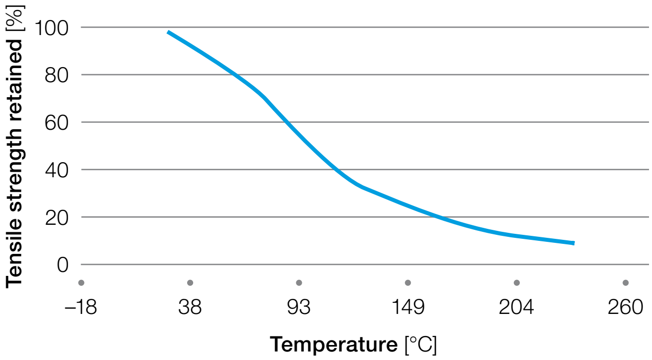
So when welding shear joints, high power, a high amplitude booster, low pressure, and slow horn speed are suggested for initial setup, and further adjustments may then be made as necessary. When welding the parts, caution should be used since excessive amplitude and/or too long an application time could destroy the part. The strongest welds are generally achieved by switching off the ultrasonic emission before releasing pressure on the welding joint. However, if difficulty attaining a hermetic seal is encountered, it may be helpful to stop the horn movement before switching off the ultrasonic emission. The shear joint fit before welding should have sliding clearance to obtain the maximum weld strength.

Often a fixture is required to support the sides to prevent deflection or breakage of the parts during welding. Fixtures may be made from aluminum, steel, epoxy or other materials and may include a lining of rubber or cork. The fixture must fit the part well in the area of the shear joint to give proper support.

Weld Strength

Welds will typically be much lower in strength than the bulk material. This is because there is very little glass fiber reinforcement across the weld, so the strength of the weld is primarily dependent on neat resin strength. Even when welding unreinforced plastics, weld strength is never as great as the strength of the bulk material. Some of the stronger Ryton® PPS compounds (Ryton® R-4XT, R-4-200, and BR42B) may attain weld strengths as high as 50 MPa (7,500 psi), but for most Ryton® PPS compounds weld strengths should not be expected to exceed more than about 35 MPa (5,000 psi). Furthermore, weld strength will be reduced at elevated temperatures, as shown in Figure 3.

Figure 3: Tensile strength retention of unfilled PPS at elevated temperatures



It is also important to remember that there are a variety of other factors that may compromise the ability to achieve optimum weld strength. The weld strength is dependent on the overall surface area of the weld, which may or may not be as large as expected. The quality of injection molded components is also of great importance to the weld strength. Defects in the molding, such as internal weld lines or voids, affect ultrasonic energy transmission and can act as energy absorbers within the component. This may result in damage to the part, such as cracking or overheating, and poor weld quality as a result of insufficient energy transmission to the weld. Surface contamination with lubricants or mold release agents may impede the welding process by preventing generation of frictional heat, and can also chemically compromise the strength of the weld. Finally, the PPS polymer at the weld will be in the amorphous state because it is rapidly melted and cooled during the welding process. Consequently, should the part experience temperatures above about 85 °C (185 °F) in service, thermally induced crystallization of the PPS polymer may generate additional stress in the weld.

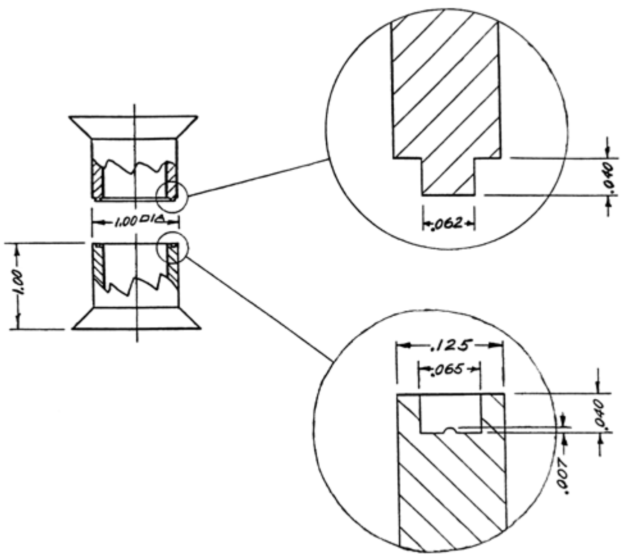
Appendix I

Ultrasonic Welding Tests

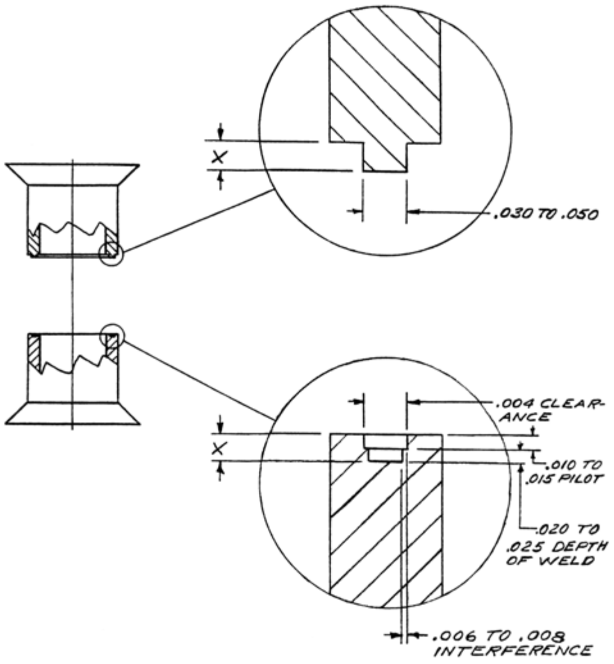
Test specimens designed to be tensile tested using an Instron tester were molded on a 125 ton Cincinnati injection molding machine. The test specimen configuration and dimensions are shown in the figures below. A fixture lined with rubber was used to support the specimens during welding. Welding was done using a 400-series model 4120 Branson ultrasonic welder with 1:1 booster and horn number 613-005-020. Tests were conducted using 40 % glass fiber reinforced PPS compound Ryton® R-4, and 65 % glass and mineral filled PPS compounds Ryton® R-8 and Ryton® R-10.

Ryton® PPS compounds were found to be relatively easy to weld, but the joint design was critical to the weld strength. The shear joint was found to be suitable for Ryton® R-4, R-8, and R-10 compounds, while the butt joint was found to be successful only with Ryton® R-4. The Ryton® R-8 and R-10 compounds' melt did not appear to be mobile enough to flow together in the butt type joint. With Ryton® R-4, the double shear joint produced welds that required approximately 600 pounds tensile load to break while the butt joint tested approximately 100 pounds tensile load to break. No attempt was made to determine the actual stress (in psi) to break because the actual area that was welded varied somewhat with each specimen.

Ultrasonic weld test specimen butt joint with energy director



Ultrasonic weld test specimen double shear joint



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