# Methods of Polymer Weld Quality Evaluation

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## Introduction

Evaluation of the quality of polymer welds is essential to the development and production maintenance of a welding process. However, it can be challenging to select an evaluation method due to the wide variety of options. A comparison of some popular weld quality evaluation methods is discussed in this paper, as well as the preparation procedures for each and what can be learned from each method.

There are many techniques available to evaluate quality of polymer welds. Traditionally, these methods are categorized as destructive or nondestructive. However, they can also be categorized by whether the information provided is quantitative (numerical and objective) or qualitative (observation-based and subjective). The table below lists some of the more common evaluation methods for plastic welds, and the ones which have been selected for comparison in this paper have been highlighted.

**Table 1:** Types of testing

| Quantitative | Qualitative |
|---|---|
| Pressure decay leak testing | Cross-sectional analysis |
| Tensile testing | Computerized tomography (CT) scanning |
| Peel testing | Microtome slicing |
| Bend testing | Visual inspection |
| Creep testing | X-ray |
| Fatigue testing | Ultrasonic testing |
| Dimensional analysis | Fractography |

## Experimental Procedure

Two assemblies were welded for evaluation at each of the seven parameter sets described in Table 2. Several intentional defects were created such as, over welding, under welding, and insufficient pressure. Finally, notches were cut into the bottom halves of two assemblies, one each from Sets B and D. All fourteen were pressure decay leak-tested. One of each pair (seven total) were then CT-scanned and tensile-tested. The remaining seven were cross-sectioned, and half of those were also cryomicrotome-sliced.

**Table 2.** Parameters for ultrasonically welded assemblies

| Set | Plastic | Ultrasonic Weld Settings | | | Laser Weld Settings | | |
|---|---|---|---|---|---|---|---|
| | | Amplitude (µm) | Collapse (% ED) | Force (N) | Power (W) | Speed (cm/min) | Force (N) |
| A | Polybutadiene Terephthalate | 40 | 233 | 654 | N/A | | |
| B | Polybutadiene Terephthalate | 18 | 100 | 654 | | | |
| C | Polycarbonate | 29 | 100 | 654 | | | |
| D | Polycarbonate | 12.7 | 67 | 654 | | | |
| E | Polybutadiene Terephthalate to Polycarbonate | 29 | 100 | 654 | | | |
| F | Polyamide | N/A | | | 103 | 152 | 698 |
| G | Polyamide | | | | 67 | 152 | 138 |

"%ED" refers to the percent of the designed energy director height. The Set A assemblies were over-collapsed, while the Set D assemblies were under-collapsed.

## Results and Discussion

The tensile and leak tests resulted in a numerical quality evaluation of the samples, detailed in Table 3. However, some of these results can be misleading. For example, the assemblies from sets A and C both leaked profusely, but this leak occurred outside the weld area, at a hole in the center of the cap, demonstrating how leak testing addresses the integrity of the full assembly, not just the weld joint. In fact, sets A and C both significantly out-performed sets B and D in tensile testing. Of the laser welded samples, Set F, which was welded with greater pressure and power, was stronger in tensile and provided a better leak-tight seal than set G (see Table 3).

While imaging tests cannot provide any numerical ranking of the weld, they do provide quite a bit of information that cannot be obtained by purely quantitative tests. Figure 1 clearly shows the improved compression of the melt on Sets A and C which would correlate with greater tensile strength than Sets B and D. The section of Set E shows the clear distinction of the joint between the dissimilar materials, indicating poorer weld quality. The laser welded parts sections show porosity filled and uneven welds, where the good leak test results from set F would not have indicated such a poor weld.

The cryomicrotome slices (Figure 2) show much the same information as was seen in the cross sections. However, the variation in transparency in these thin slices can be correlated to crystallinity in the sample. Note how the amorphous Polycarbonate is much less opaque than the semi-crystalline Polybutadiene Terephthalate in the Set C image where they have been welded together.

**Table 3.** Tensile and leak test results

| Set | Max Tensile (N) | Leak Rate for Each Assembly in Set (cm³/min) | |
|---|---|---|---|
| A | 2734 | Major Leak | Major Leak |
| B | 118 | -1.4 | Major Leak (Notched) |
| C | 5551 | Major Leak | Major Leak |
| D | 2032 | 0.41 | Major Leak (Notched) |
| E | 2740 | -0.06 | 237 |
| F | 2080 | 0.93 | 1.08 |
| G | 1506 | 169.42 | 328.16 |

The greatest advantage of CT scanning is the ability to see the entire extent of the weld joint and the surrounding assembly. While the resolution is reduced from what can be seen in cross-sections and cryomicrtomes, porosity and areas with lack of fusion can be clearly identified and located. This can be very helpful in failure analysis as a first step – locating the failure area to be sectioned for closer examination.

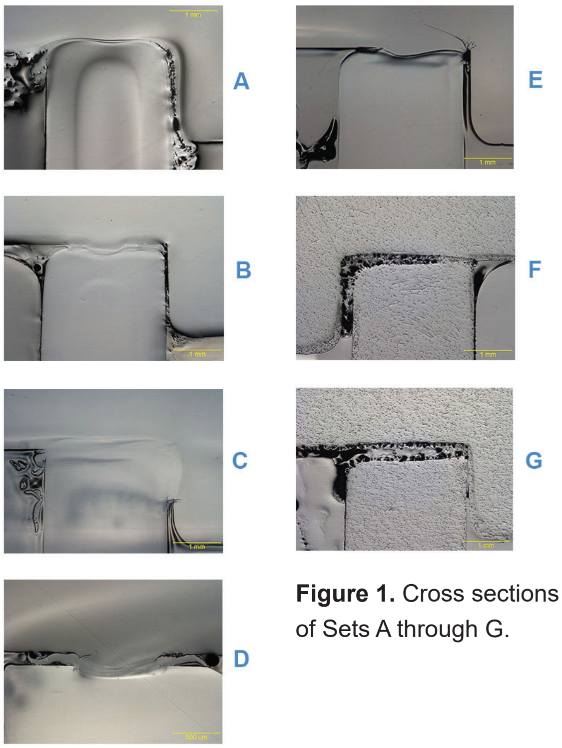

**Figure 1.** Cross sections of Sets A through G.

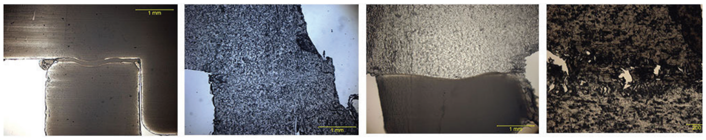

**Figure 2.** Cryomicrotomes of Set B, Set C, Set E, and bonded zone of Set F weld at higher magnification (left to right)

To view a video of the CT scan of the set D assembly visit https://ewi.org/rotational-view/. The notch that was cut into the weld can be seen at about the 0.5 second mark.

## Conclusions

When it comes to evaluating weld performance, it is often beneficial to select a few methods to be used in combination to fully characterize a weld. The advantages and disadvantages of each evaluation method explored in this review are summarized in Table 4.

**Table 4.** Flaws detectable by evaluation method

| Method / Flaw | Leak Test | Tensile Test | Cross Section | Microtome Slice | CT Scan |
|---|---|---|---|---|---|
| Lack of Fusion | | X | X | | |
| Misalignment | | | X | X | X |
| Porosity | X | | X | X | X |
| Degree of Collapse | | X | X | X | X |
| Discrete Gap/ Inclusion | X | | | | X |
| Change in Crystallinity | | | | X | |

*An X indicates the flaw can be detected with the method.

***Miranda Marcus**, Applications Engineer, is EWI's technical lead for plastic and composite welding technologies. She has extensive knowledge of plastic welding techniques including ultrasonics, laser, spin, hot plate, vibration, thermal staking, radio frequency and infrared. Miranda frequently consults on joining projects to identify process parameters, assist in tooling design, provide joint design recommendations, review overall part design, and troubleshoot production failures.*