Amplitude and Weld Strength

Amplitude Profiling provides many potential benefits for ultrasonic welding, including:

- Increased weld strength;
- Reduced part marking;
- Increased resistance to solvents;
- Less flash and particulate.

This TechnoLog discusses how Amplitude Profiling increases weld strength.

What Is Amplitude?

Amplitude is the peak-to-peak longitudinal displacement at the face of the horn and is the most critical parameter in ultrasonic welding (refer to TechnoLog TL-2, Amplitude Reference Guide, for more detail on amplitude).

As shown in Figure 1, the horn face amplitude is the product of the gains of the horn, booster, and converter.

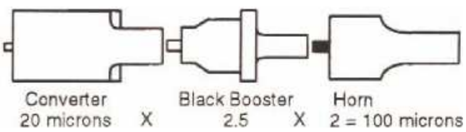


Figure 1.. Amplitude at the face of the horn — equation..

What Is Amplitude Profiling?

In standard practice, the amplitude of the horn face remains constant during the entire weld cycle. Recent advances in technology have made it possible to change the amplitude of the horn face during the weld cycle. This is known as Amplitude Profiling. Figure 2 illustrates a typical profile where the amplitude is reduced during the cycle. This type of profile can increase weld strength.

How Amplitude Profiling Increases Weld Strength

During the ultrasonic welding process, the thermoplastic material goes through several phases:

1) Start of melting (solid to solid material contact);
2) Buildup of melt (molten and solid layer);

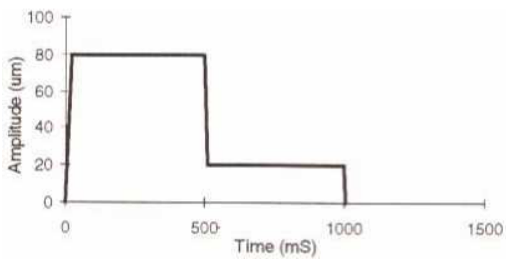


Figure 2.. Changes in amplitude — a typical cycle graph..

3) Steady state melt (molten layer);
4) Solidification of weld (during hold time).

To start the weld (phases 1 and 2), the amplitude and booster should be appropriate for the material and application, based on the guidelines in TL-2. This will ensure that the entire welding surface is heated uniformly and quickly to its softening point. Once the molten layer is fully formed and the entire weld surface has been wetted with the molten polymer (phase 3), the amplitude should be reduced to initiate the two mechanisms which increase weld strength:

1) Molecular entanglement
2) Reduced residual stresses

The first mechanism, increased molecular entanglement, is the result of two basic physical relationships:

A) Amplitude controls bondline temperature;
B) Bondline temperature controls melt viscosity.

In terms of (A), the average heating rate of the polymer is proportional to the amplitude squared. It is possible, therefore, to control the temperature (similar to controlling the barrel temperature in an injection molding machine) by controlling the amplitude. Actual temperatures are seen below at different amplitudes (Figure 3, over).

As thermoplastic materials such as polycarbonate, ABS, and polystyrene are heated, they gradually soften, or more precisely, their viscosity decreases. The higher the temperature, the easier the melt flows. Therefore, controlling the amplitude enables the user to control the melt flow (B).

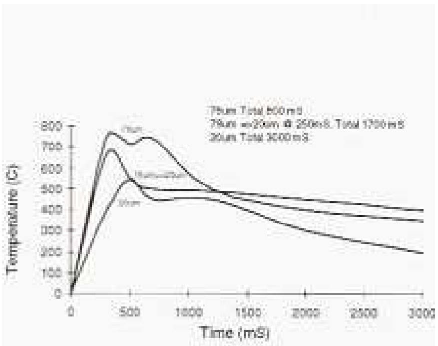


Figure 3.. Weld area temperatures at different amplitudes

When the melt flow moves quickly across the weld surfaces (high temperature due to high amplitudes), the molecules of the plastic tend to align themselves with the flow. If the velocity of the melt is moderate, the molecules tend to align themselves in a more random orientation and become entangled (see Figure 4). If the molecules are entangled, the weld is stronger. In order to break the weld, a fracture must form through or around the molecular chains.

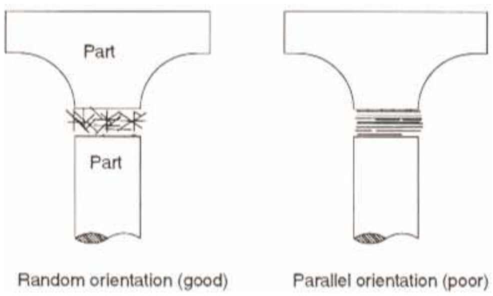


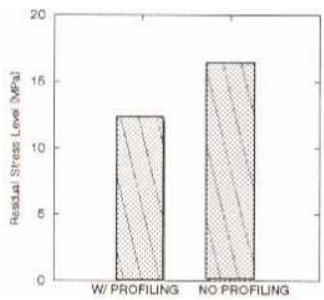
Figure 4.. Orientation with and without Amplitude Profiling..

The effects of Amplitude Profiling on molecular entanglements in the weld area have been confirmed by FTIR (Fourier Transform Infrared) microspectometry.

The second mechanism that helps produce stronger welds is the reduction of residual stresses. Residual stresses are stresses remaining from the welding process and are produced by squeeze flow and temperature gradients. As previously detailed, squeeze flow is moderated by Amplitude Profiling, and this effect alone may reduce residual stresses. Additionally, there are fewer temperature gradients (because of the moderation of the weld area temperature), thereby further reducing residual stress.

As the graph in Figure 5 shows, there is a 34% decrease in the residual stresses in the weld area when amplitude profiling is used. Because of this, the energy required to break a weld is higher and, therefore, the weld is stronger.

Figure 5.. Residual stress in welds made with and without Amplitude Profiling..



While the benefits of Amplitude Profiling will vary for each application and can only be determined by testing, laboratory tests have shown increases from a few percent to 100%. In general, a typical application should gain 10- 30% in weld strength when Amplitude Profiling is used.

Setting Up Amplitude Profiling

While every application requires fine tuning of the welding parameters and the amplitude profile, there are three guidelines that can be used to set up an application with Amplitude Profiling:

1) Choose the starting amplitude using Branson's Amplitude Reference Guide (TL-2);
2) Drop the amplitude by 30-70% of the initial amplitude at a point 50-90% into the weld cycle time;
3) Extend the weld cycle time by 20-50%.

M aterial Suitability for Amplitude Profiling

Amplitude Profiling is suitable for both amorphous and semi-crystalline materials. The chart below illustrates the typical percentage of increase in weld strength when amplitude profiling is used. Results will vary depending on the specific application and equipment used.

Mat erial	*% IIncreased Weld*
Polycarbonate	
ABS	
Nylon	
PBT	