DUPONT PERFORMANCE POLYMERS

Joint Design: A Critical Factor in Strong Bonds

GENERAL GUIDELINES FOR ULTRASONIC, VIBRATION AND SPIN WELDING

Introduction

Welding techniques for assembling parts molded with DuPont thermoplastic resins conventionally require an input of energy that results in heat. This heat causes a brief melting of material at the interface of two parts to be joined. Simultaneous application of pressure produces a strong, homogenous bond.

Techniques range from simple processes such as hot plate welding to electromagnetic/induction heating and laser welding. These techniques are used to join large or complex parts. Hot plate welding is seldom used with engineering plastics because of their higher melt temperatures and rapid solidification when heat is removed. Electromagnetic welding utilizes a magnetically “activated” thermoplastic in the joint interface which is heated by electromagnetic coils while under clamping pressure. (An induction welding variation uses metal inserts which are heated by the magnetic field.) Laser welding relies on the transmissive and absorptive characteristics of the materials to be welded. Because of the specialized nature of these methods, designers should contact their DuPont representative for specific application assistance.

The methods covered in this overview, ultrasonic, vibration and spin welding, offer quick, precise and economical means of assembly. Each method requires close attention to joint design, holding and alignment fixtures, and material moisture.

Safety Considerations

Read the Safety Data Sheets (SDSs) for the specific products being processed. While processing thermoplastic resins, all potential hazards must be anticipated and either eliminated or guarded against by following established industry procedures. Hazards include:

- Thermal burns resulting from exposure to hot surfaces
- Fumes and particles generated during the welding process
- Formation of gaseous and liquid degradation products
- High noise levels generated by welding equipment

SDSs include information such as hazardous components, health hazards, emergency and first aid procedures, disposal procedures, and storage information.

Note: Adequate ventilation and proper protective equipment should be used during all aspects of material processing. Refer to the DuPont Ventilation Guide for more detailed information.

Ultrasonic Welding

Ultrasonic welding, a versatile technique for joining small parts, uses high frequency (20 kHz or 40 kHz) vibrations to develop the intermolecular heat that melts interfacing surfaces. Vibrations are applied from a custom-designed tool, called a “horn” or “Sonotrode” through the upper part to be welded. Required welding intensity for a particular joint is developed by using different horn configurations and welding variables.

This technique is very fast (usually less than two seconds) and can be easily automated for high speed assembly operations. The resulting welds are homogenous joints with strength approaching that of the base material in the case of unreinforced materials. Ultrasonic joints are particularly suitable where a hermetically-sealed or structural joint is required.

Joint configuration is perhaps the most critical factor for good welding. Two basic designs are used:

- The Shear Joint (**Figure 1)**, developed and recommended by DuPont for engineering plastics.

- The Energy Director (**Figure 2**), used primarily for amorphous plastics (e.g., acrylic, styrene etc.).

Shear joint welds are achieved by first melting the contacting edges, then continuing the melt along the vertical walls as the parts telescope together. Telescoping prevents exposing the weld region to air, which could cool it too rapidly, causing brittleness. Weld strength, determined by the depth of telescoping, can be increased even beyond that of the adjacent wall by designing the depth at 1.5 to 2 times the wall thickness. For conservative calculations, assume joint strength efficiency to be approximately 1/3 of the base resin's strength for glass-filled materials with an average content of 30%. (Fillers and reinforcements do not contribute additional strength to a welded joint).

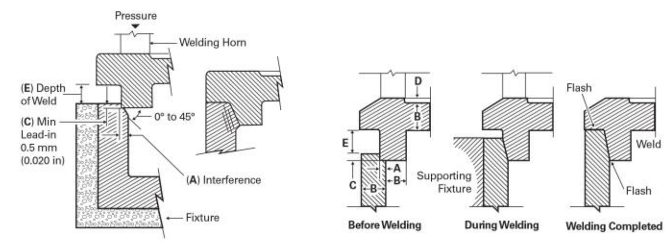
Where flash is objectionable, flash containment traps (**Figure 3**) should be included in the design.

High moisture content can result in very weak or ineffective welds. For example, exposure of nylon parts to warm air 23 °C (73 °F) at 50 percent relative humidity for 24 hours can seriously degrade a weld. Preferably, parts should be welded in a dry- as-molded condition (0.2 percent moisture for PA-66). Because of the multi-directional forces developed during welding and the small amplitude vibrations, supporting fixtures to prevent unintended wall movement are very important. Fixtures must provide solid support around and under the joint, and the horn must be as close to the interface as possible for maximum energy transmission. Energy-director joints should not be used with crystalline thermoplastics where a sealing or structural bond is required.

Vibration Welding

Vibration welding is basically friction welding. The upper and lower halves of a part to be welded are placed in form-fitting fixtures mounted on platens of the welder. The upper half is then reciprocated at high speed (100 to 240 Hz) and pressure (2 to 4 MPa/290 to 580 psi) against a stationary lower half.

Figure 1. Ultrasonic Welding – Shear Joint



Preferred

Dimension A		
Maximum Part Dimension	Interference per Side (Range)	Part Dimension Tolerance
Less than 19 mm (0.75 in)	0.2 to 0.3 mm (0.008 to 0.012 in)	± 0.025 mm (± 0.001 in)
19 to 38 mm (0.75 to 1.50 in)	0.3 to 0.4 mm (0.012 to 0.016 in)	± 0.05 mm (± 0.002 in)
Greater than 38 mm (1.50 in)	0.4 to 0.5 mm (0.016 to 0.020 in)	± 0.075 mm (± 0.003 in)

Acceptable

Dimension B This is the general wall thickness.

Dimension C 0.5 to 0.6 mm (0.020 to 0.024 in) This recess is to ensure precise location of the lid.

Dimension D This recess is optional and is generally recommended for ensuring good contact with weld horn.

Dimension E Depth of the weld 1½ to 2 times the width of **B** for maximum joint strength.

Figure 2. Ultrasonic Welding – Energy-Director Joint

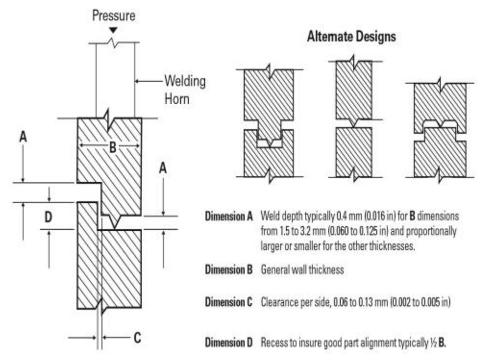
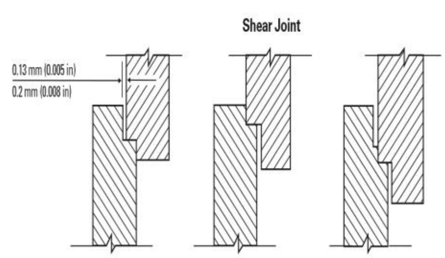


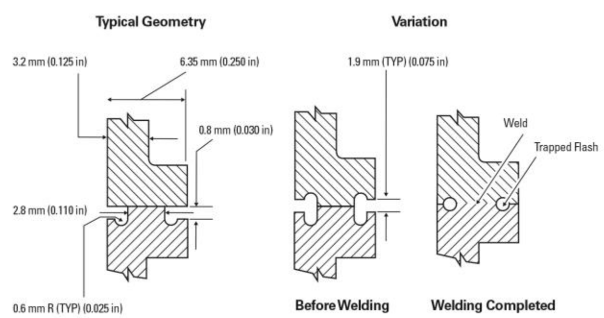
Figure 3. Flash Traps for Shear Joint



The major advantage of vibration welding is the ability to weld large, complex parts—to 0.61 x 0.46 m (2 x 1.5 ft.) in specially designed equipment. The weld area is not restricted to the periphery. Internal surfaces such as dividers or supports are easily welded with proper design and welding fixtures.

Joint and part design, however, must permit unrestricted relative motion in the direction of the reciprocating travel ±0.9 mm (± .035 in) at 240 Hz. If at all possible, the weld joint should be in a single plane. Multi-plane welds are possible, if the appropriate transitions are made between the weld joint planes. The joint plane(s) must always be parallel to the plane of travel. Joints are normally two flat flanges approximately twice the wall thickness. If flash containment is desired, traps may be designed into the joint (**Figure 4**).

Figure 4. Typical Vibration Weld Joint with Flash Trap



As with ultrasonic welding, material moisture content is critical. Parts should be in the dry-as-molded condition for optimal results. Properly designed holding fixtures are essential. Parts must be held securely in relative position and the joint uniformly supported and aligned to assure that there is no loss of reciprocating action.

Spin Welding

The most efficient method for joining circular parts is spin welding. The equipment is relatively simple and the speedy process—around 5 seconds—provides a strong, hermetically sealed bond. As in vibration welding, this process produces a friction weld. One part is held stationary, while the other is rotated. For a proper weld, the rotating part must have a relative joint velocity of 1-6 meters per second (3-20 fps), with a joint pressure of approximately 2 to 4 MPa (290 to 580 psi). Weld time is typically around 2 seconds, followed by a hold time of 0.5 - 2 seconds. If a specific alignment between the parts being welded is required, welding equipment is available that can achieve this.

Joint design, firm welding fixtures and dry material, again, are keys to successful spin welding. Recommended joint designs are shown in **Figures 5 and 6**. Part size is generally limited by joint area—58 cm^2 (9 in^2) is a typical upper limit, though larger parts have been done with special equipment. With proper dimensioning, internal and external joints can be welded simultaneously.

Figure 5. Joint Design for Basic Shapes

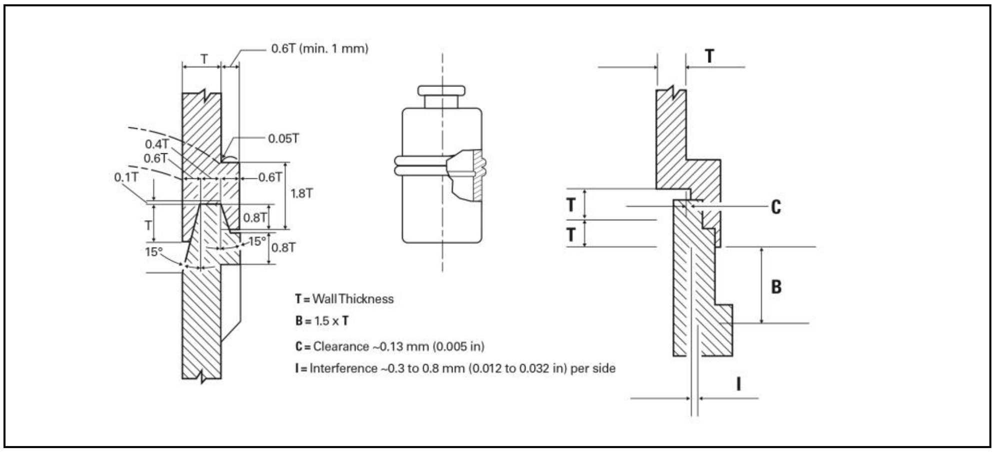
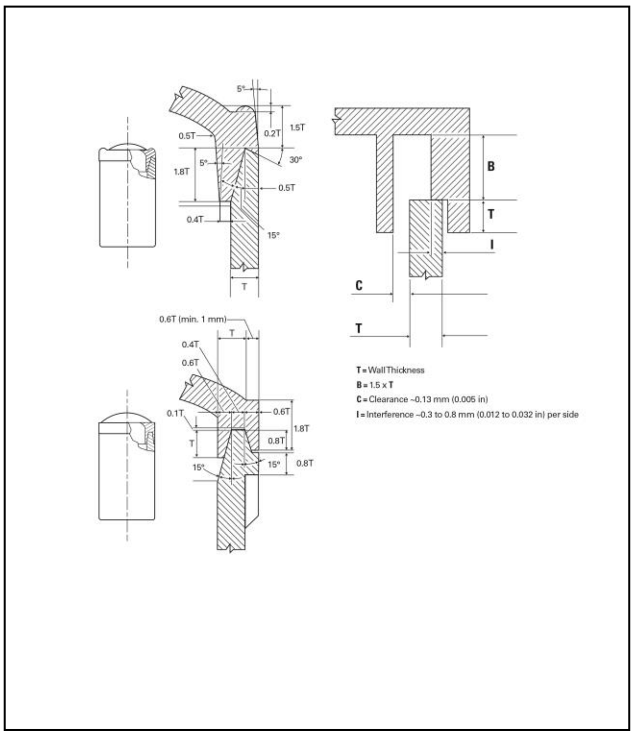


Figure 6. Joint Design for Caps or Bases



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