Chapter 66

Impact Resistant Polystyrene

Heated Tool Welding

IPS

For impact polystyrene (IPS), hot plate welds of the same strength as the parent material were readily achieved. However, the amount of material displaced was large. An essential requirement for the control of material displacement was the use of displacement limit stops. The position of the stops was important, since improved joint strength was achieved for stops set at 1.0 mm, which was the maximum stop position on the equipment used. The weld consolidation period could be limited to <5 seconds as an aid to process efficiency, as both pressure and time had little effect on tensile strength.

It is apparent that sufficient heat soaked material, behind the melt fronts, must be available to provide > 2.5 mm material displacement in the consolidation stage. At a hot plate temperature of 205°C, a minimum of 20 seconds heating time was necessary to provide the required heat soaked material. However, using a hot plate temperature of up to 255°C, a reduced heating time, <15 seconds, would fulfill the requirements of > 2.5 mm displacement in the consolidation state to give joints with high tensile strength values.

Reference: Watson, M., Murch, M., *Recent Developments in Hot Plate Welding of Thermoplastics,* ANTEC 1989, conference proceedings - Society of Plastics Engineers, 1989.

Ultrasonic Welding

Chevron: 6800

Near field ultrasonic welding of impact polystyrene was successful, producing stronger bonds than semicrystalline materials. It was generally found that increasing the weld pressure initially increases the weld strength, with further increases in pressure decreasing strength due to unfavorable molecular alignment. Increasing the weld time increased energy dissipated and strength. Increasing the amplitude of vibration increased the energy dissipated and strength (although not as much as in semicrystalline materials) - with the exception of low amplitudes.

Reference: Benatar, A., Eswaran, R.V., *Near-Field Ultrasonic Welding of Thermoplastics,* ANTEC 1989, conference proceedings - Society of Plastics Engineers, 1989.

Chevron: 6800

Far field ultrasonic welding of high impact polystyrene was successful. The weld strengths improved with increasing pressure, amplitude of vibration at the joint interface, and weld time. For long weld times, the weld strength decreased slightly with increasing weld time due to increased flow resulting in unfavorable molecular orientation.

Reference: Benatar, A., Cheng, Z., *Far-Field Ultrasonic Welding of Thermoplastics,* ANTEC 1989, conference proceedings - Society of Plastics Engineers, 1989.

Dow Chemical: Styron 498 (features: high impact)

This study was designed to identify which resins could be effectively ultrasonically welded to themselves and other resins, and to identify the maximum bond integrity. Besides looking at the weld strength of various thermoplastic resins, this study explores the effects of gamma radiation and ethylene oxide (EtO) sterilization on the strength of these welds. A wide variety of resins used in the healthcare industry were evaluated including: ABS, polycarbonate (PC), polycarbonate/ ABS blends (PC/ABS), styrene acrylonitrile (SAN), thermoplastic polyurethanes (TPU), rigid TPU's (RTPU), high impact polystyrene (HIPS), and general purpose polystyrene (GPPS).

The strength of customized "I" beam test pieces was tested in the tensile mode to determine the original strength of each resin in the solid, nonbonded test piece configuration. Data from this base line testing was used to determine the percent of original strength that was maintained after welding. Only amorphous resins were used in this study. The most commonly used energy director for amorphus resins, a 90° butt joint, was used as the welding architecture.

Every attempt was made to make this a "real world" study. The aim during the welding process was to create a strong weld while maintaining the aesthetics of the part. One of the most important factors in determining whether or not a good weld had been achieved was the amount of flash or overrun noticed along both sides of the joint. Another characteristic of a good weld was a complete wetting of the cross sectional weld area. The problem here, however, was that only clear polymers used as the top piece, allowed the whole weld to be seen.

Almost all resins involved in the study could be welded together with some degree of success (except for thermoplastic urethanes which didn't bond to the polystyrenes). Overall, it apppeared that resin compatibility and the ability to transfer vibrational energy through a part and not similar glass transition temperatures, were the overriding characteristics that lead to the best welds. Although not shown in this study, it should be noted that the ability of a resin to be welded is also a function of the architecture of the ultrasonic weld. Some resins which welded well in the architecture used for this study may not weld well with other architectures.

The HIPS resin tested bonded well to itself, the other polystyrenes, and the low acrylonitrile (AN) SAN grade. As with the other polystyrenes in the study, HIPS did not bond well to the urethanes. It showed limited bonding compatibility to the PC's, the higher AN SAN, and the higher heat RTPU. Examination of these welds after testing showed that the HIPS had melted, but the energy director on these higher Tg materials was still intact (not melted) and was embedded in the HIPS. This would indicate that the HIPS resin became the glue that held the pieces together, and there was limited molecular intermeshing. Overall, the HIPS samples were unaffected by the gamma sterilization although the EtO sterilization did reduce the bond strength somewhat for most of the HIPS resin combinations.

Reference: Kingsbury, R.T., *Ultrasonic Weldability of a Broad Range of Medical Plastics,* ANTEC 1991, conference proceedings - Society of Plastics Engineers, 1991.

Dow Chemical: Styron XL-8035MFD (applications: floppy disk; features: 45 Rockwell M hardness, 85 Rockwell L hardness)

Ultrasonic welding is performed easily with Styron XL-8035 MFD resin using either 20 kHz or 40 kHz welders. In general, ultrasonic benefits and procedures for Styron XL-8035 MFD (microfloppy disk) resin are similar to those of Styron 498 or XL-8023VC. Welding in the energy or time mode is recommended - the energy mode is preferred. Compared with welding ABS MFD parts, HIPS MFD parts may require slight adjustments based on welder set up and fixturing. Whether the MFD is made of ABS or HIPS, the same welding cycle and weld strength can be achieved.

Reference: *Styron XL-8035 MFD High Impact Polystyrene Resin for Microfloppy Diskettes,* supplier marketing literature (301-1607-791X SMG) - Dow Chemical Company, 1991.

Dow Chemical: Styron (manufacturing method: injection molding)

Excellent results are obtained from ultrasonic welding of Styron to itself.

Reference: *Styron Polystyrene Resins For Applications Requiring Impact Resistance,* supplier design guide (301-471-1281) - Dow Chemical Company, 1981.

IPS

The results from ultrasonic lap welds with impact polystyrene show clearly that an optimum welding force exists. The optimum welding force was 200 N at an amplitude of 29 µm. Maximum ultimate breaking forces are only achieved at or near the optimum welding force and cannot be increased any further after an optimum welding time.

The generator energy and thus also the change in damping are not in themselves process parameters that can be used to monitor the weld seam quality. In order to reliably monitor the quality of the weld seam strength during the welding process, it is necessary to control the welding force, the welding time and the amplitude and/ or displacement.

Reference: Netze, C., Michaeli, W., *Correlation of Welding Parameters, Energy Conversion and Mechanical Weld Seam Properties for Ultrasonic Welding*, ANTEC 1991, conference proceedings - Society of Plastics Engineers, 1991.

Adhesive and Solvent Bonding

Dow Chemical: Styron 6000

Parts molded from Styron 6000 Series resins can be solvent bonded together with such solvents as methyl ethyl ketone, acetone, ethylene dichloride, perchloroethylene and trichloroethylene. Up to 15% (by volume) of unmodified polystyrene can be added to these solvents to increase viscosity.

Solvent and adhesives are applied by dipping, roller coating, brushing, spraying, flow guns and other means. For better appearance and strength, tongue-and-groove, lap and V-groove joints are preferred over butt joints.

Reference: *Styron 6000 Ignition Resistant Polystyrene Resins*, supplier marketing literature (301-01673-192R SMG) - Dow Chemical Company, 1992.

Dow Chemical: Styron (manufacturing method: injection molding)

Molded parts made of Styron resin may be solvent welded to each other with a number of effective solvents. Methylene chloride is commonly used if a fast drying solvent adhesive is desired. Methyl ethyl ketone or a mixture of 30 % methyl methacrylate monomer and 70 % butyl acetate are effective as medium drying solvent adhesives. Up to 15 % of Styron resin granules can be dissolved in any of these solvents to add body to the adhesive.

Many of the common rubber-based adhesives may be used to bond parts made of Styron resin to a variety of other materials such as metal, wood, and glass. Adhesives should be chosen carefully to prevent premature failure of the composite due to stress cracking.

Reference: *Styron Polystyrene Resins For Applications Requiring Impact Resistance*, supplier design guide (301-471-1281) - Dow Chemical Company, 1981.