Chapter 64

Polystyrene

Welding

BASF AG: Polystyrol

Welding preference is given to ultrasonic techniques.

Reference: *Polystyrol Product Line, Properties, Processing,* supplier design guide (B 564 e/2.93) - BASF Aktiengesellschaft, 1993.

Spin Welding

PS

In spin welding, irrespective of the material involved, braking the spin with an abrupt stop always gave a higher weld quality than continuous braking. Weld quality initially increases with increasing friction time. Once phase III (steady state friction phase) is reached, a longer friction time no longer gives increased strength. The highly brittle standard polystryene can be friction welded with difficulty. Maximum welding factors (strength of weld/ strength of bulk material) of 0.45 were attained with low axial pressure (0.05-1 MPa).

Reference: Tappe, P., Potente, H., *New Findings in the Spin Welding of Plastics,* ANTEC 1989, conference proceedings - Society of Plastics Engineers, 1989.

Ultrasonic Welding

PS (note: with regrind polystyrene)

The addition of regrind polystyrene to the virgin polystyrene decreases both the tensile strength and elongation. Comparing the tensile strength of 32.9 MPa for virgin polystyrene to a tensile strength of 23.7 MPa for 100% regrind, a decrease of 27% was observed. The elongation was reduced as well, from 1.8% for virgin polystyrene to 1.4%.

The effect of the regrind polystyrene on the strength of the ultrasonically welded joint follows the same trend as that observed in the mechanical properties. The shear strength of the virgin polystyrene is 30.2 MPa, which decreases to 21.3 MPa for the 100% regrind samples. Comparing the 29% reduction of the shear joint strength, to the 27% reduction of the tensile strength (because of the increase of regrind from 0% to 100%), it could be concluded that the effect of regrind polystyrene on the ultrasonic welding process is mainly due to the change of mechanical properties of the polymer. In testing, the addition of regrind polystyrene does not significantly affect the ultrasonic welding process.

In this investigation, the data show that the greatest decrease in both tensile and shear strength occurs when the amount of the regrind polystyrene exceeds 25%. Therefore, some recommendations for the production process may be based on this data.

Other experiments have indicated that the variation of the amount of the regrind polystyrene has only a slight change on the viscosity of the polymers. This may be considered as one of the reasons that the regrind polystyrene does not significantly alter the ultrasonic welding process.

As to the reduction of the strength of the regrind polystyrene, it it most likely because the regrinding process introduces some unavoidable contamination and also creates a change as the polymer chains are shortened.

Reference: Infantino, B., *Ultrasonic Welding of Regrind Plastics,* ANTEC 1994, conference proceedings - Society of Plastics Engineers, 1994.

Adhesive and Solvent Bonding

BASF AG: Polystyrol

Polystyrol articles can be bonded together with the aid of solvents, e.g. toluene or dichloromethane, but this applies only to articles produced from the same material.

Reference: *Polystyrol Product Line, Properties, Processing,* supplier design guide (B 564 e/2.93) - BASF Aktiengesellschaft, 1993.

Dow Chemical: Styron 615APR (features: transparent)

In tests conducted to evaluate the bondability/compatibility of plasticized PVC tubing to rigid, transparent thermoplastics, none of the solvent combinations with polystyrene came close to meeting the accepted criteria for bond strength. Assembly was easy except with acetone, where the tubing was difficult to insert and the luers were immediately cracked upon contact with the acetone. Straight methylene chloride and straight MEK produced slight crazing. The solvents which worked best with polystyrene were either straight cyclohexanone or 1,2-dichloroethane.

Reference: Haskell, A., *Bondabilitly/Compatibility of Plasticized PVC to Rigid, Transparent Thermoplastics,* ANTEC 1989, conference proceedings - Society of Plastics Engineers, 1989.

Adhesive Bonding

PS Huntsman: XC2245-HIY-9100

A study was conducted to test for bond strength on a representative matrix of commonly used plastics and the adhesives best suited to them. For many of the plastics evaluated, the effect of polymer composition on bond strength was evaluated by compounding plastic formulations with each of the most commonly used additives and fillers for that plastic; common grades were used for the remaining resins. The effect of each additive and filler was determined by comparing the bond strength achieved with the specially compounded formulations to that of the neat plastic. In addition, the effect of surface roughening and chemical treatment of the plastic surface on bond strength was examined.

The block-shear (ASTM D 4501) test was chosen as the test method because it places the load on a thicker section of the test specimen that can withstand higher loads before experiencing substrate failure. In addition, the geometry of the test specimens and the block-shear fixture helps minimize peel and cleavage forces in the joint. How well the block-shear test method reflects the stresses that an adhesively bonded joint will experience in real world applications should be considered. Also, limitations on the data due to the variety of additives and fillers used by different companies should not be ignored.

Prism 401, when used in conjunction with Prism Primer 770, achieved the highest bond strengths on PS, typically substrate failure. Prism 401 and Super Bonder 414, both cyanoacrylate adhesives, and Loctite 3105, a light curing acrylic adhesive, normally achieved the second highest bond strengths. Black Max 380, a rubber toughened cyanoacrylate adhesive, and Depend 330, a two-part no-mix acrylic adhesive, achieved the lowest bond strengths. The addition of an impact modifier additive increased the bondability of PS with cyanoacrylate and light curing acrylic adhesives.

Surface Treatments

The use of Prism Primer 770, when used in conjunction with Prism 401, caused a statistically significant increase in the bondability of all the formulations of PS evaluated, except for the roughened PS, where Prism Primer 770 caused a statistically significant decrease in its bondability. Surface roughening caused a statistically significant increase in the bond strengths achieved on unprimed PS when using cyanoacrylate adhesives, but had no statistically significant effect when using acrylic adhesives.

Other Information

Polystyrene is compatible with acrylic adhesives but can be attacked by their activators before the adhesive has cured. Any excess activator should be removed from the surface immediately. Polystyrene is incompatible with anaerobic adhesives. Recommended surface cleaners are isopropyl alcohol and Loctite ODC Free Cleaner 7070.

Table 64.1: Shear strengths of polystyrene to polystyrene adhesive bonds made using adhesives available from Loctite Corporation. Values are given in psi and (MPa).[b,c]

Plastic Material Composition (Huntsman XC2245-HIY)		Loctite Adhesive					
		Black Max 380 rubber toughened cyanoacrylate (200 cP)	**Prism 401** surface insensitive ethyl cyanoacrylate (100 cP)	**Prism 401/ Prism Primer 770** polyolefin primer for cyanoacrylate	**Super Bonder 414** general purpose cyanoacrylate (110 cP)	**Depend 330** two-part no-mix acrylic	**Loctite 3105** light cure acrylic (300 cP)
Unfilled resin	4 rms	450 (3.1)	1350 (9.3)	>1750[a] (>12.1)[a]	500 (3.5)	350 (2.4)	1350 (9.3)
Roughened	32 rms	750 (5.2)	>800[a] (>5.5)[a]	750 (5.2)	800 (5.5)	350 (2.4)	1350 (9.3)
Antioxidant	0.06% Irganox 245 0.02% Irganox 1076	450 (3.1)	>1450[a] (>10.0)[a]	>3300[a] (>22.8)[a]	1250 (8.6)	350 (2.4)	1350 (9.3)
UV stabilizer	0.31% Tinuvin 328 0.31% Tinuvin 770	450 (3.1)	1350 (9.3)	>1750[a] (>12.1)[a]	500 (3.5)	350 (2.4)	500 (3.5)
Impact modifier	15% Kraton D1101	900 (6.2)	>2100[a] (>14.5)[a]	>1750[a] (12.1)[a]	>2300[a] (>15.9)[a]	150 (1.0)	>2000[a] (>13.8)[a]
Flame retardant	4% Saytex HBCD-SF 1% Antimony Oxide	450 (3.1)	750 (5.2)	>1750[a] (>12.1)[a]	>850[a] (>5.9)[a]	50 (0.3)	1350 (9.3)
Lubricant	0.5% Zinc Stearate	450 (3.1)	>1200 (>8.3)[a]	>1750[a] (>12.1)[a]	500 (3.5)	50 (0.3)	1350 (9.3)
Colorant	4% CP204230	450 (3.1)	450 (3.1)	1500 (10.3)	500 (3.5)	350 (2.4)	1000 (6.9)

[a] The force applied to the test specimens exceeded the strength of the material resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.
[b] All testing was done according to the block shear method (ASTM D4501).
[c] For more information on data presented in this table, contact Loctite Corporation at 800-562-8483 (1-800-LOCTITE). Request the "Design Guide for Bonding Plastics."

Reference: *The Loctite Design Guide for Bonding Plastics*, supplier design guide (LT-2197) - Loctite Corporation.