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Characteristics of Thermoplastics for Ultrasonic Assembly Applications

Basic Principles

The basic principle of ultrasonic assembly involves conversion of high-frequency electrical energy to high-frequency mechanical energy in the form of reciprocating vertical motion, which, when applied to a thermoplastic, can generate frictional heat at the plastic/plastic or plastic/metal interface. In ultrasonic welding, this frictional heat melts the plastic, allowing the two surfaces to fuse together; in ultrasonic staking, forming or insertion, the controlled flow of the molten plastic is used to capture or retain another component in place (staking/forming) or encapsulate a metal insert (insertion).

Thermoplastics can be ultrasonically assembled because they melt within a specific temperature range, whereas thermosetting materials, which degrade when heated are unsuitable for ultrasonic assembly.

Weldability of any thermoplastic depends on its stiffness or modulus of elasticity, density, coefficient of friction, thermal conductivity, specific heat and T_m or T_g.

Rigid plastics exhibit excellent welding properties because they readily transmit vibratory energy. Soft plastics, having a low modulus of elasticity, attenuate the ultrasonic vibrations, and as such are more difficult to weld. In staking, forming or spot welding, the opposite is true. Generally, the softer the plastic, the easier it is to stake, form or spot weld.

Resins

Resins are classified as amorphous or crystalline.

Ultrasonic energy is easily transmitted through amorphous resins and as such, these resins lend themselves readily to ultrasonic welding. Amorphous resins are characterized by random molecular arrangements, and a broad melting temperature range that allows the material to soften gradually before melting and flow without prematurely solidifying.

Because the molecular structure in the crystalline resins attenuate a great amount of energy, crystalline resins do not readily transmit ultrasonic energy, and they require higher energy levels than amorphous resins. These resins are characterized by a high, sharply defined melting point that causes melting and resolidification to occur rapidly. For these reasons, when welding crystalline resins, higher amplitude and energy levels should be used, and special consideration should be given to joint design.

Near-Field / Far-Field Welding

Before discussing welding characteristics, the difference between near-field and far-field welding must be understood. Near-field welding refers to welding a joint located 1/4 inch (6 mm) or less from the area of horn contact; while far-field welding refers to welding a joint located more that 1/4 inch (6 mm) from the horn contact area. The greater the distance from the point of horn contact to the joint, the more difficult it will be for the vibration to travel through the material, and for the welding process to take place.

The differential, if any, in the melt temperature of the materials being welded should not exceed 30 degrees F (17 degrees C), and the materials' molecular structure should be compatible; i.e.: blends, alloys, copolymers, and terpolymers. Moisture content, mold release agents, lubricants, plasticizers, fillers, reinforcing agents, regrinds, pigments, flame retardants, and resin grade are all variables that can influence weldability.

Variables Influencing Weldability

The moisture content of parts molded from resins that are hygroscopic (moisture absorbent) can be problematical. Nylon (and to a lesser degree polycarbonate and polysulfone) present most of the problem, and parts molded in these resins should be stored in sealed polyethylene bags with an appropriate dessicant immediately after molding. If moist parts are welded, the escaping vapors may cause voids and fissures in the molten material resulting in a weld of poor integrity.

Mold release agents such as zinc stearate, aluminum stearate, fluorocarbons and silicones are not compatible with ultrasonic welding. If it is necessary to use a mold release agent, the paintable/printable grades that permit painting and silk screening should be considered. Other release agents should be removed with either TF Freon for crystalline resins or a 50/50 solution of water and liquid detergent.

Lubricants, whether waxes, stearates or fatty esters, reduce intermolecular friction within the polymer and inhibit the ultrasonic assembly process. However, since they are generally dispersed internally, their effect is usually negligible.

Plasticizers, which usually impart flexibility and softness to a resin can interfere with a resin's ability to transmit vibratory energy. FDA-approved plasticizers do not present as much of a problem as metallic plasticizers, but experimentation is recommended.

Although fillers and reinforcing agents such as glass and talc can increase the ultrasonic weldability of soft thermoplastics considerably, they should be judiciously used. When additive content exceeds 10%, premature horn wear may result, and specially treated steel or carbide-faced titanium horns might be required. When filler content approaches 35%, there may be insufficient resin at the surface to attain hermetic seals; and when filler content exceeds 40%, insufficient plastic is present at the interface to form a positive bond. Reinforcement composed of long glass fibers are always more problematical than reinforcement composed of short glass fibers.

Ultrasonic assembly is one of the few methods that permits regrinding of parts, since no foreign substance is introduced into the resin. Ultrasonically assembling parts which have been manufactured from regrind parts presents no problem provided that the percentage of regrind is not excessive, and the plastic has not been degraded. Regrind limitations suggested by the resin suppliers should be observed.

Although most pigments do not interfere with the ultrasonic process, some oil-based colorants can adversely influence weldability. Non-oil based pigments should be used.

Flame retardants greatly affect the weldability of thermoplastics and the effects of these various additives should be investigated experimentally prior to resin selection. The grade of resin can have a significant influence on weldability. There is a great difference between injection/extrusion grades and cast grades. Their molecular weight, melt temperature and modulus of elasticity are quite different. Injection/extrusion grades should only be used with injection/extrusion grades, and cast grades should only be used with cast grades.

Chart I
Characteristics of Thermoplastics

MATERIAL	SPOT WELDING	STAKING SWAGING	INSERTING	FIELD OF WELDING NEAR	FIELD OF WELDING FAR
AMORPHOUS:					
ABS	E	E	E	E	G
ABS/POLYCARBONATE	G	G	G	G	F
ABS/PVC	G	G	F	G	F
ACRYLIC	G	F	G	G	F
ACRYLIC MULTI-POLYMER-XT POLYMER	G	G	G	G	F
ACRYLIC/PVC	G	G	F	G	F
ACRYLIC – IMPACT MODIFIED	F	F	P	F	P
BUTADIENE – STYRENE (BDS)	G	G	G	G	F
CELLULOSICS – CA, CAB, CAP	P	G	E	P	–
MODIFIED PHENYLENE OXIDE	E	E	E	E	G
POLYARYLATE	F	F	G	G	F
POLYCARBONATE	G	F	G	G	F
POLYETHERIMIDE	G	G	E	E	G
POLYSTYRENE, G.P.	F	F	G	E	E
POLYSTYRENE, IMPACT MODIFIED	F	F	G	G	P
PVC – RIGID	F	G	E	P	P
PVC – FLEXIBLE	P	–	–	P	–
SAN – NAS – ASA	F	F	G	E	E
STYRENE-MALEIC-ANHYDRIDE	E	E	E	E	G
SULFONE POLYMERS	F	F	G	G	F
CRYSTALLINE:					
ACETAL COPOLYMER	F	F	G	G	F
ACETAL HOMOPOLYMERS	F	F	G	G	F
FLUOROPOLYMERS	–	–	–	P	–
NYLON	F	F	G	G	F
PC-PET	G	G	E	E	G
POLYESTER – PBT	F	F	G	G	F
POLYESTER – PET	F	F	G	G	F
POLYETHERETHERKETONE	G	G	E	E	G
POLYETHYLENE (LDPE, HDPE)	G	F	G	P	P
POLYETHYLENE (UHMW)	–	–	–	–	–
POLYMETHYLPENTENE	G	F	E	F	P
POLYPHENYLENE SULFIDE	F	P	G	G	F
POLYPROPYLENE	E	E	G	F-P	P

E - Excellent **G - Good** **F - Fair** **P - Poor** **– Not Suitable for Ultrasonic Assembly**

Chart II
Compatibility of Thermoplastics

	ABS	ACRYLIC MULTI POLYMER	ACETAL	ACRYLICS	CELLULOSICS	ABS/POLYCARBONATE	ABS/PVC	BDS	MPPO	NYLON	PC/PET	POLYARYLATE	POLYCARBONATE	POLYESTER-PBT	POLYESTER-PET	POLYETHERTHERKETONE	POLYETHERIMIDE	POLYETHYLENE	POLYPROPYLENE	POLYSTYRENE	PVC	SAN	ATYRENE-MALEIC-ANHYDRIDE	SULFONES
ABS	■	●		■		●	●	●														●	■	
ACRYLIC MULTI POLYMER	●	■		●		●	●															●		
ACETAL			■																					
ACRYLICS	■	●		■		●	●															●	■	
CELLULOSICS					■																			
ABS/POLYCARBONATE	●	●		●		■	●						●										●	
ABS/PVC	●	●		●		●	■														●		●	
BDS	●							■												●			●	
MPPO									■											●				
NYLON										■														
PC/PET											■		●		●									
POLYARYLATE												■												
POLYCARBONATE						●					●		■										●	
POLYESTER-PBT														■										
POLYESTER-PET											●				■									
POLYETHERTHERKETONE																■								
POLYETHERIMIDE																	■							
POLYETHYLENE																		■						
POLYPROPYLENE																			■					
POLYSTYRENE								●	●											■		●	●	
PVC							●														■			
SAN	●	●		●																●		■	●	
ATYRENE-MALEIC-ANHYDRIDE	■			■		●	●	●					●							●		●	■	
SULFONES																								■

■ Denotes compatibility

● Denotes some compatibility, but not all grades and compositions are compatible.

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Printed in U.S.A. 1C/06/11