



Ultrasonic Welding of Plastics

R&D Center

I . Plastics welding(bonding)

1. Welding and Bonding

- (1) Welding : Extra adhesive is not required.
- (2) Bonding : Extra adhesives and bonding agents are required.

2. Types of welding

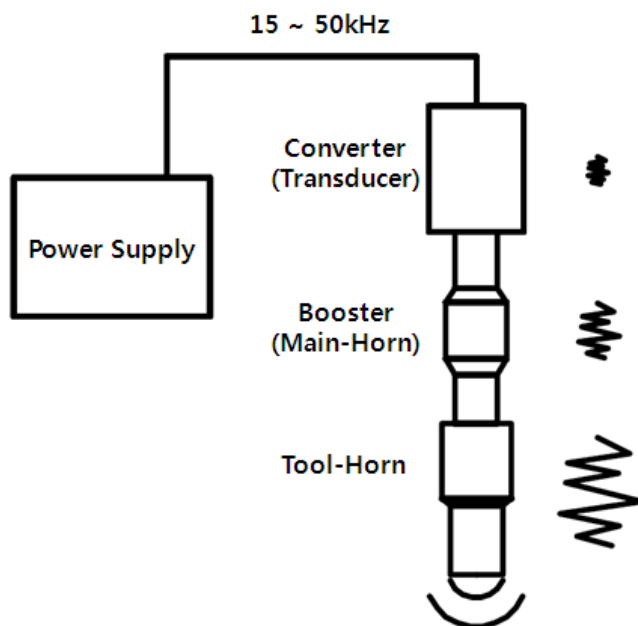
- Ultrasonic welding
- Ultrasonic heat staking
- Hot-plate welding
- Spin welding
- Vibration welding
- Laser welding

3. Types of bonding

- Solvent and adhesive bonding
- Radio frequency bonding
- Electromagnetic bonding

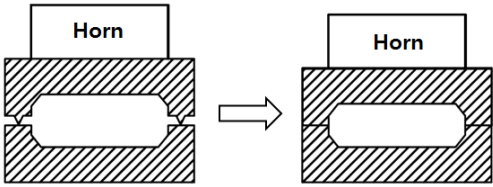
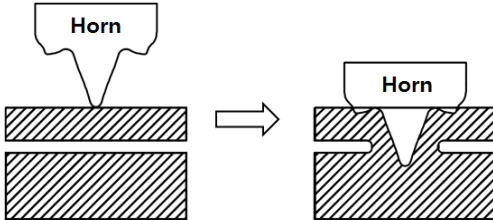
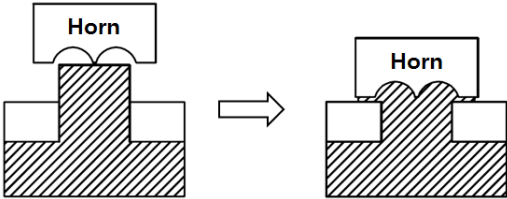
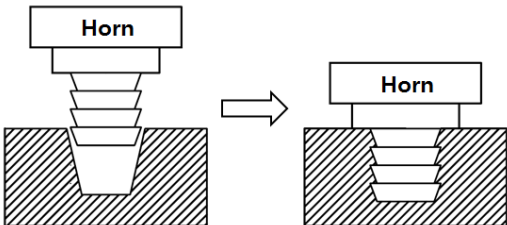
4. Technology of plastics ultrasonic welding and processing

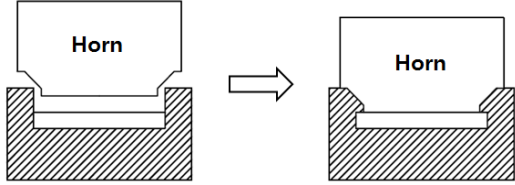
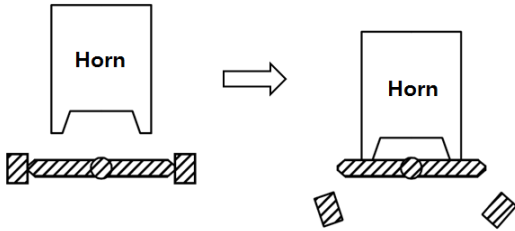
- (1) Principle of ultrasonic welding



The ultrasonic welding machine converts incoming power(110V(220V) 60/50Hz) to electric energy using an oscillator. This electric energy is converted to mechanical energy via a converter to create a vibration frequency of 15~70 kHz(normally, 20~40kHz) and the amplitude of the vibration is controlled and pressurized through the horn. The plastics are fused due to the momentary friction heat at the contact surface.

(2) Ultrasonic welding and processing methods

Methods frequently used		
Welding		<p>Most frequently used method. Instant friction heat is produced when is applied ultrasonic vibration to the protrusion on the joint for welding. The plastics melt due to this instant heat to generate strong adhesion.</p>
Spot Welding		<p>Method for joining two plastic boards partially using a miniature hand welding machine not like other test methods such as hole or energy director. Vibrating ultrasonically, the pilot of the spot welding tip passes through the top component. As bottom section is penetrated by tip, the displaced molten plastic flows between the two surfaces into the surrounding interface area and forms a permanent molecular bond. This method is applied to huge plastic parts like automotive snowplow parts, trailers, furniture, etc., or parts when preciseness is required or welding is difficult with standard welding machines.</p>
Staking		<p>Method to assemble plastics and metal. The plastic stud protrudes through a hole in the component to be locked in place. High frequency ultrasonic vibrations from the horn are imparted to the top of the stud, which melts and fills the volume of the horn cavity to produce a head, locking the component in place. Like other methods, concentrate ultrasonic energy and minimize the contact area of horn and plastics stud to reduce welding time.</p>
Inserting		<p>Method to encapsulate a metal component in a thermoplastic part. In ultrasonic insertion, a hole slightly smaller than the insert diameter is either molded or drilled into the plastic part. Ultrasonic vibrations travel through the driven component to the interface of the metal and plastic. Frictional heat is generated by the metal insert</p>

		vibrating against the plastic, causing a momentary, localized melting of the plastic. As the insert is driven into place, the molten material flows into the serrations and undercuts of the insert. When ultrasonic energy ceases, the plastic resolidifies, locking the insert in place. The mold wear problem encountered when the horn contacts the metal insert is alleviated.
Other methods		
Swaging		Method to take on the form of attaching metal or glass to plastics or by plating plastics to metal. After transforming plastics by a specially designed horn, the plastics in contact with the horn melts and is welded by ultrasonic vibration. Plastics like PP(high elasticity), high-back, ABS, PE, Cellulose etc., are used and this technique is applied to vanity cases, tubes, and metal screens.
Gate Cutting		Product is separated by cutting gate and runner. Cutouts are beautiful and many tiny parts can be cut in a short time. A special design is required at the gate cutting parts.

(3) Characteristics of ultrasonic welding

Characteristics	Bad cases
<ul style="list-style-type: none"> - Adhesive is not required. - Momentary welding (0.1 s ~ 1 s) - Clear and no transformation or corruption of product surface. - Cost reduction and mass production - Excellent and rigid welding surface - Easy to use 	<ul style="list-style-type: none"> - Recycled materials are used. - Resin that has differing chemical structure - Foreign substance contamination - Long distance between the horn and the welding plane - Inappropriately designed injection-molded parts

(4) Problems and remedies when welding and spot welding

Problem	Solution
Insufficient welding	Increase welding time.
	Increase welding force.
	Decrease press descending speed.
Too much welding	Decrease welding time.
	Decrease welding force.
Insufficient strength of product	Increase welding time.
	Increase hold time.
	Increase welding force.

	Decrease press descending speed.
Flash(burr)	Decrease welding time.
	Decrease welding force.
	Decrease the size of energy director(weld line).
	Loosen tolerance at joint part.
Scratch on the surface	Decrease welding time.
	Decrease welding force.
	Examine combination of tool horn and main horn.
	Examine if there are scratches on the tool horn.
	Examine the fitting of the horn and product.
	Examine the fitting of jig(fixture) and product.
	Put the shim into the jig.
	Examine if stud(clamped bolt) is loose.
Broken product	Decrease welding force.
	Decrease welding time.
	Decrease press descending speed.
Separation of product or cracking after welding	Increase hold time.
	Decrease welding time.
	Increase welding force.
Overload machine	Decrease welding force.
	Decrease press descending speed.
	Adjust tuner of power supply.
	Examine if the bolt is loose.
	Examine the fitting of tool horn and main horn.
	Deficiency of power supply capacity.
Non-uniform welding of joint parts	Examine the size of product.
	Redesign the energy director(weld line).
	Remake the jig.
	Examine if the parts are fixed tightly to prevent motion during welding.
Non-uniform welding state in same welding condition	Examine the product size.
	Examine the product tolerance.
	Examine the plastics mixture.
	Examine if the air pressure is constant.
	Examine if the voltage is constant.
	Redesign the joint parts(weld line).
	Dry the product(reduce moisture)
Welding product is not aligned.	Examine if the tool horn is aligned with jig.
	Redesign the product size.
	Examine if the jig is fixed tightly.

(5) Problems and remedies when staking

Problem	Solution
Head shape is formed inappropriately	Increase welding time.
	Increase hold time.
	Increase welding force.
Bent boss	Decrease press descending speed.
	Increase welding time.
	Decrease welding force.
Broken boss	Decrease welding force.
	Decrease press descending speed.

Plastic-smeared horn	Increase welding time.
	Decrease welding time.
Lengthy staking time	Decrease welding time.
	Decrease hold time.
	Increase welding force.
	Increase press descending speed.
Non-uniform head shape after staking	Decrease staking groove size.
	Increase boss height.
Too much flash(burr)	Decrease staking groove size.
	Decrease boss height.
	Groove is not aligned to the boss.
Head shape is formed inappropriately and collapsed.	Boss melts and that decreases pressurizing force.
	Decrease press descending speed.
Head is distorted	Decrease welding force.
	Examine alignment of jig and product, product, and horn.
Loose product after staking	Decrease hold time.
	Adjust the height of stopper.
	Increase welding time.
Broken boss root	Round off boss root.
	Align horn and boss.
Plastics flow out from between the product	Inappropriate location of metal parts.
	Use external clamping equipment.
	Adjust welding time.

5. Ultrasonic property of thermoplastic resin

(1) Factors regarding welding property of thermoplastic resin : hardness, modulus, density, friction coefficient, heat conductivity, Tg, etc.,

1) Modulus

- a) High modulus materials : Excellent ultrasonic welding effect of welding due to their ability to transmit ultrasonic energy
- b) Low modulus materials : Poor welding effect for typical welding but good effect for staking or spot welding due to decreased ultrasonic energy.

2) Amorphous and semi-crystalline polymer

- a) Amorphous polymer : Can be welded easily due to its ability to transmit ultrasonic vibrations. Has a broad softening temperature range that allows the material to soften gradually, melt and flow without prematurely solidifying.
- b) Semi-crystalline polymer : Has sharp melting and re-solidification points due to the crystalline structure. This is the result of a very high energy requirement of high power and amplitude on the joint interface.

(2) Direct welding and indirect(transmit) welding

- a) Direct welding : Distance between contact surface of tool horn and joint part is within 6 mm.
- b) Indirect welding : Distance between contact surface of tool horn and joint part is over 6 mm.
- c) The longer the transmission distance, the harder the transmission of ultrasonic vibration energy.

(3) Other factors related with ultrasonic welding property

- a) Moisture content : If hygroscopic parts are allowed to absorb moisture, when welded the water will evaporate at 100 °C, with the trapped gas creating porosity and often degrading the resin at the joint interface.
- b) Mold release agents : Zinc stearate, aluminum stearate, fluorocarbons, silicones, TF, and freon inhibit ultrasonic welding.
- c) Lubricants : Reduces intermolecular friction within the polymer. Since molecular friction is a basis for ultrasonically induced temperature elevation, lubricants can inhibit the ultrasonic assembly process. However, since they are generally dispersed internally, like internal mold release agents, their effect is usually minimal.
- d) Plasticizer : These are added to resins to impart flexibility but can also 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.
- e) Fillers : Fillers like glass and talc enhance the ability of some resins to transmit ultrasonic energy by imparting higher rigidity. However, it is very important to recognize that a direct ratio between the percentage of fillers and the improvement of weldability exists only within a predescribed quantitative range.
 - With many fillers, when filler(especially long glass-fiber) content exceeds 10% the presence of abrasive particles at the resin surface can cause horn and fixture wear. In this situation the use of hardened steel or carbide-faced titanium horns is recommended.
- f) Colorants : Most colorants, either pigments or dyes, do not interfere with ultrasonic assembly; however, occasionally some pigments in which oil is added can influence weldability.

6. Main horn

There are differences between amplitude from a vibrator and amplitude to weld plastics. Main horn controls the amplitude.

(1) Main horn of low amplitude is required

- a) For a large tool horn or tool horn of high amplitude, a high pressurizing force is needed (overload)
- b) Ultrasonic oscillation is difficult to initiate.
- c) Oscillation stops at low pressure.
- d) The product is damaged.
- e) Plastics or hanger fittings are damaged during insertion.
- f) Heat is produced near the horn.

(2) Main horn of high amplitude is required

- a) Vibration energy for welding is low : welding time grows longer or welding results are poor.
- b) Vibration energy passes through welding parts: product is damaged by jig or vibration is transmitted.
- c) Power(70~100%) is needed for a proper oscillator.
- d) Bottom of the boss melts before the edge of the boss melts when staking.
- e) The product is broken due to long welding time.

7. Tool horn

A vibrator has its limit of amplitude. The amplitude of a vibrator is increased primarily by installing the main horn to get amplitude from a vibrator. The amplitude of a tool horn is increased to amplitude to weld plastics.

(1) Shape of horn

a. Exponential type

Rate of expanding cross sectional area is the same on the entire axis, as akin to compound interest.

b. Conical type

Easy-to-process products. Rate of amplitude rarely increases, even though diameter to flange is over 10. Normally, a horn is inserted when amplitude is low and load is high.

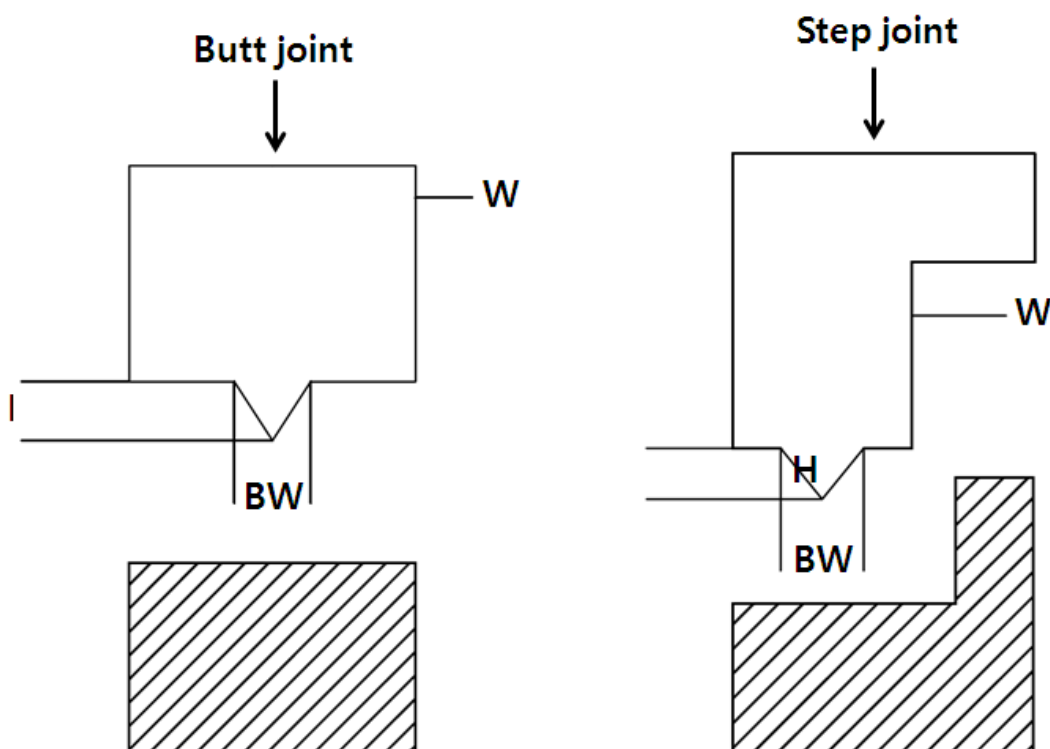
c. Step type

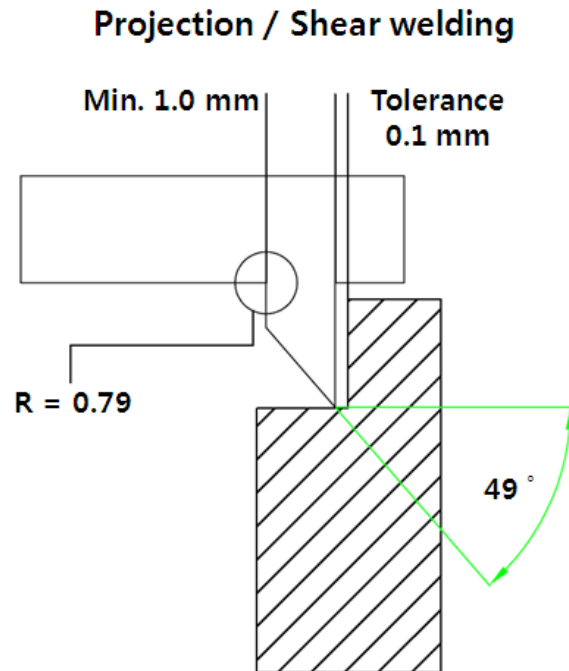
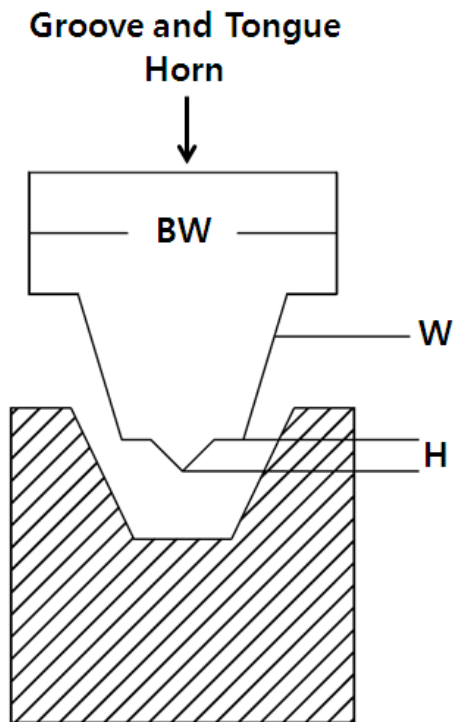
Easy-to-process products and rate of amplitude expansion is the highest among the tool horns.

8. Designing welding parts

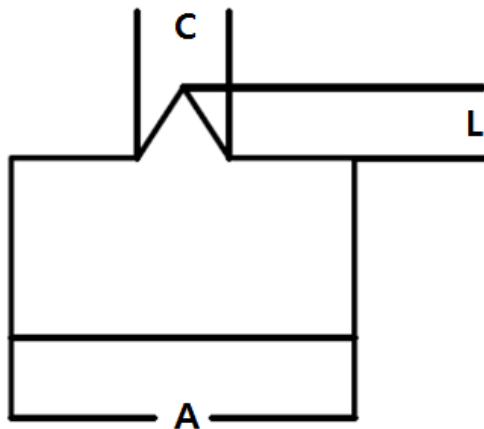
(1) Design of energy director

Consider materials, welding strength, appearance, product shape, tightness, etc., when designing welding parts. Design of ultrasonic welding parts can be divided into design of energy director and shear welding. A mountain-shaped boss is installed at the welding parts to enable early melting via concentrated ultrasonic vibration energy.





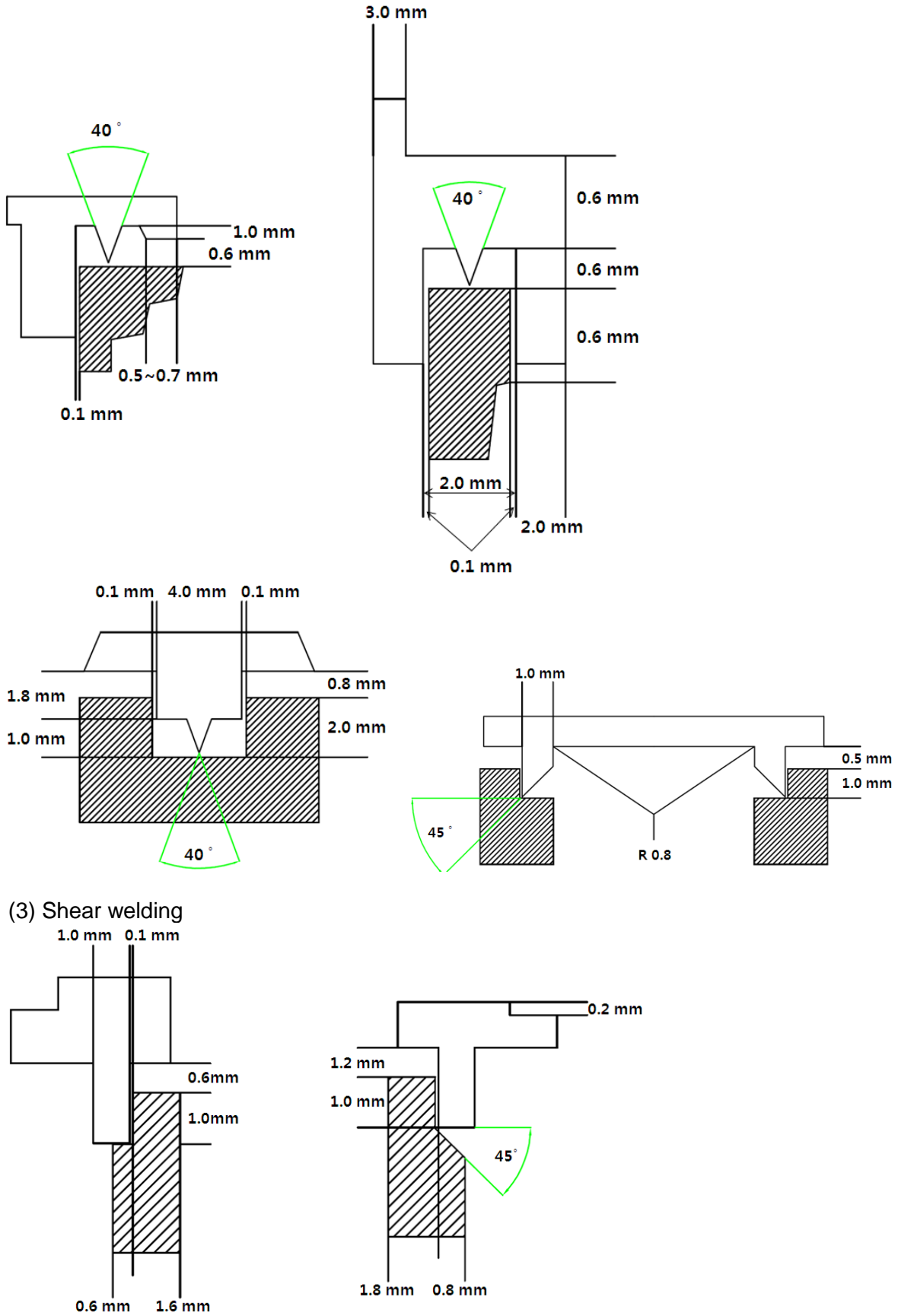
- Selecting size of energy director : Design energy director to 1/10 of the width of the product.



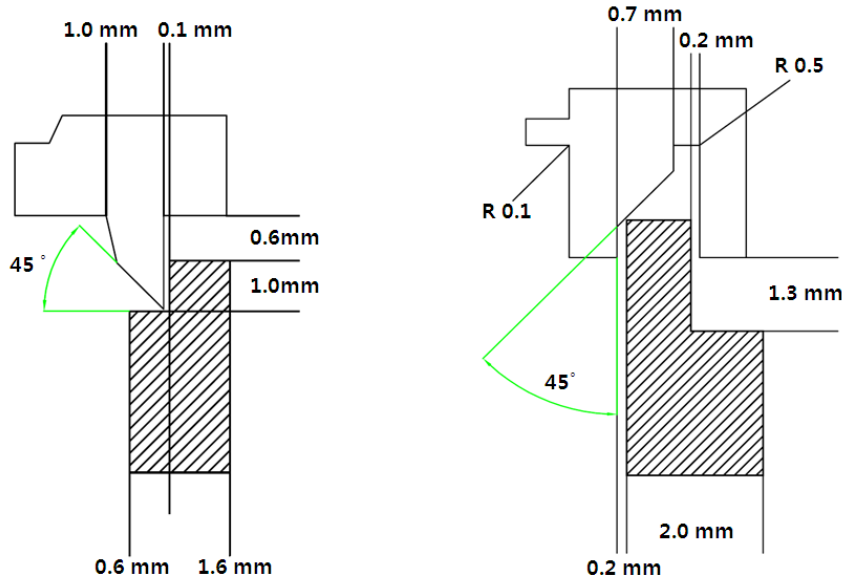
L is 1/10 of A
C is twice of L

(2) Effect of energy director size

- When energy director is too small: Hard to produce energy director when injection molding and melt quantity is insufficient to achieve high welding strength.
- When energy director is too large : Welding can be slow. When designing energy director With a height over 4 mm and width over 0.8 mm, two energy director is recommended.



(3) Shear welding



Transformed shape of energy director is a shear welding.

Design of energy director is inappropriate since resin melts within a melting range and solidifies under the melt temperature. Some parts may solidify before welding.

Strong classified welding is produced by early melting in shear welding. In addition, continuous welding through vertical walk and welding occurs by hardening. Welding parts don't solidify fast because they don't contact air.

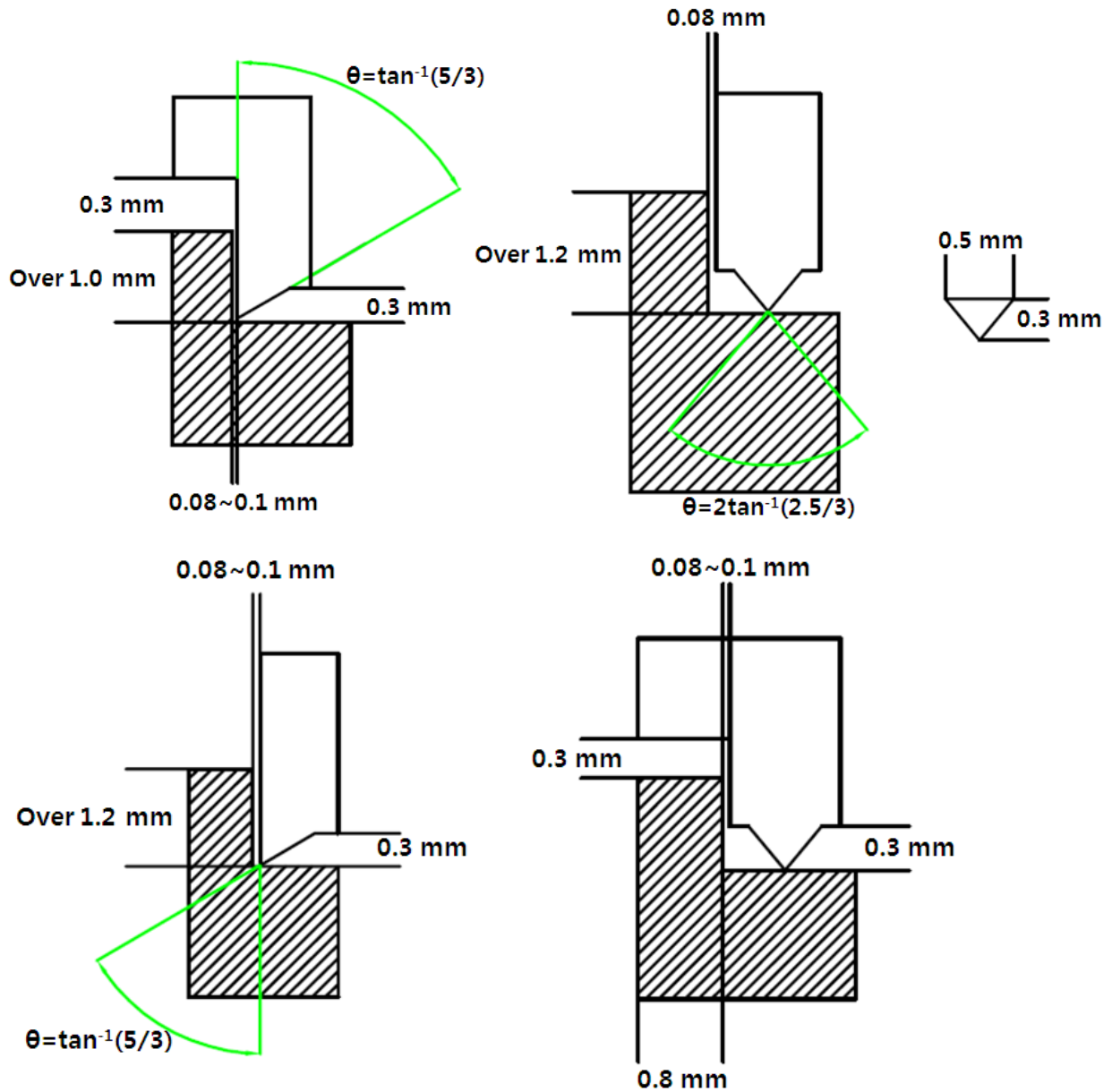
Welding distance can be adjusted and determines welding strength. If you are willing to increase the strength, the distance should be 1.25 to 1.5 times of the wall thickness.

(4) Precautions

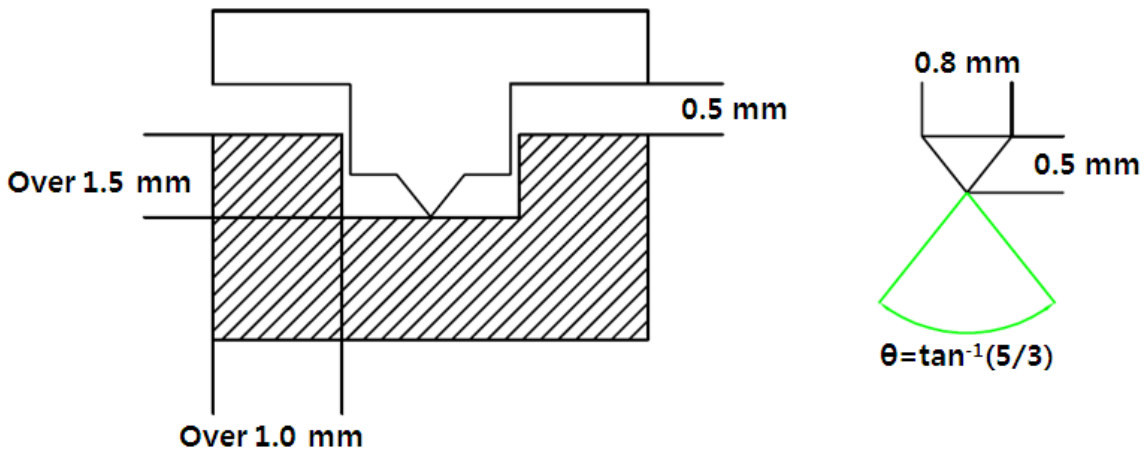
- Recycled materials are not recommended when injection molding.
- Avoid designing gate near energy director.
- Avoid UV coating of energy director joint.
- When drying after coating, injection-molded parts should not be exposed to high temperature too long(Hardening problems).
- Avoid designing lower case at the energy director or edge.

(5) Designing normal energy director

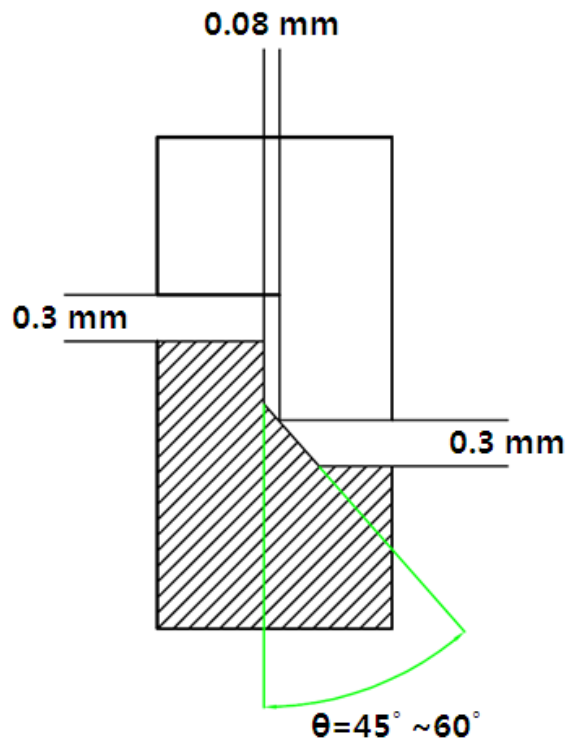
- Battery pack, adaptor energy director



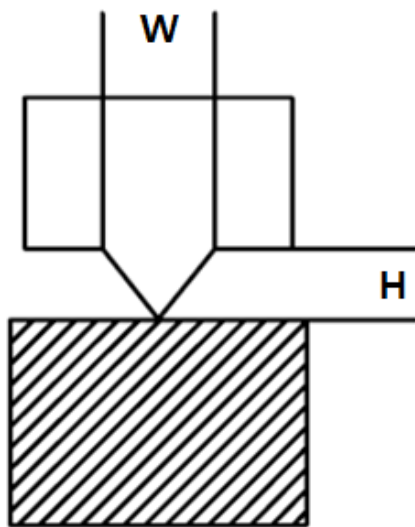
- note book energy director



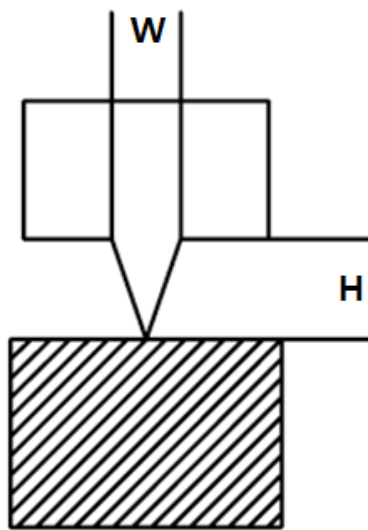
- Seal welding(Different according to material)



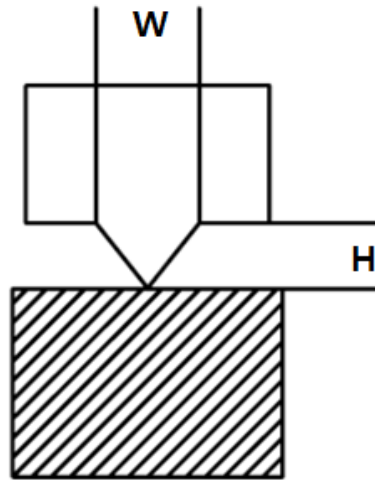
- Avoid designing energy director at edges.
- Normally W should be twice of H but if this is hard to produce, W should be equal or higher than H. (Observe the picture below.)



- Product of Design B has a higher welding property and tensile strength than Product A design under the same welding conditions.



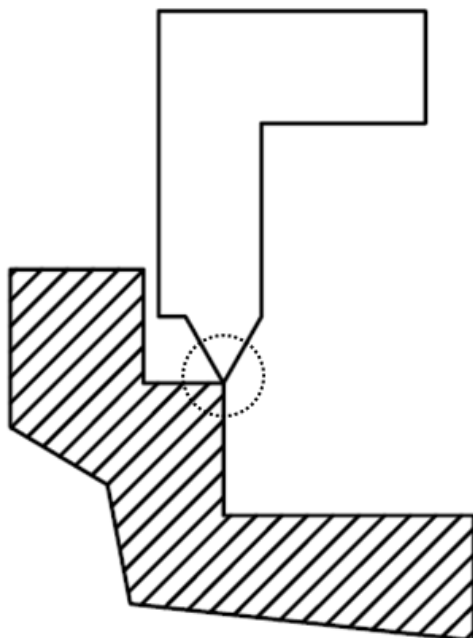
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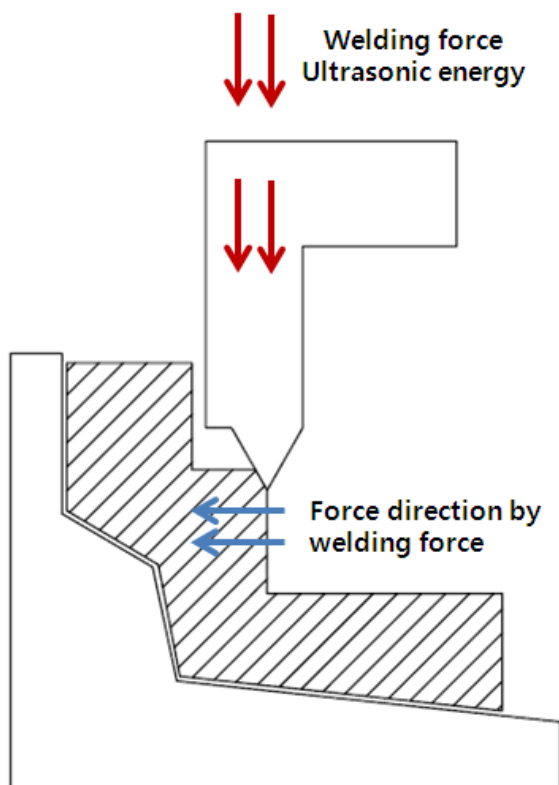
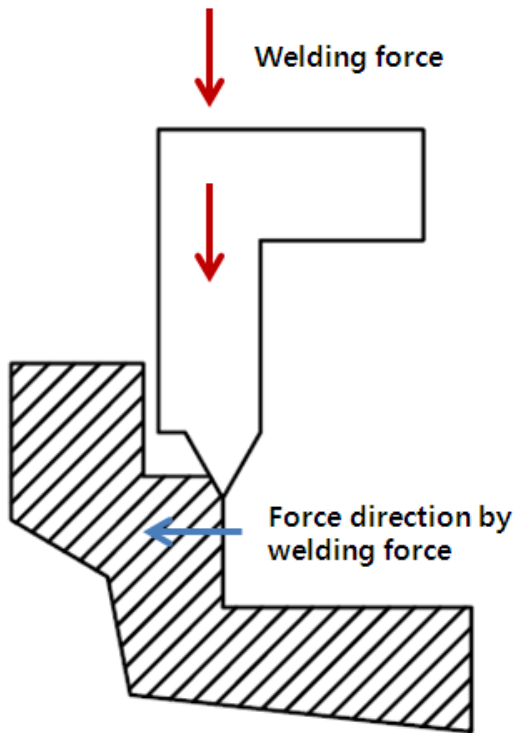


B

(6) Problems when energy director is at the edge

- When pressurizing force of ultrasonic machines is permitted, the gap between the upper and lower case occurs due to a bent edge or energy director. When pressurizing force is small, the same problem occurs due to welding temperature.
- The point where the pressurizing force is concentrated, coating can break or collapse since there is friction with jig due to ultrasonic energy.





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