AESTHETIC ASSEMBLY - THE ART TO ATTRACTIVE BONDING

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Abstract

After carefully molding a beautiful product, nothing is worse than seeing it destroyed during assembly. Every joining process is capable of causing marking, flash, particulate, damage to appendages, or other aesthetic defects. However, with proper part design and processing, a finished weld can be imperceptible or even a cosmetic asset. The art to attractive bonding is specific to each process or type of product. Whether processing parts through ultrasonic, spin, vibration, hot plate, laser welding or thermal staking, methods do exist to improve the appearance of the overall product after bonding.

Introduction

Welding is a common necessity for a wide variety of industries, including automotive, medical, electronics, and consumer products. Whether there are components that must be securely enclosed or the part geometry is too complex to be processed in one piece, a secondary joining step is often required.

A wide variety of products must have aesthetic welds, or bonds. Packaging, especially clamshells, are probably the most prominent example. Some other demanding cosmetic applications are vehicle headlamps and taillights, spoilers, battery enclosures, medical devices, toys, dishware and utensils, electronics housings, facemasks, fencing, furniture, and filters. For these products, and many others, melt flow must be contained, flash or particulate eliminated, tool marks prevented, and any other part damage eradicated.

The methods for preserving cosmetics are as varied as the welding processes available. Each assembly process can produce its' own variety of decorative debacle. Fortunately, for each potential aesthetic issue, there is a solution.

Ultrasonic Welding

Ultrasonic welding uses piezo-electric ceramics that convert electrical current into mechanical motion. High frequency (15 kHz up to 90 kHz) vibrations are transmitted through the plastic part to the joint where intermolecular stress and strain cause melting of the surface of both parts, and welding. Ultrasonic welding is used for a wide variety of applications including clamshells, electronics housings, medical applications, and fabric welding.

Joint Design

One of the most common cosmetic defects that result from ultrasonic welding is flash; melted material that is pushed out of the joint at the weld interface. In addition to being unsightly, this flash can also be a functional defect in certain applications. For example, air or water filter housings usually cannot have flash internally.

Fortunately, flash can be easily avoided through proper joint design. Generally, in production, there is balance between weld strength and amount of flash. In order to get greater strength, more collapse of the joint is required, and more flash is produced. Simply adding a flash trap to the part design, however, can allow sufficient strength with no flash. Figure 1 shows some common ultrasonic joints that can effectively hide flash and produce a strong weld.

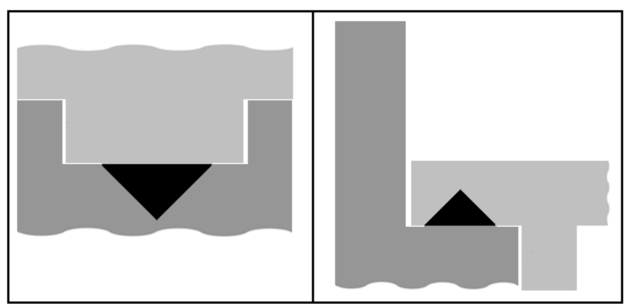

Figure 1: Ultrasonic Joints that Hide Flash

De-Gating

A second common defect with ultrasonic welding is de-gating of small features in the assembly during the weld. Because ultrasonics depends on high frequency vibration of the parts, there is a chance for cracks to form in areas with sharp corners or small cross-sectional areas. Sometimes these cracks are so severe that small features can be complete sheared off, or de-gated.

There are two main ways to prevent this type of damage. Either increase the radii or cross-section of the troubled area, or decrease the amplitude of the process. However, reducing amplitude often has a negative impact on the weld, as it essentially reduces the energy available to weld the parts. Therefore, whenever possible, it is best to eliminate small or fragile features when ultrasonic welding will be used.

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Surface Marking

When welding textured parts, there is a strong possibility that the ultrasonic horn will mar the contact surface. On textured surfaces, there may be shiny places where the texture has been removed during welding. To prevent this occurrence, simply put a layer of thin film between the part and the horn. Figure 2 shows an example of this type of cosmetic flaw.

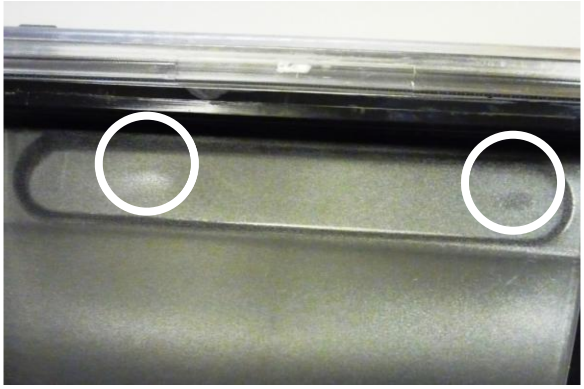

Figure 2: Ultrasonic Welding can cause damage to the parts texture.

Marking can also occur when the horn leaves a residue on the part, see Figure 3. This is most often seen with aluminum horns or with titanium horns that are welding white parts. Using chrome plated aluminum horns is the best way to prevent this type of problem.

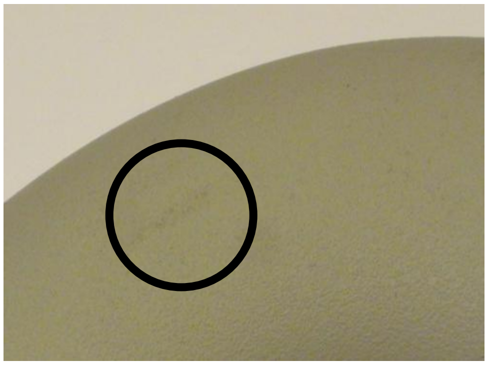

Figure 3: Ultrasonic welding with an aluminum horn can leave residue on the part.

Film & Fabric

As mentioned in the introduction, clamshell packaging is one of the biggest areas where cosmetic assembly is required. Ultrasonic welding is one of the processes most often used for such applications. A wide range of weld patterns have been developed to improve the appearance of such welds. Figure 4 shows some common welding patterns used for clamshells.

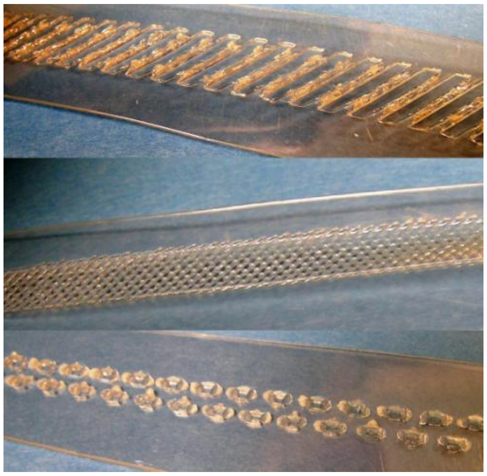

Figure 4: Examples of patterns used to weld clamshells

These same patterns can also be used for welding of fabrics, as is often done for shower curtains, plastic bed sheets, or even clothing. In fact, fabrics can be welded using ultrasonics, very similarly to how they can be sewn, using a rotating anvil under a stationary horn that is operated by a foot pedal. An even wider range of attractive patterns can be used for fabric welding; some are shown in Figure 5 below.

Figure 5: Patterns used to weld film or fabric

Spin Welding

Another common welding process is spin welding. In this process, one of the parts is held stationary, and the other is spun at high revolutions per minute to generate frictional heat at the circular joint. While spinning, the parts are pressed together to form a weld. Spin welding is often used to join pipes, insulated cups or bowls, and filter housings, among others.

Joint Design

The biggest drawback, cosmetically, to spin welding is that it generates a significant amount of flash. Unlike ultrasonic welding, the parts are moving during the weld process, meaning that the melt layer is also in motion.

Subsequently, more melt must be generated to ensure good contact between the parts and a strong weld. Figure 6 shows an example of the type of flash generated during spin welding.

Figure 6: Spin weld flash

Therefore, for every application where aesthetics is a concern, the part should be designed to hide that melted material, some weld joints that can hide flash are shown in Figure 7. With out-of-round parts, however, it is often not possible to contain the flash simply by using a different joint design. In these instances, a secondary flash removal step is required.

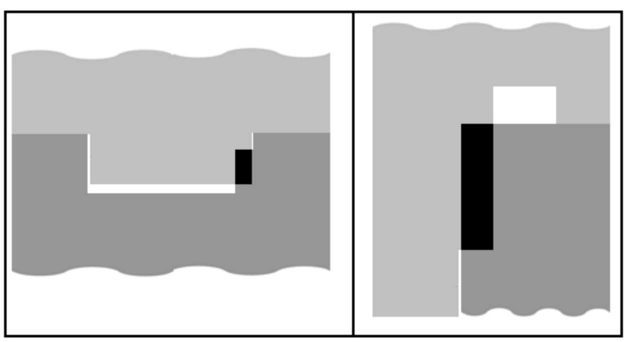

Figure 7: Spin weld joint designs that can hide flash while providing a strong weld.

Particulate

In addition to solid pieces of displaced material, spin welding tends to generate particulate (tiny particles of plastic dust). Most times, this can be blown out after welding, but sometimes it cannot be present at all (as with medical or food industry applications). Reducing the rotational spin welding speed reduces the generation of particulate. Additionally, soft materials like polypropylene tend to produce much more particulate during welding, as shown in Figure 8.

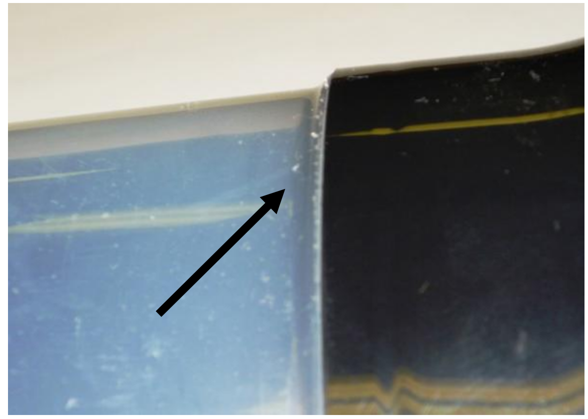

Figure 8: Spin welding particulate

Tooling Marks

Like most other welding processes, there is the possibility of leaving tooling marks on the parts. Typically, this occurs on the upper part when it is not securely held in place using designed driving features. Tooling marks occur when the upper part slips in the tool. When the fixture is made of urethane, this can cause black marks on the parts. When it is made from stainless steel or aluminum, it can leave gouges in the parts, see Figure 9.

Figure 9: Spin welding tooling marks

To avoid this type of marking, it is essential to provide driving features on the part itself. A "driving feature" is simply some type of protrusion or depression on the upper part upon which the upper tool can apply rotational force. In addition, the parts should have relatively consistent external dimensions.

Vibration Welding

Vibration welding is one of the most often used welding processes for large parts, such as vehicle headlamps and taillights, glove boxes, intake manifolds, fencing, and even furniture. In this process, one part is held stationary while the other is vibrated horizontally on top of it at low frequency (120 Hz - 240 Hz) and high amplitude. During this vibration, the upper part is also pressed down on to the lower part to create the weld.

Joint Design

Vibration welding depends on the movement of large amounts of melted material to generate a weld. Therefore, for this process as well, the joint design is critical for flash containment. With the proper design, a strong flash free weld can be achieved consistently. Figure 10 diagrams some joint designs that can produce a strong weld with no flash.

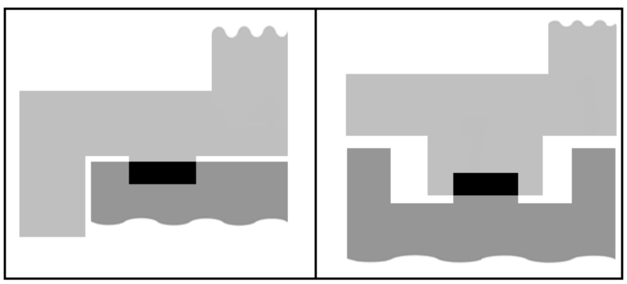

Figure 10: Vibration joint design diagrams

De-Gating

As with ultrasonic welding, the movement of the parts during vibration weld can cause de-gating of small features. The high amplitude used in vibration welding causes excess stress on large projecting features. De-gating is especially likely to occur when the base of the feature has a small cross-sectional area or sharp corners.

Tooling Marks

Vibration welding is similar to spin welding in that driving features on the part are required to prevent tooling marks. In the absence of such features, a knurl pattern may be used to grip the part. The use of a knurl, however, will cause abrasions on the part, as shown in Figure 11.

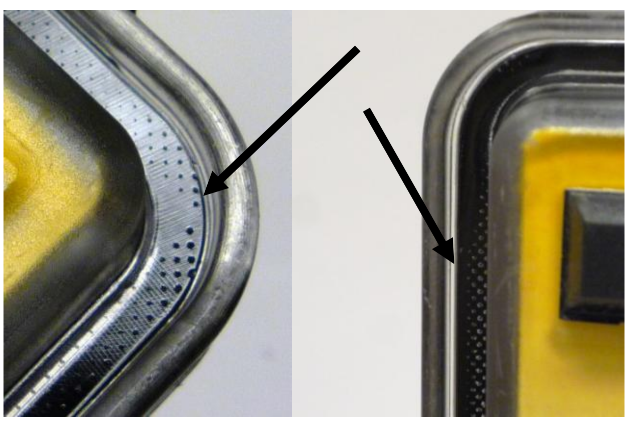

Figure 11: Vibration welding tools often use knurling to grip the parts.

If such marking is not acceptable a urethane upper tool combined can sometimes be used to prevent scratches on the part. Often, a vacuum must be used with urethane tooling to provide sufficient holding force. Whatever tooling material is used, the parts must still be kept as dimensionally consistent as possible.

Hot Plate Welding

In hot plate welding, the two parts to be joined are pressed against or brought into close proximity of a heated surface to generate a melt layer, then pressed against each other to complete the weld. In this style of welding, the joint may be contoured quite extensively and strong hermetic welds are generally achievable. Nothing can be captured inside the parts, however, as any internal components would be damaged by the hot plate. Hot plate welding is often used for large pipes or tanks.

Joint Design

Although hot plate welding generates a lot of flash, it is the most controlled, good-looking flash of any weld process. The melted material pushed of the joint when the two parts are pressed together forms a very nice rounded line that can almost look as if it was designed to be there, this can be seen in Figure 12. However, if the double line of melt does not suit the application at hand, it can be hidden with a change of joint design.

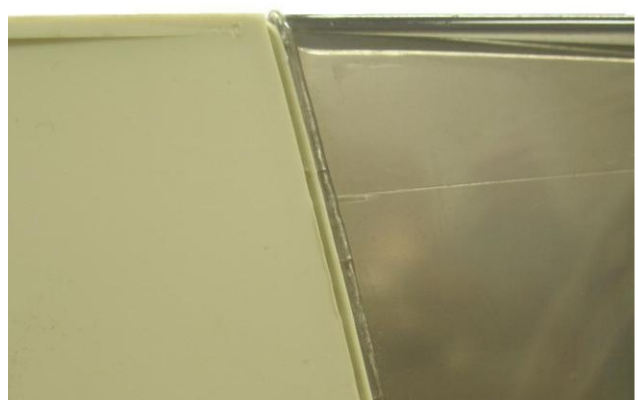

Figure 12: Hot plate flash can look very controlled and nice

Out-Gassing

One of the unique potential cosmetic issues with hot plate welding is out-gassing. When plastic is heated, it emits gasses that can discolor the parts when they are welded, especially on metalized surfaces. The effects of out-gassing are identified in Figure 13. This can be eliminated by applying a vacuum to one of the parts to extract the fumes before they can cause any discoloration or degradation.

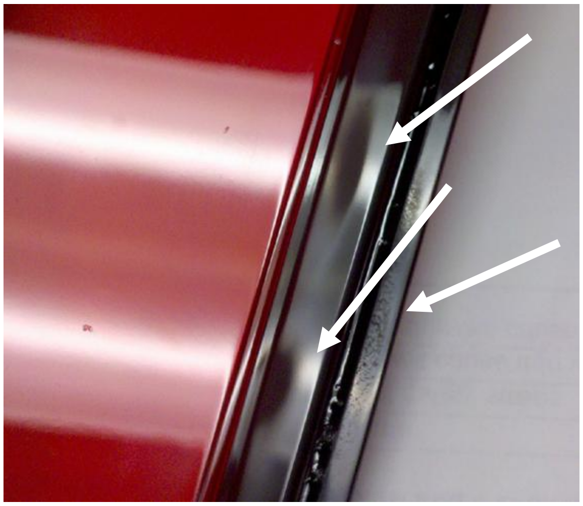

Figure 13: Hot plate out-gassing

Warping

Due to the high heat input used in hot plate welding, the parts can be warped during welding. The best way to prevent this is to use thicker part walls. Excess warping can also be avoided by using vacuums and clamping in the tooling to keep the parts in the correct shape during the weld.

Laser Welding

One of the newest polymer joining processes is laser welding and is growing in popularity, particularly for medical applications. This assembly method uses a focused laser beam to heat the weld joint. The two parts are simultaneously pressed together to create the weld. Laser welds are known for being very clean; flash and particulate free. Laser welding never causes de-gating of features and generally never causes warping. Still, for some components, there is potential for cosmetic defects.

Surface Degradation

If improperly set up, there is a chance that surface degradation will occur during welding. This happens if the top part absorbs too much of the laser energy or if the bottom part absorbs too little. This can be somewhat adjusted for by changing the focal point of the laser, but it is best avoided by choosing the materials with good laser welding properties at the outset.

Burning

The greatest potential for aesthetic flaws in an established process is marring from dirt or dust that is burned by the laser during the weld. Any dust in the path of the laser will absorb the weld energy and cause a disparity in the weld. To prevent this, it is important to maintain the cleanliness of the lens and the weld joint.

Burning can also appear in the process set-up phase as over-welding. An example of over-welding by laser is shown in Figure 14. To resolve this issue, decrease wattage to lessen the laser energy or increase the travel speed of the laser. In some systems, over-welding can be eliminated by adjusting the focus point of the laser so that it is further from the part.

Figure 14: Laser over-welding causes burns at the joint

Thermal Staking

Thermal staking is a method of mechanically bonding two parts by melting and reforming one of the parts to contain the other. Most often, a post on the part with the lower melting temperature is melted and formed into a dome shape to hold in the second part, similar to a rivet. Thermal staking is frequently used to contain circuit boards or to replace screws on consumer products.

Stake Design

The most common cause of unattractive stakes is improper post or tool detail design. It is vital that the staking detail has the same volume as the unformed post. If it is too small, excess material can be pushed out around the base of the stake. If it is too larger, the detail will be only half-formed and uneven in appearance. Figure 15 shows two of the most common staking detail design.

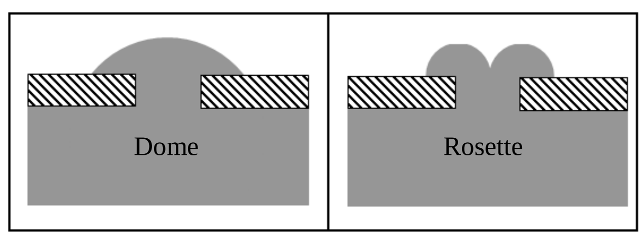

Figure 15: Thermal staking design diagrams

Sticking

Even if the post and staking detail are properly designed, however, there is a chance that the formed dome can be marred if the melted material sticks to the thermal tool. This is especially common with soft materials, like polyethylene. Happily, it can easily be avoided through temperature modulation and the use of post cool. Figure 16 shows the type of stringy wisps of material that can be left behind when the parts sticks to the thermal tool.

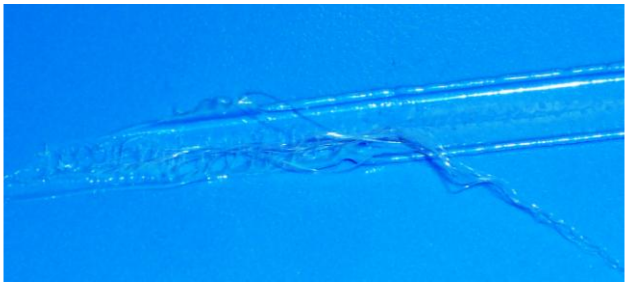

Figure 16: Thermal sticking

Conclusion

If an application must be beautiful, then it is best to begin considering the assembly method early in the design process. Most of the common cosmetic defects can be avoided with proper part design. Planning for aesthetic assembly in these early stages will help allow a widened processing window in production and reduce reject rate.

However, if a part is already in production without having planned for the welding process, do not panic. There is plenty that can be done to prevent unsightly flash, marking, or other defects. Figures 17-20 show some examples of attractive welds.

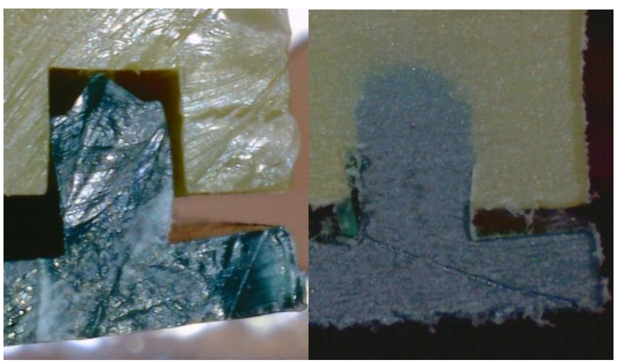

Figure 17: A well-designed ultrasonic joint results in a strong, flash free, weld

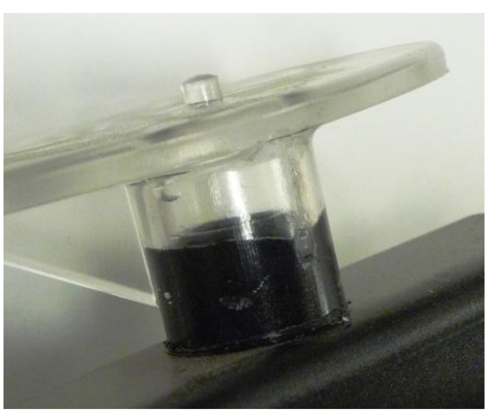

Figure 18: An attractive spin weld, free of tool marking, particulate, and flash

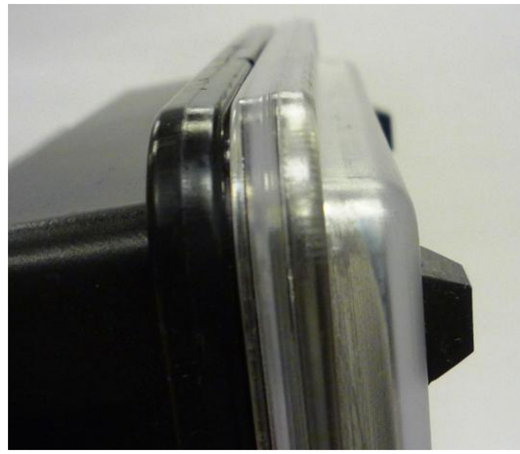

Figure 19: A properly designed vibration joint shows no flash

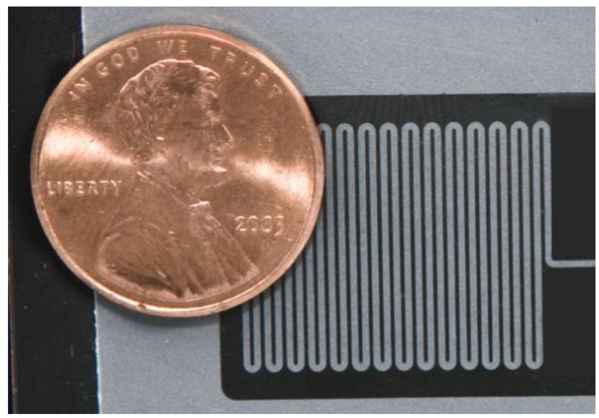

Figure 20: Laser welding is one of the cleanest joining methods available. Photo courtesy of Leister Corporation.

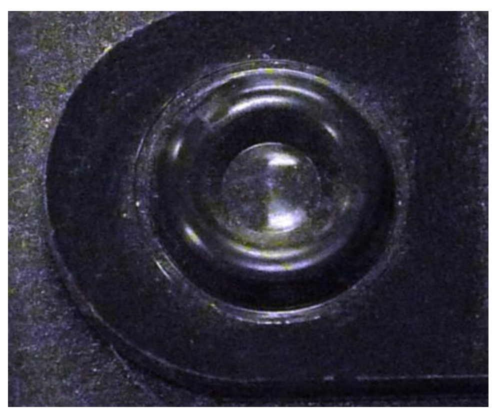

Figure 21: A nicely formed thermal stake