An Introduction To Vibration Welding

A Telsonic Plastics Joining Technology

PLASTIC WELDING | METAL WELDING | CUTTING | CLEANING | SIEVING

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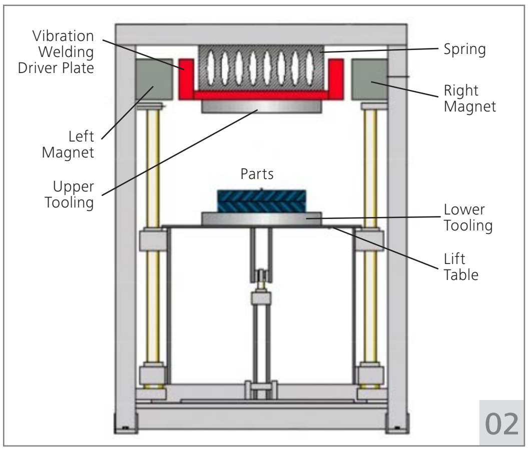
The choice of joining technology in any application is influenced by a range of factors including material combinations, the size of the component, its geometry, production volumes and of course any functional requirements.

As a technology leader in plastics joining, Telsonic has developed a range of ultrasonic welding systems and modules which are used widely on many different thermoplastic materials, especially on small and medium sized components, where the process operates at high speed. Vibration welding, on the other hand, is also ideally suited to a range of thermoplastic materials, but capable of joining large components or those which have a three dimensional, stepped, or continuous profile. This informative article by Jochen Bacher, President of TELSONIC Ultrasonics Inc. explains the principles and benefits of Vibration Welding.

Ultrasonic And Vibration Welding – Comparing The Processes

Vibration welding is effectively a friction welding process which generates heat at the mating surface of two parts, through relative motion of the surfaces. This differs from the ultrasonic welding process, where the heat is created from a combination of friction between the surfaces and inner-molecular movement at frequencies of 15 kHz to 70 kHz and movement measured in microns. By comparison, vibration welding is defined by frequencies of between 100 Hz and 300 Hz and associated amplitudes of between 0.75 mm to 2 mm, (0.030 inch to 0.080 inch). Depending on the pressure applied during the welding cycle, typically weld times range from 2 to 10 seconds.

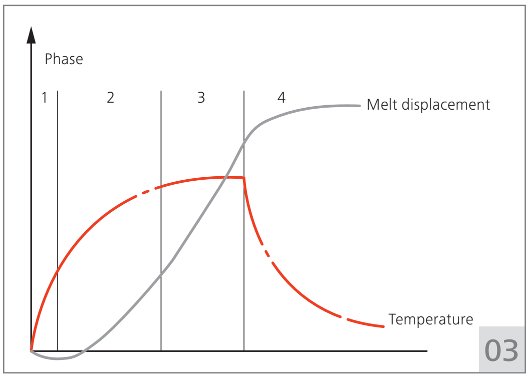


01 Infrared preheating

02 Vibration welding principles

The Vibration Welding Process Is Defined In Four Separate Phases

Phase one	The vibration of the rigid parts creates friction which generates heat at the joint interface, but the material is still in a solid state
Phase two	The glass transition temperature is reached, and viscous flow occurs. Heat is generated by displacement of molten polymer. Movement of the parts toward each other begins (melt down)
Phase three	The melt transition reaches a steady phase at which the melt temperature of the material is reached and the parts starting to bond with the molded plastic. The melt is flowing laterally, and weld penetration increases linearly with time
Phase four	The vibration stops and a sufficient hold time to cool the weld under pressure is introduced. Weld penetration continues because the clamping pressure causes the molten polymer to flow until it solidifies



03 Relationship between melt displacement and melt temperature through the different vibration welding phases

It is also important to understand the relationship between melt displacement and melt temperature through the different vibration welding phases. To achieve good weld strength the vibration welding time needs to be long enough to be within phase three, where there is linear melt displacement. In addition, the hold time needs to be long enough to allow for any displacement of material once the vibration stops.

Materials – Amorphous Versus Crystalline

Amorphous and semi-crystalline plastics are both high-temperature polymers. The difference between the two lies in their molecular structure. Amorphous Thermoplastics include mostly translucent plastics such as: Polymethyl methacrylate (PMMA/Acrylic), Polystyrene (PS), Polycarbonate (PC), Polysulfide (PSU), Polyvinyl chloride (PVC), Acrylonitrile butadiene styrene (ABS) and Polyetherimide (PEI). These polymers have a randomly ordered molecular structure that lack a rapid melting point. The result is that amorphous materials soften gradually as the temperature increases.

Unlike amorphous thermoplastics, semi-crystalline plastics have a highly ordered molecular structure with defined melt points. Common semi-crystalline materials are Polyethylene (PE), Polypropylene (PP), Polybutylene terephthalate (PBT), Polyethylene terephthalate (PET) and Polyetheretherketone (PEEK).

Whilst amorphous materials soften gradually when the temperature rises, semi-crystalline plastics do not. Instead, they remain solid until a specific amount of heat is absorbed. The materials then quickly change into a low viscosity liquid. This melting point is generally higher than the upper range of amorphous thermoplastics.

Welding Dissimilar Materials

Vibration welding is able to join dissimilar materials by melting the thermoplastic and creating a mechanical lock between dissimilar materials. Generally, weld times are 1 to 3 seconds for amorphous and 3 to 10 seconds for semi-crystalline plastics.

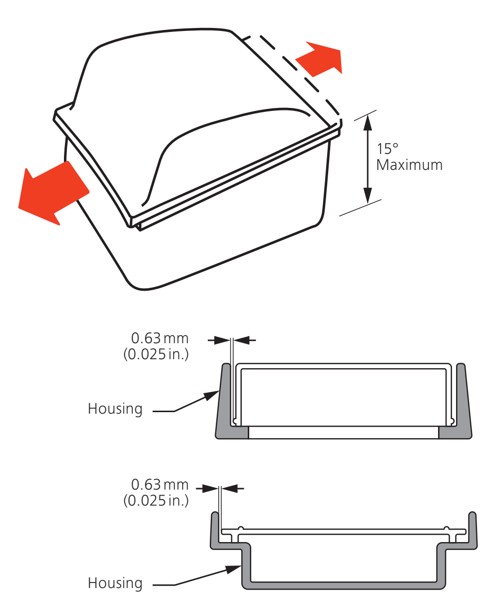
The weld pressure required is dependent upon the specific material, part design, and how the part is fixtured. Usually, less pressure is needed for amorphous material. Some materials change rapidly from their solid state to a melt condition, which indicates the need to lower the pressure. Most state-of-the-art machines allow pressure profiling to accomplish better weld quality by adjusting the weld pressure during the weld cycle.

Designing For Success

For vibration welding to be successful the following basic rules need to be implemented in the part design. The weld flange must be dimensioned to allow space for 0.8 mm (0.030 inch) amplitude using high frequency between 250 and 300 Hz, and up to 2 mm (0.080 inch) on low frequencies between 100 to 150 Hz. The weld surface in the vibration direction needs to be flat, however, good welding results are still possible with a maximum of a 15-degree angle.

The sketches below illustrate a butt joint design for vibration welding with a flange butt joint, ribbed flange butt joint, and a thermo-formed butt joint with a return flange.

The melt displacement will result in the presence of flash on the outside of the weld joint. The physical appearance of flash is very different depending on the material. Some materials tend to produce flash which has a long, "fuzzy" appearance, whilst others produce flash as debris. To accommodate flash most part designs include a "flash trap". Often, prototype welds will be required to determine the optimum design that will eliminate the appearance of flash. The size of the "flash trap" should be at least 30 % greater than the calculated weld displacement. The integration of IR pre-heat into the vibration welding process has shown major improvements on flash appearance especially with clear amorphous thermoplastics.



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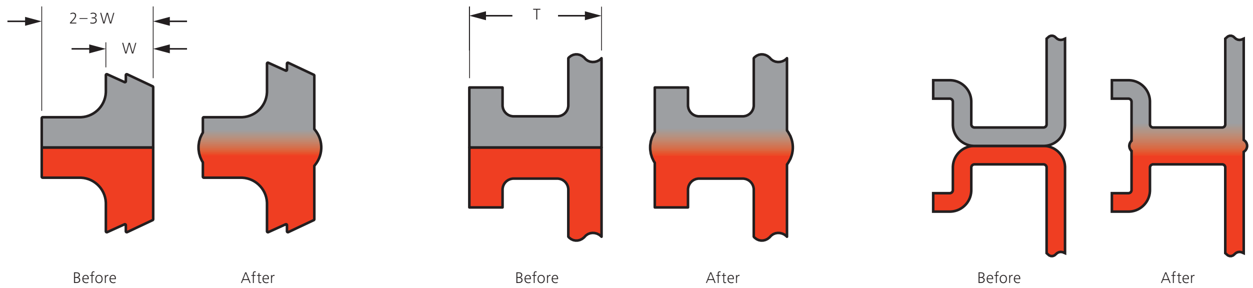

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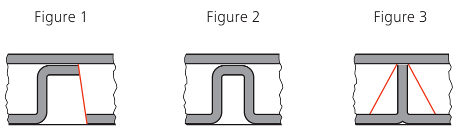
Additional Design Requirements

When welding internal ribs, support for the flanges will be required, especially if they are not aligned with the direction of vibration. The most efficient way is to support ribs such as this using the vibration tooling as shown in figures 1 and 2 below. If, however the design does not allow for these features then support ribs need to be incorporated into the moulded part to stabilise the wall, as shown in figure 3. To design the parts successfully to implement these design features, all parameters such as material, potential for fixturing the part, and part design need to be investigated.



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04 For vibration welding to be successful, basic rules need to be followed and implemented in the part design

05 A butt joint design for vibration welding with a flange butt joint, ribbed flange butt joint and thermoformed butt joint with a return flange

06 If welding internal ribs, support of the flanges is needed especially if they are not in vibration direction

Versatile Areas Of Application

The versatility of the vibration welding process can be seen in the wide range of applications and market sectors which have adopted the technology. Many automotive components, such as instrument panels, spoilers, engine covers, air intakes and light clusters are all joined using vibration welding. Other sectors which use vibration welding include white goods and garden products where parts such as washing machine drums, chain-saw housings and even plastic logistics pallets rely on this technology for their manufacture.

Summary

The many advantages and benefits of vibration welding can be seen in the table below. As for any technology, there are some areas of limitation, and for vibration welding, these are generally restricted to the shape of the welding surface, thin wall sections and internal ribs can sometimes be difficult to weld, and the sound level means that acoustic enclosures are required. The technology also requires a higher level of investment.

Advantages Of Vibration Welding

- Ability to weld complex and irregular shapes
- Welding of large parts
- High strength welds and hermetic seals
- Multiple parts can be welded at a time
- No additional material needed
- Little surface preparation needed
- Can be used to encapsulate other parts
- Parts can be handled immediately after welding
- High process reliability
- High production rate
- Quick tool changeover

Telsonic offers a comprehensive range of vibration welding systems which are available with hydraulic or electric servo operation. Welding modes include depth & time and it is possible to save and analyse welding results. The systems, which feature safety circuits and sound insulation housings, offer optional infrared pre-heating technology and are also capable of multi-stage welding.

07 Vibration welding is a versatile process, capable of being used for a wide range of applications. Introducing IR pre-heat into the vibration welding process delivers major improvements on flash appearance, especially with clear amorphous thermoplastics, such as the automotive lens example shown here

08 Telsonic has partnered with Daeyoung to deliver the best of both worlds in plastics joining

09 Jochen Bacher, President, TELSONIC Ultrasonics Inc.