

INFRAWELD®, THROUGH-BEAM WELDING AT THE IR SPECTRUM

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Abstract

Engineers may choose from multiple plastic joining methods when contemplating assembly, and although light energy may not be at the top of the list of choices...in some cases it should be. The InfraWeld process, offered by Extol, Inc. of Zeeland, Michigan, harnesses infrared (IR) light energy for through-beam welding. Engineers have successfully implemented the process in many challenging and highly sensitive applications across multiple industries. One example, bonding head-impact countermeasures (HIC) and wire retention clips to the B-surface of automotive headliners, reduces weight and cost by eliminating adhesives. The automotive industry has utilized this exceptional technology in other applications such as attaching noise, vibration, and harshness (NVH) pads to interior trim panels, and assembling taillight inner lenses to bezels. The medical device industry has embraced the InfraWeld process to eliminate adhesives in applications such as simultaneous, full perimeter, through-beam welding of concentric thermoplastic tubes.



Figure 1. InfraWeld module

Introduction

Many proven technologies exist for assembling plastic components. Each process has strengths and weaknesses in its ability to robustly join various geometries and material compositions. Some well-known traditional methods include:

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

These familiar technologies heat plastic to a semi-molten state and with controlled pressure and displacement, produce a welded joint or re-form the surface with a shaped tool. With each of these methods, heat transfer occurs primarily through conduction, convection, or radiation. Conduction and convection are the most widely applied modes of heat transfer in plastics joining processes. However, radiation is impressively effective, too.

Radiation heat transfer is the same type of heat transfer that occurs when one feels warmth while standing near a fire or in the rays of sunshine. Heat energy radiates from warmer objects to the cooler objects. In the previous examples, radiation heat transfer occurs because the temperature of the fire and sun is significantly higher than the temperature of one's skin.

The InfraWeld process utilizes infrared radiation emitted from a technical grade halogen lamp. Infrared energy is comprised of electromagnetic waves in the range of 750 nm–1 mm, which is outside of the spectrum of wavelengths of visible light from 400 nm–750 nm.

In the InfraWeld process, infrared energy is used to bond a transparent or translucent material to a compatible opaque material with through-beam welding. The subject material pigment and properties affect its absorptivity or transmissivity. The absorption of the infrared energy heats the plastic to a molten state, enabling the molecular bonding of compatible materials. The InfraWeld process was derived from InfraStake®, a previously developed technology that uses focused infrared light energy as the heat source to form or stake a molded plastic boss or stud.

The InfraWeld process differs from laser welding. Lasers emit light waves that are monochromatic, coherent, and collimated, which produces energy intensely focused on a small point [1]. However, the InfraWeld process heats with a range of wavelengths and the electromagnetic waves are not in phase or collimated. These performance differences offer a complimentary set of light energy technologies for plastics joining applications.

Anatomy of an InfraWeld module

The standard InfraWeld module's key components consist of: the body, the lamp assembly, the reflector, and the concentrator. The InfraWeld body is an aluminum cylinder which houses the main components. It is typically mounted to a short-stroke air cylinder via a mounting adaptor attached to the back of the body. The body also captures a molded power cable connector and air fitting. These provide power for the lamp and a pneumatic connection for both weld pressure and cooling air flow.

The lamp, which is the infrared energy source, is installed into the lamp holder, which contains a portion of the electric circuit. These items comprise the lamp assembly and are attached to the reflector. The reflector surrounds the lamp and directs the infrared energy toward the concentrator. An O-ring, affixed to the base of the reflector, provides an internal seal to contain positive air pressure.

The concentrator is placed over the end of the body of the InfraWeld module, capturing the reflector and lamp assembly internally. It is locked in position by a dowel and hook arrangement. The concentrator is designed to focus the infrared light at the desired bond location.

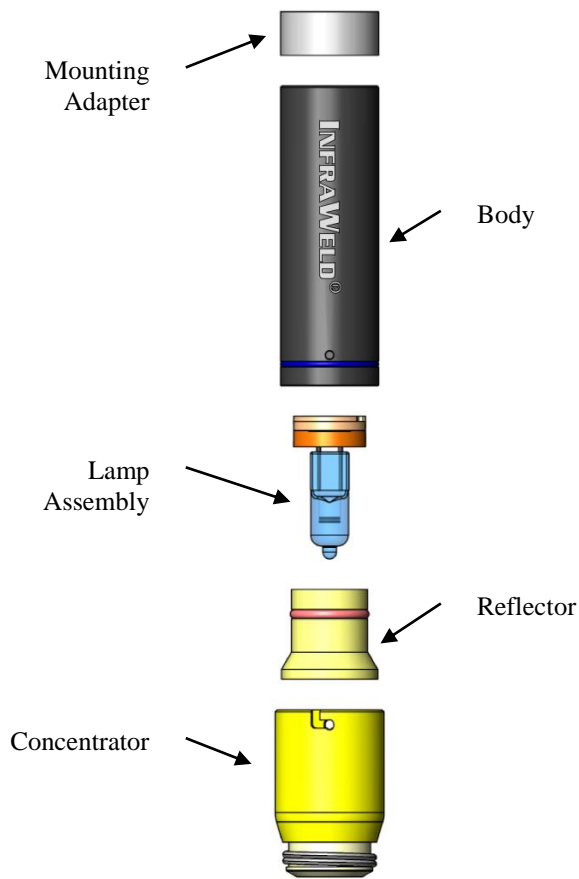


Figure 2. Exploded view of InfraWeld module

The overall design allows the InfraWeld module to be quickly disassembled without tools. The concentrator is removed by rotating it and pulling it off of the body, and the reflector simply pulls straight out of the body as it is retained by the friction between the O-ring and the body.

Process Overview

The InfraWeld process can be described in four basic steps:

1. Clamping
2. Heating
3. Bonding
4. Cooling

Clamping

A consistent challenge in plastic assembly is properly positioning the components of an assembly during the joining process. Plastic parts are often warped or differ slightly from optimum CAD dimensions. In the assembly equipment, the parts can often be correctly positioned and clamped together near a joint, but not directly at the joint. A distinct advantage of the InfraWeld process is that clamp force is applied directly by the concentrator, securing parts together precisely at the bond location.

Heating

Once the sub-assembly is securely clamped together, the heating phase of the process is executed. Sufficient heat, by means of infrared radiation, is typically generated through the utilization of a 12-V, 100-W, technical grade, halogen lamp. The lamp emits both visible light and invisible, infrared light. The work is performed by the emission of infrared light. In the through-beam welding process, the infrared light is transmitted through the transparent or translucent material of the top surface and absorbed by the opaque material of the second surface at the interface between the two materials. The energy absorbed by the opaque material heats the interface to a semi-molten state and through the application of controlled pressure, the surfaces are bonded.

Bonding

As the surfaces are heated to a semi-molten state, a means of applying controlled pressure is required to assure material bonding. Four different methods of applying controlled pressure can be used with the InfraWeld process. The correct method is determined by the application details. The common methods are air pressurization, mechanical clamping, mechanical punch actuation, and pretension.

Of these methods, air pressurization is the most common. This is achieved by pressurizing the module and sealing the contact surface through a flexible seal secured to the face of the concentrator. The localized pressure inside the module applies the necessary force required to achieve the bonding at the heated interface.

In applications which require mechanical clamping, pressure is applied to the assembly by the controlled force provided at the concentrator surface. The two rigid materials are secured together by the clamping force that is distributed to the molten interface.

In certain applications, a mechanical punch – mounted inside the InfraWeld module, is implemented to drive the molten materials together after they have been heated sufficiently by the infrared energy transmission.

Bonding by the pretension method requires one material to be stretched over another before the welding process. When the materials are heated, the molten materials are compressed together by the pretension in the assembly.

Cooling

During the cooling or normalization phase, the lamp is de-energized and the semi-molten surfaces resolidify. Cooling air is passed over the bonded area through the InfraWeld module to speed the resolidification process and reduce the time required prior to handling the assembly. Once the material is sufficiently normalized, the InfraWeld module is retracted from the assembly.

Case Studies

The following case studies demonstrate variations of the InfraWeld process. The use of through-beam energy transmission to heat the subject materials is a constant but the means of applying force vary. To review, the typical force application methods are:

- Air pressurization
- Mechanical clamping
- Mechanical punch actuation
- Pretension

Spot-Welding Head Impact Countermeasures (HIC) to Automotive Headliner

Utilizing pressurized air, the InfraWeld process attached 1-mm thick, natural colored polypropylene (PP) head impact countermeasures (HIC) and wire retention clips to the B-surface of an automotive headliner featuring grey Azdel® (Azdel is a PP product). Before InfraWeld, hot melt adhesive was commonly used to secure the HIC components and wire harness retention clips to the headliner.

Machines heated the adhesive to the appropriate processing temperature, and either an operator handling a manual dispensing device or a robot with a dispensing tool system applied it to the headliner. The operator or an automated device then positioned the B-surface components into the adhesive on the headliner before the adhesive would cure. The hot-melt was a messy, heavy consumable, and the heated dispensing devices presented a burn hazard to the operators along with a general maintenance burden.



Figure 3. HIC and wire retention clips secured to headliner by InfraWeld process

The InfraWeld process eliminated the non-value added adhesive by spot-welding the compatible HIC and headliner materials. In this instance, replacing hot melt adhesive with the InfraWeld process produced a weight savings of up to 1.46 lbs and a cost savings of up to \$3.27 per vehicle. The InfraWeld process, a green technology, eliminated the need for non-compatible fasteners (adhesive in this case) and enhanced the recyclability potential of the assembly.

In this case, the concentrator was equipped with a flexible seal to retain pressure at the contact surface and to assure application of a calibrated force to mix the PP into the Azdel surface of the headliner. In the heating process, the focused infrared energy was transmitted through the translucent PP components and absorbed by the grey scrim of the headliner. The heat generated at the interface softened the materials. The force generated from the pressurized module displaced the semi-molten PP surface into the headliner Azdel surface. With processing parameters of 3.5 seconds of heat time, 10 seconds of hold time, and 10 seconds of cool time, the bond achieved the parent material strength of the headliner scrim. The operator could handle the assembly immediately after the welding process.



Figure 4. Close-up of HIC InfraWeld spot-weld

Spot-Welding Automotive Taillight Inner Lens to Bezel

In this study, mechanical clamping was used to leverage the rigidity of a polycarbonate (PC) inner taillight

lens to spot-weld a 2-mm thick, clear and translucent red PC inner lens to a 2-mm thick, black PC taillight bezel.

As opposed to the more typical means of assembling inner taillight assemblies, namely with ultrasonic welding and/or heat staking, through-beam IR energy transmission was applied in this application.

Ultrasonic welding can be an expensive process when simultaneously welding multiple points because a generator is required for each welding stack. In an effort to reduce cost, ultrasonic stacks are often sequenced to reduce the number of generators needed in the assembly machine. This results in increased machine cycle times, however the InfraWeld process is capable of welding multiple points simultaneously without sequencing.

An additional advantage in using the InfraWeld process in this application was that molded energy directors or weld ribs were not required. The InfraWeld process achieved a homogenous bond between the lenses at the spot-weld locations with flat surfaces.



Figure 5. Welding taillight inner lens to bezel

The IR energy was transmitted through the translucent red PC inner lens and absorbed by the black PC bezel. The heat absorbed by the bezel softened both materials at the interface of the joint and the mechanical clamping of the concentrator compressed the molten components together, bonding the materials. The processing parameters were 4 seconds of heat time and 5 seconds of hold time.

In addition to single point spot-welds produced with standard InfraWeld modules, custom InfraWeld modules can be designed and implemented to create a hermetically sealed, linear weld.



Figure 6. Close-up of polycarbonate spot-weld with the InfraWeld process

Spot-Welding NVH Pads to Trim Panel

The implementation of an internal mechanical punch to the InfraWeld module enabled the process to bond white PP based noise, vibration, and harshness (NVH) pads to a black PP trim panel.

Previously, either pressure sensitive adhesives or ultrasonic welding methods were used to attach NVH pads to trim panels. Pressure sensitive adhesives added an extra component to the assembly and required the disposal of backing paper during every assembly. Pressure had to be applied to the length of adhesive to bond the components together, which is complicated by the contour of trim panels. Ultrasonic welding offered an advantage over adhesives, eliminating the need for an extra component in the assembly, but introduced the risk of marking the A-surface during the welding process.



Figure 7. NVH pad bonded to trim panel with the InfraWeld process

The InfraWeld module securely clamped the NVH pad to the trim panel at the concentrator surface. In the heating stage, the IR energy was transmitted through the white NVH pad, and was absorbed by the black trim panel. The IR energy heated the black trim panel and the PP of the NVH Pad to a semi-molten state. After the heating phase, a mechanical punch pneumatically extended to displace and bond the semi-molten materials.

The spot-welds achieved the parent material strength of the NVH pad. The processing parameters were 3.5 seconds of heat time and 5 seconds of hold time.



Figure 8. Close-up of NVH pad, InfraWeld spot-weld

Simultaneous, Full Perimeter, Through Beam Welding of Concentric Thermoplastic Tubes

Utilizing pretension in the assembly, the InfraWeld process hermetically sealed a thin, transparent film to a concentric, rigid, white, thermoplastic tube in a medical device. InfraWeld replaced adhesives to bond the film to the rigid tube. Bonding the materials with adhesives proved to be messy and dispensing the adhesive presented poor quality in the assembly. The adhesive dispensing needle was not able to slide between the film and the rigid tube without displacing the film, causing misalignment of the assembly. InfraWeld provided a more repeatable and robust process.

A custom, circular InfraWeld module created a simultaneous full perimeter bond on an approximately 0.4-inch diameter tube without contacting the assembly. The custom, circular InfraWeld module incorporated eighteen lamps with a common, optimum focal point. The circular module welded 360-degrees of the tube simultaneously and created a thin, hermetically sealed weld that achieved the parent material strength of the film.

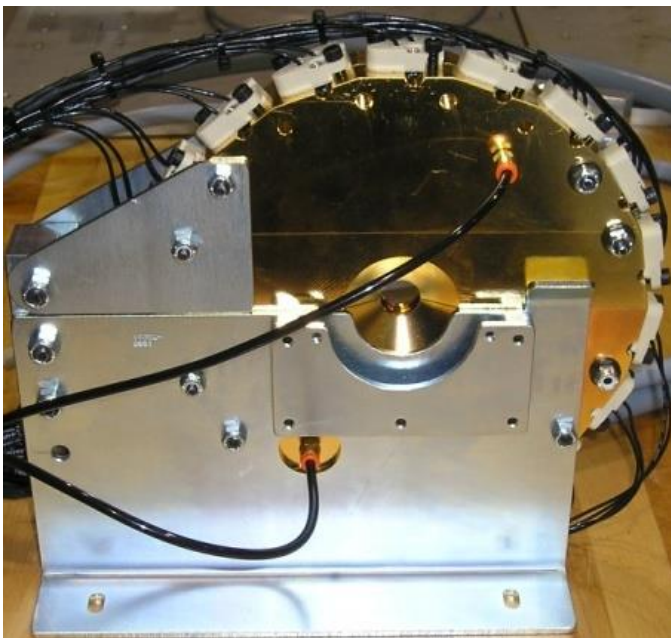


Figure 9. Circular InfraWeld module

Before welding, the slightly undersized film was stretched over the rigid tube creating tension in the assembly. A fixture precisely aligned the tubes into the center of the InfraWeld module.

In the heating stage, the infrared energy passed through the clear film and was absorbed by the rigid, white thermoplastic tube. The energy absorbed by the rigid tube softened the tube and the film while the pretension in the assembly forced the compatible molten materials together. The InfraWeld process bonded the film to the tube with 4 seconds of heat time and 6 seconds of cooling time.

Conclusion

The InfraWeld process has proven to be a unique, efficient plastics joining process. The brief descriptions of these diverse applications show the flexibility of this light energy process. The InfraWeld process should be added to the list of considerations when choosing a robust plastic joining method for a wide range of applications.

References

1. Nobelprize.org. (2002, December 19). *Laser Facts*. <http://www.nobelprize.org/educational/physics/laser/facts/index.html>