THE USE OF LASER WELDING TO REDUCE COSTS AND STANDARDISE ASSEMBLY PROCEDURES

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ABSTRACT:

Greater automation, increased productivity and higher quality result from the use of laser welding to replace traditional processes for joining plastics. Manufacturers of a wide range of products, including medical, electronic, automotive, textile, consumer goods and packaging, benefit.

Adhesive bonding, mechanical fastening, vibration, ultrasonic and other welding methods most commonly join plastics. Currently, the myriad of approaches impede new product engineering and design abilities, restrict manufacturing parameters, limit high-speed or high-volume capabilities, mar the finished products’ aesthetics or reduce joint strength and performance.

Clearweld® is a patented plastic laser welding technology solution offered by Gentex Corporation. It provides proven solutions for product designers, engineers and manufacturers seeking the ability to increase automation and manufacturing productivity, reduce production costs, while providing superior quality joint performance and unprecedented, finished product appearance.

For new or enhanced plastic laser welding ideas in the medical, electronic, automotive, textile, packaging and consumer good markets, Clearweld provides many benefits:

- Precise, colourless welds
- Design flexibility
- Hermetic seals
- Simultaneous multi-layer or complex geometry welds
- Transparent or light-coloured opaque applications
- Biocompatible

Multiple companies worldwide are capitalising upon Clearweld’s engineering services to assist customers in successful implementation of their plastic laser welding application.

CLEARWELD PRODUCTS

Clearweld enables the welding of thermoplastic substrates using NIR laser systems. Gentex Corporation provides a unique product range, tailored to meet all the requirements of laser welding:

- Custom-compounded resins contain near-infrared (NIR) absorbing additives that convert laser energy into heat to facilitate the welding process, in the range 808 to 1100nm (Fig.1, left).

- Clearweld coatings contain infrared absorbing materials, designed for use with lasers in a wavelength in the range 940 to 1100nm (Fig.1, right).
Fig. 1 Transmission of Clearweld absorbers, left as additives, right as coatings.

CLEARWELD SERVICES

Clearweld services demonstrate the continual improvement paradigm provided by Gentex Corporation, through:

- Engineering services to support your application and resources
- Integrated support services to reduce implementation time and cost
- A global network of partnerships comprised of material suppliers, equipment providers and certificated dispensing equipment suppliers.
- A network of local assistance for product evaluation.

Clearweld products are supported through attention to detail in the Design Cycle, shown in Fig. 2

Fig. 2 The Design Cycle
THE CLEARWELD PROCESS

The following guidelines are presented for information only, it is recommended that a Design of Experiments is undertaken to quantify the specification.

1. Absorber concentration and energy density have the greatest impact on weld strength. They are somewhat linear in their effect on the welding result. A quantified change in either one will have a similar effect on the weld strength that is achieved.
2. The absorber concentration and energy density should be balanced to prevent overheating of the samples and a reduction in weld strength. Gentex has produced an atlas of welding conditions that is used to assist, Fig. 3 shows an example.

Fig. 3 Absorber concentration and energy density.

LASER CONFIGURATIONS

The laser beam can be directed on to the part by a number of techniques:

1. Single beam – contour
2. Scanning beam
3. Curtain
4. Simultaneous

Unlike laser welding with an absorptive substrate such as carbon black, the laser beam does not have to be as precise when using Clearweld. With an absorptive bottom substrate, the laser beam must be precise since heating and melting will occur in all areas that the beam contacts. However, with Clearweld, heating and melting of a substrate that is exposed to the laser will only occur where the Clearweld material interacts with the laser.

Single Beam or Contour

When welding using a single beam, the laser hits the weld interface as a beam, or point. Moving the part under the beam or moving the beam across the part produces the weld. A number of means, including a conveyor belt, x-y table, or rotary table, can move the part. The laser can be moved by attaching it to a CNC router or a robotic arm.
**Quasi-simultaneous or Scanning**

A scanning system also uses a single beam, however a series of mirrors attached to galvanometer motors deflects the beam to the appropriate path. The advantage of this system is that the laser and welded parts remain stationary.

**Curtain**

A curtain laser system uses a series of laser beams combined side by side, or one or more laser beams spread out by optics, to form a line (or curtain). The laser curtain or part is moved to expose the weld interface.

**Simultaneous or Array**

Simultaneous systems consist of a series of laser beams arranged in the shape of the part to be welded. There are no moving parts, and the entire weld interface is heated at one time.

**WHY USE CLEARWELD?**

**To Make Money by Offering Better Products.**

- Improved product quality
- Reduced production costs
- Better product features

Clearweld adds value to a variety of scenarios in multiple industries. The following are illustrations of how the technology can be applied.

**Improved Product Quality in the Electronics Industry.**

Electronics manufacturers are faced with producing high-quality components containing sensitive internal mechanisms, which consistently sustain damage when ultrasonically welded. Clearweld is an option to simplify the manufacturing process, reduce component rejection rates and improve the finished components' quality and production rates.

The major requirements for a Clearweld joint are:

- Flat, mating surfaces.
- Adequate clamping pressure applied to the mating surfaces.
- Transmission through the top substrate so the laser energy reaches the interface.

The design review will recommend joint configurations that allow the application of a Clearweld coating to the joint area. The weld joint must be perpendicular or at an angle to the laser beam *i.e.* not parallel with the laser beam, as shown in Fig.4:

![Simultaneous Laser Energy](image)

**Fig. 4** Re-designed joint configuration and application of simultaneous laser energy.
Clearweld coatings are low-viscosity, solvent-based liquids that are applied in production by various liquid dispensing systems. Typical solvents that are used in Clearweld coatings include ethanol, acetone, and methyl ethyl ketone. The amount of coating applied is measured in terms of nanolitres per square millimetre. The solvent is a carrier and is flashed off rapidly, leaving a film of absorbing material on the surface of the plastic. Typical drying times are between 1 and 7 seconds. It is possible to use assisted drying such as pre-heating of parts or post-heating with an infrared lamp to flash solvents off more quickly. Coatings may be applied off-line.

To complete the assessment, dispensing trials validate the conceptual design via an EFD 741V-SS/7000 System, which is designed for easy integration into automated production lines. EFD’s automated dispensing systems have been tested and certified to deliver precise and repeatable flow control and deposit placement in the Clearweld process, Fig. 5 shows the EFD system.

Fig. 5 EFD 741V-SS Valve and 7000 Series Controller

A diode laser welding procedure, utilising a simultaneous laser welding system is effective for high-volume production of parts with the same geometry. Simultaneous systems consist of a series of laser beams arranged in the shape of the part to be welded. There are no moving parts, and the entire weld interface is heated at once.

The manufacturing results included increased design options directly overcoming past product design limitations, set forth by ultrasonic welding; introduction of an automated production cell to increase production rate; ability to control and increase product quality.

**Reduced Production Costs in the Automotive Industry**

For many years, plastics have been gaining ground for automotive bodywork components. Where plastics used to be restricted to mirrors, grilles and wheel covers, they are now regularly used for components such as bumpers. In some cases, the entire bodywork is made of plastic panels (e.g., MCC smart). Plastics have advantages over metal, as described:

- Weight reduction when the part is re-designed to be fit for purpose
- Lower tooling costs, especially for small to medium production runs
- Potential for time and cost savings

At present, there are numerous methods of producing a colour-matched plastic component

1. In-mould decoration
2. Simultaneous on-line painting with metal bodywork components
3. Off-line painting and subsequent return to the assembly line for mounting
4. Self-coloured plastic, sometimes with subsequent clear coating or printing
5. Clearweld resin systems.
Until recently the problem with laser welding plastic components was that one part of the assembly had to contain carbon and so the designer could only create black components. This restricts the use of laser welding to under the hood applications. The automotive company was seeking to improve this situation and apply laser welding in other areas. The production of high quality coloured components was necessary to meet a design specification.

Clearweld resin systems enable laser welding of thermoplastics while offering extensive colour matching flexibility. The custom-compounded resins contain NIR absorbing additives that convert laser energy into heat to facilitate the welding process. Clearweld Resin Systems can be injection moulded or extruded. The benefits are as follows:

- Consistent, clean, high quality joining
- No secondary dispensing step in production
- Welding performance optimised
- A variety of laser technologies and powers may be used
- Extensive colour matching flexibility, including transparent colours
- Thermally stable in a variety of processes

A Clearweld resin system was developed for use with an Nd YAG laser at 1064nm. The appropriate Clearweld additive system was selected based on the colour requirements of the company, which allowed an extensive colour range.

The joint design was evaluated, with the configuration shown in Fig.6 being decided on by the project team from the automotive company, systems integrator and Gentex Corporation.

![Fig. 6 The re-design of the automotive joint for Clearweld.](image)

Then, a laser welding procedure utilising a quasi-simultaneous system was developed to join the parts. Quasi-simultaneous systems utilise a scanning system, which uses a single beam with a series of mirrors attached to galvanometer motors to deflect the beam to the appropriate path. The advantage of this system is the laser and welded part remain stationary and fit-up tolerances are greater since some collapse is experienced in the joint.

Overall, the manufacturing results included reduced fabrication stages, with over painting no longer necessary and an increase in design flexibility as traditional limitations were significantly reduced and colour matching to the colour scheme was enabled.

**Better Product Features in the Medical Industry**
Clearweld can be applied effectively to parts without damaging the appearance of surrounding surfaces. This is of particular importance in the medical industry and is an indicator of basic quality management.

Increased consumer empowerment means that design now plays a greater role in product development and is the key factor in driving the need for more innovation in design. Clearweld enables the engineer through:

- Clean, optically clear joints
- When needed, a hermetic seal is possible
- Fast, less than 1sec/weld is possible
- Non-contact and so no surface damage
- No particulate generation, with little or no flash
- No third body as with adhesives
- Low residual stress, so thin, flexible substrates can be joined without distortion

A Design for Manufacture analysis provided new ideas for simplifying the existing design in terms of integration of parts and part count reduction. The manufacturing analysis allowed the design team to assess alternative designs and production processes, quantify manufacturing costs and make the necessary trade-off decisions between part consolidation and increased material and manufacturing costs.

Of particular concern was the biocompatibility of the Clearweld coating and the customer was convinced by the information given in Table 1, which lists the tests and results performed by independent testing organisations on behalf of Gentex Corporation. Additional information relating to such testing can be provided upon request.

**Table 1 Medical Biocompatibility Testing of Clearweld**

<table>
<thead>
<tr>
<th>Test</th>
<th>Clearweld Material Tested</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cytotoxicity</td>
<td>Raw IR absorber</td>
<td>Nontoxic</td>
</tr>
<tr>
<td></td>
<td>Coating applied to plastic — pre laser exposure</td>
<td>Nontoxic</td>
</tr>
<tr>
<td></td>
<td>Coating applied to plastic — post laser exposure</td>
<td>Nontoxic</td>
</tr>
<tr>
<td>USP Systemic Toxicity</td>
<td>Coating applied to inert substrate — pre laser exposure</td>
<td>Met the requirements of USP Class VI</td>
</tr>
<tr>
<td></td>
<td>Coating applied to inert substrate — post laser exposure</td>
<td>Met the requirements of USP Class VI</td>
</tr>
<tr>
<td>USP Intracutaneous</td>
<td>Coating applied to inert substrate — pre laser exposure</td>
<td>Met the requirements of USP Class VI</td>
</tr>
<tr>
<td>Toxicity</td>
<td>Coating applied to inert substrate — post laser exposure</td>
<td>Met the requirements of USP Class VI</td>
</tr>
<tr>
<td>USP Muscle Implantation</td>
<td>Coating applied to inert substrate — pre laser exposure</td>
<td>Met the requirements of USP Class VI</td>
</tr>
<tr>
<td></td>
<td>Coating applied to inert substrate — post laser exposure</td>
<td>Met the requirements of USP Class VI</td>
</tr>
<tr>
<td>Extraction and</td>
<td>Coating applied to inert substrate — post laser exposure</td>
<td>No toxic by products were identified</td>
</tr>
<tr>
<td>Identification of</td>
<td>Irradiated dye washed with methanol for extraction</td>
<td>Decomposition</td>
</tr>
</tbody>
</table>

1 Cytotoxicity study using the Agarose Overlay Method
2 Cytotoxicity study using the MEM Elution Method

The clear parts were redesigned to allow the application of a Clearweld coating to the joint area and again, the part was dispensed via an EFD 741V-SS/7000 System. For this application an in-house Ultra™ TT Automation System, which combines the 741V-SS
dispense valve with an advanced tabletop 3-axis positioning platform and integrated
dispensing controls into one compact bench-top unit, shown in Fig. 7 was used, with e re-
designed joint as shown in Fig. 8.

![EFD Ultra TT Dispensing System](image)

**Fig. 7** EFD Ultra TT Dispensing System

Using a contour laser system to produce parts, the consequences of the manufacturing
change gave rise to improved intrinsic product strength, enabling enhanced performance and
reducing defects in the finished product.

**SUMMARY**

The previous examples show different aspects of the Clearweld technology package available
from Gentex Corporation and illustrate a number of points:

1. Product design has to undergo a number of evolutionary steps to make the best use
   of the technology.
2. Innovations in materials or fabrication methods demand interdisciplinary effort by
design, development and production staff.
3. The route to innovative product development is basic engineering, linked to economic
   confidence in the probability of achieving success.
4. The Clearweld team is available to support your innovations.