Quality Control

Laser Plastic Welding – Impossibly Consistent

The engineering and technology sector has grown to become a fascinating industry. Cutting-edge technological developments are often heralded with celebrity-like distinction. Even a variety of television series are based on technological innovation and similar topics litter the front pages of every magazine from *Wired* to *Men’s Journal*.

But, engineering is not just about innovation. There is a practical side to engineering, a boring side. The part of the process chain where a team of engineers has to decide if they can not only manufacture the product in a cost effective manner, but also do it in a method that satisfies regulations.

The point I am trying to make is that great engineering feats are not the ones that make headlines, but the ones that make production.

And in today’s manufacturing world the gatekeeper that sits between a new product and its road to production greatness is quality control.

**Quality Control**

In the automotive industry it is about cost savings. Minimize rejects, minimize expenses. In such high volume production, the smallest percentage of rejects can lead to massive losses.

Similarly, the medical industry, although still driven by cost savings, often has an extra layer of quality requirements imposed upon it. Effects, from the rigorous testing required by the FDA, ripple throughout the entire product development process, from concept to the manufacturing floor.

In fact, in a study conducted by Qmed and UBM Canon (*Qmed & the UBM Canon Medical Device Media Group, 2011*), quality control was realized as the highest priority factor for medical device manufacturers selecting vendors and suppliers, and rightfully so. When such high demand is placed on product quality there can be no weak link in the chain.

Regardless if quality controls are company-imposed or controlled by government regulation, they are a prerequisite to competing in the manufacturing world.
Laser plastic welding, a revolution in assembly

Laser plastic welding, a roughly decade-old assembly method, boasts its own resume of breakthrough applications. From micro-fluidic devices, created at unparalleled accuracy, to clean-room class V applications, impossible with other welding methods. Laser plastic welding is leaving a noticeable mark in the assembly world.

This welding process makes use of a finely-focused laser beam. The part to be welded is comprised of two pieces with dissimilar characteristics: an upper, laser transmissive layer and a lower, laser-absorbing layer. The laser energy projects through the upper part and is absorbed by the lower piece (see Figure 1, page 1). The absorbed heat melts the plastic at the interface between the two parts and creates a weld.

The benefits of laser welding versus other plastic joining methods are many: precise heat placement, a clean welding process, unmatched precision and the ability to weld complex and three-dimensional parts, among other advantages.

But likely the most important capability of laser plastic welding is quality control from its robust process monitoring systems. The simple fact that laser plastic welding is capable of producing highly-complex parts requires that it also have the ability to monitor the complexities of its own process at a very accurate level.

Process Monitoring Methods

Laser plastic welding is often selected as the joining method of choice for precision and intricacy. Many of the parts in question have high tolerances requirements, therefore, the quality assurance and validation must be equally as precise, able to measure the tiniest deviations from the tolerance abilities boasted by laser welding.

In itself, the process of laser plastic welding is extremely reliable and repeatable. However, the process can be hindered by deviations in the parts to be welded. The two causes for concern are geometric and optical deviations.

There exist five different types of process monitoring techniques for laser plastic welding, ensuring that any part, regardless of its nuances or the variations in the part, are able to be monitored effectively.

1. Melt-collapse Monitoring
The most robust and often used process monitoring method is collapse monitoring. This technique makes use of the natural convergence of the joining parts as they move together under clamping force.

Typically, parts are designed with a collapse rib, such as you see in Figure 3. This rib, once melted and introduced to clamping pressure, will collapse. The measurement of this collapse can be used to determine weld quality.

The laser welding process itself is highly-reliable, but deviations in part dimensions can result in poor welds. If the two joining parts are warped, this can leave gaps. Gaps of more than 0.05mm are known to degrade weld quality significantly.

Introducing a collapse rib that is greater in height than the part tolerances can ensure that the distance of collapse will overcome the tolerances.

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Once an adequate melt-collapse is determined in testing, parameters are entered into the system. If a part fails to fall within the proper collapse parameters during production it will be marked for rejection and all data will be stored for later evaluation.

The device that measures the collapse is known as a *linear voltage distance transducer*. It is accurate to less than 0.01mm, which is overkill as even the most precise injection molding processes are incapable of producing dimensional tolerances of less than 0.02mm.

### 2. Pyrometer

Pyrometers measure the temperature within the welding zone. Temperature inconsistencies are directly correlated to inconsistencies in the weld.

Pre-defined upper and lower temperature limits are developed in testing. If anomalies from burned contaminates or inconsistent part dimensions cause the radiation to fall outside of the defined “temperature envelope” the part will be flagged and the data stored.

Pyrometers are typically used when melt-collapse monitoring is impossible, for example in the case of radial welding of a catheter, where pressure is created via an interference fit and not clamp tooling.

### 3. Reflection Diagnosis

![Figure x – Reflection diagnosis concept](image)

This method measures reflected light, but rather than measuring the intensity or temperature this method measures the divergence of the reflected light from the surface of the part.

Parts that are correctly molded, fit together perfectly, with no gaps between them; therefore, the only surface of the part as a whole is the upper layer surface.

Parts incorrectly developed may have gaps. In such an occurrence the part would technically have two surfaces, the surface of the upper layer and the surface of the lower layer.

This system is able to compare the divergence of the reflected light. Parts with gapping and, therefore, two surfaces, are identified by two peaks of light, whereas properly fitting parts will only reflect a single peak.

### 4. Burn Detection

Burn detection is used to recognize surface scorching. Scorch marks are typically caused when the laser strikes a contaminant on the surface of the plastic, resulting in a burn.

Such burns emit radiation that is outside of the typical reflected wavelengths and can therefore be distinguished.

Although scorch marks, usually no more than a few tenths of a millimeter across, rarely have the capability of compromising the weld quality, they are often unacceptable for aesthetic reasons.

### 5. Camera-Assisted Vision Systems

In some cases weld quality can be determined by a simple visual inspection. However, being a manual process, this is very impractical and unreliable.

![Figure 4 – Camera view of a flaw](image)

Vision systems are capable of monitoring the weld seam automatically and to a much higher accuracy.
Figure 4 shows an example of the system detecting a visible seam inconsistency. This was most likely the result of a gap or particulate hindering thermal transfer at the weld interface.

Data, Data, Data

All of the methods above can be integrated easily into an automation line, where the process monitoring systems communicate with the automation line and failed parts can be immediately discarded.

However, in-line process monitoring is only half of the battle. The data collected from the monitoring of each part can be accumulated and used to even further improve the accuracy of the process and the quality of the resulting parts.

A universal and highly-functional software system is capable of integrating data from each process monitoring technique.

When perfect replication from part-to-part is a must, then data is an engineer’s most important tool.

Transmission Testing

One of the most important factors for determining viability of laser plastic welding for an application is the transmission rate of the materials in question.

Laser welding requires that the upper layer have a minimum level of transmission to allow enough laser energy to the interface for welding to occur.

The TMG2 is a transmission measurement and testing tool developed by LPKF Laser & Electronics. This handheld system can quickly and accurately determine the transmission rates of the plastic in question. It is excellent for sampling and individual part testing.

Even more exciting is the integration of this technology into a production line. A newly developed system allows for transmission testing of each part to take place right inside the production process.

Laser plastic welding is a very precise process. Fluctuations in material transmission can affect the consistency of a weld. Variations in transmission rates are often the result of upstream processes like compounding and injection molding.

In-line transmission measuring can ensure that each part going into production has the proper transmission rate for a quality weld. Consistency is the key.
Laser Plastic Welding, Resume of Qualifications

Laser plastic welding is capable of meeting the strictest regulations and engineering practices. The process monitoring techniques provide the foundation for Six Sigma process performance.

Below is short list of laser welding quality certifications:

- DIN ISO 9001
- ISO/TS 16949 (Quality management systems – special requirements when applying ISO 9001:2008 for volume and spare parts production in the automotive industry)
- GMP (Good Manufacturing Practices) – Regulation for quality assurance of production processes and environments for the production of pharmaceuticals, active substances and medical products.
- Clean room compliance with cleanness class ISO
- Satisfies protection classes IP67 and IP69K.

Conclusion

Laser plastic welding boasts incredible advantages, advantages that are expanding horizons for what is possible in device manufacturing. No matter how simple or complex an application, laser welding is capable of high levels of quality assurance and repeatability.

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For general questions or information regarding design and feasibility, please contact the author.

Don’t forget to download a copy of LPKF’s Laser Plastic Welding Design Guidelines, a document for engineers and designers in the concept and design stage of an application.

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