More Complexity and Higher Quality

Laser plastic welding for new product layouts

Malte Borges

The demands for more complexity and higher quality joining methods are rising continuously in the automotive and medical technology sectors, as well as in consumer goods. There are major differences between laser plastic welding and other technologies – this is why it is conquering more and more areas of applications with new laser systems and methods.

According to the latest study by Frost & Sullivan, there will be another major increase in the use of plastics in vehicle construction. The reasons mentioned by the study are lower weight, rugged properties, better design flexibility, and major cost benefits thanks to lower processing, assembly and finishing costs. According to the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart, fifty percent of all the materials used in medical technology are now made of plastic. The institute also forecasts that the use of technical and high-performance plastics will grow above average in the near future by approximately eight percent.

Reliable joining methods are therefore of great importance against this background. The principle behind laser plastic welding is based on the difference in transmission properties between the upper and the lower joining partners, and the method can easily compete with conventional joining technologies. Depending on the design of the process and the type of laser system used, this technology can be used to safely and economically weld products with a large spectrum of sizes: from very large components (e.g. car tail lights and fenders) all the way down to tiny microfluidic channel structures.

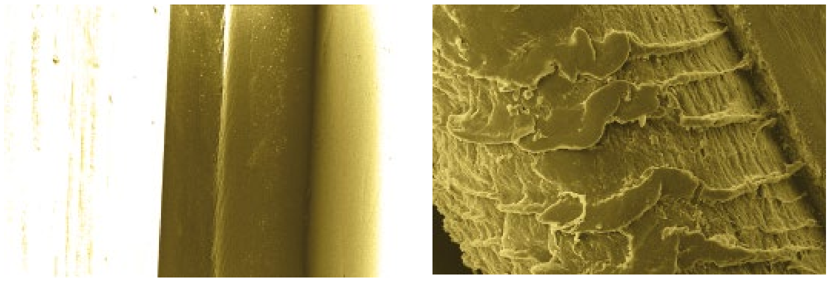

Fig. 1 Under the magnifying glass: a weld seam produced by transmission laser welding (left); a joint produced by vibration welding (right) at the same order of magnification (150×).

Demands for industrial production

The industrial processing of plastics demands very stable production processes. All joining processes take place relatively far down the process chain resulting in the finished component. This means that relatively expensive rejects are produced as a result of errors in processes taking place further upstream. Economical production depends on the following:

- Differentiating between specification-compatible and faulty joining partners
- Reliably implementing complex product layouts
- Opening the processing window as wide as possible
- Recording the processing parameters which confirm that welding has been successful

Compared to the more conventional thermal, mechanical and bonding methods for joining plastics, laser transmission welding boasts convincing technical advantages. Laser welding is a gentle technology which reduces mechanical stresses on components to a minimum. There are no vibrations at all which could damage the plastic housing or internal components. Laser welding requires no additives, and the welded surface satisfies even the highest optical specifications even in the directly visible areas. In addition, several process monitoring methods increase the reliability of the joint prior to and after welding (Fig. 1 & 2).

Comparison between the plastic welding methods

The conventional thermal, mechanical and bonding methods for joining

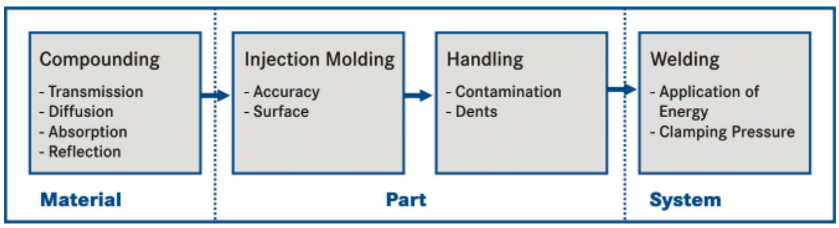

Fig. 2 Joining processes take place at the end of the production chain. It is therefore important to use proper methods to detect and to compensate errors in preliminary processes.

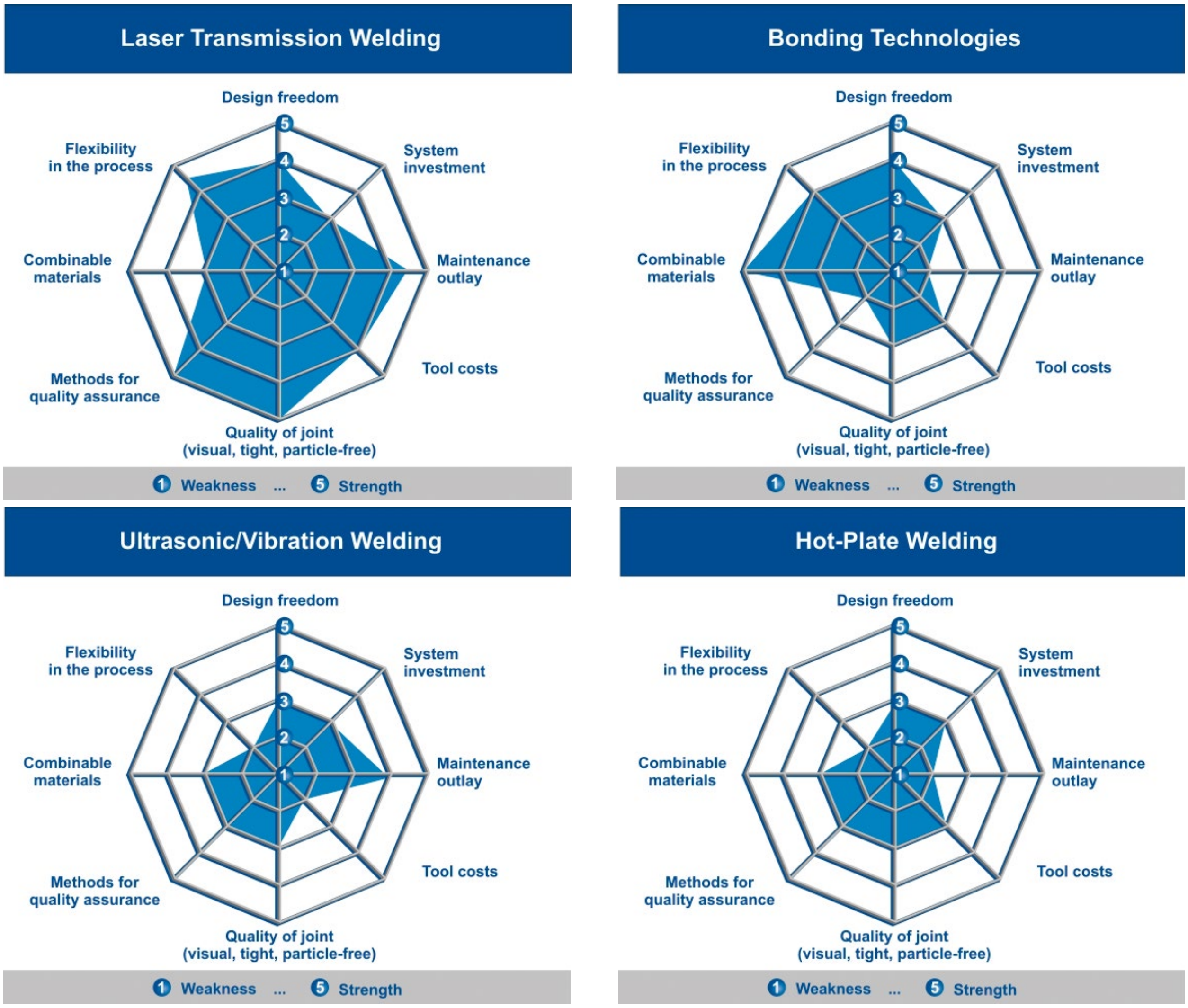

Fig. 3 Comparison between different joining methods

plastics have advantages and disadvantages depending on the application and the component. The methods can generally be differentiated from one another by comparing the effort and expense involved during preparation and operation, and by looking at the materials used, the flexibility of the layout, the process properties, and the process reliability (Fig. 3).

The run-up costs can have a significant impact on costs per part, depending on the number of components produced. The investment costs for modern laser welding systems are now similar to those involved with other methods. Laser technologies, however, score much more strongly when it comes to tool costs, consumables, and expenditure caused by wear and tear. Compared to bonding technologies, laser welding requires no additives; and compared to vibration welding methods, it does not produce any particles. There are also no cleaning costs because tools do not come into contact with any liquid materials.

Clamping tools and component holders can also be designed much more simply, and can be replaced very quickly, because laser welding does not give rise to any significant mechanical, dynamic or thermal stresses on the joining system and the components. These aspects, and the software-controlled laser tracks, underpin economical production processes with a great deal of flexibility.

Laser welding systems are almost maintenance free during production. Moreover, different process monitoring methods safeguard the reliability of the joints during the welding process itself.

Quality assurance during laser plastic welding

The transmission properties of a joining partner can be detected manually or systematically. A transmission testing device determines the laser transmission with the subsequent welding laser wavelength, to provide a set-actual comparison in accordance with the process specifications (Fig. 4).

Melt travel monitoring, pyrometer control, and burn detection monitor the joining process. The benefits: the laser can undertake corrections during

Company

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LPKF Laser & Electronics AG manufactures machines and laser systems used in electronics fabrication, medical technology, the automotive sector, and the production of solar cells. Around 20 percent of the workforce of 780 employees in total is engaged in research and development. Laser direct structuring (LDS) is the dominating technology to generate conductive tracks on 3D parts.

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the ongoing process itself, and avoid expensive rejects – without requiring any additional machine time.

During melt travel monitoring, the welding system inputs energy into the component from a referenced zero point. It records the melt travel and the time required. During “Welding by melt travel” the welding process ends when a defined travel distance has been reached. If the time required complies with the specified values, the component is classified as a good part. This is followed by a time-controlled cooling process under continuous clamping pressure. This process control can be used for instance to ensure compliance with an absolute component height. Melt travel monitoring assures the production of properly joined good parts with precise geometries, even when there are fluctuations in material properties.

Fig. 4 The TMG 3 transmission tester detects the local transmission properties of a component. It can be used as a standalone device or integrated within a production line.

Optical process diagnostic modules such as pyrometer control detect local faults. It identifies whether gaps in the weld contours prevent thermal conduction, or whether foreign bodies give rise to localized burning. The burn detection detects coupling on the surface caused by contamination for instance. All of the optical methods identify standard faults during the welding process itself, and warn the operators of any deviations. All of the welding process parameters are stored and transferred via interfaces for seamless tracking & tracing (Fig. 5).

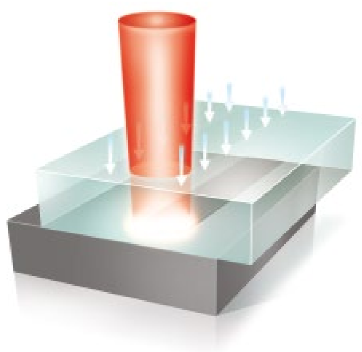
Adequate process monitoring reduces the costs involved in subsequent component inspection. Warnings are given which can avoid expensive faulty production even in the case of changed material properties or geometrical deviations.

Laser systems for plastic welding are suitable for manual operation, semi-automatic loading, and – in very

The principle behind laser transmission welding

The laser transmission welding of plastics joins together a laser-transmissive and a laser-absorbing material. The laser beam pass through the upper joining partner with very little energy loss to reach the joining zone, where the surface of the lower joining partner absorbs the energy from the laser beam. The weld seam is warmed up until it melts. The energy is transferred to the upper joining partner by thermal conduction and a moderate clamping pressure, so that the molecule chains diffuse in the contact zone. This gives rise to an adhesive bond after cooling down. The strength of a laser weld seam is very similar to that of the solid material, and achieves a welding factor of almost 1.

There are different types of laser transmission welding: the main ones are contour welding, quasi-simultaneous welding and hybrid welding.



During the laser transmission welding of plastics, the laser beam passes through the upper joining partner to join the lower laser-absorbing component.

Contour welding

During contour welding, a laser beam melts the contour locally. This method boasts very high degrees of flexibility. Complex, spatial welding contours on large components are implemented by industrial robots. Contour welding is ideal for three-dimensional weld seams and very large components.

Hybrid welding technologies

The TwinWeld3D-hybrid welding technology combines the energy input of a laser with a polychromatic light source. The whole radiation profile has an intensity peak in the center caused by the laser, which then diminishes quickly in the surrounding area. Every point along the weld seam is slowly heated up at first, and then melted by the laser beam, to then cool down slowly again under the continued influence of the halogen lamps. An air-sprung clamping roller on the robot-guided welding head provides the spot joining pressure precisely where needed, directly next to the welding track. This produces large components with very high specifications for visual quality along the weld seam – in addition to the very reliable weld itself.

Quasi-simultaneous welding

During quasi-simultaneous welding, a laser scanner guides a focused laser beam at high speed along the weld contour several times until the whole weld contour has melted. An integrated melt travel monitoring system safeguards the result of the welding. A melt travel sensor records the amount of movement over a defined time period. The reliable assessment of the success of the welding is derived from a comparison between the real travel and a set curve. Quasi-simultaneous welding is ideal for small components – the welding zone of the laser scanner limits the area which can be worked on.

Radial welding

Radial welding is a special method, and ideal for components requiring rotation-symmetrical weld seams. Relative movement between the component and the laser beam is achieved by rotary or linear axes, or a mirror system which diverts the laser beam. The joining pressure required is maintained constructively by pressing within the joining partners.

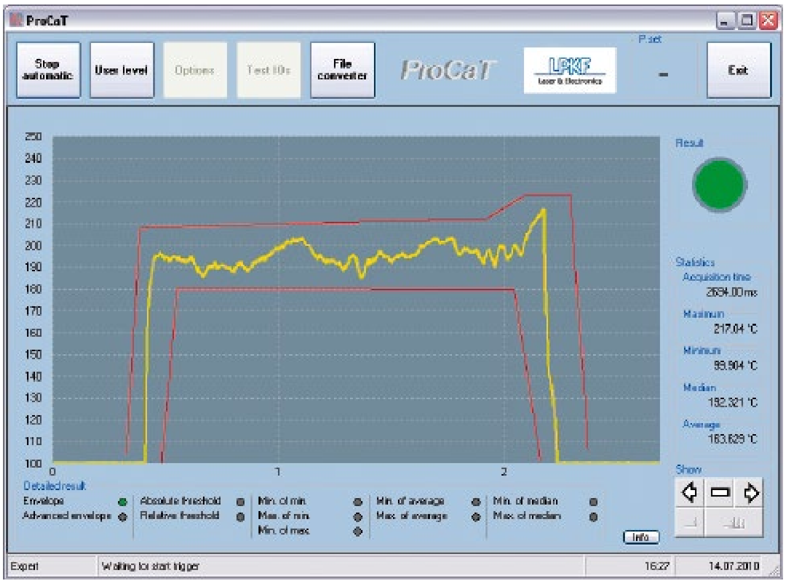


Fig. 5 Quality control by pyrometer: If the temperature profile does not leave the envelope, a safe heat transfer from the lower to the upper component is guaranteed.

compact types – also for space-saving integration in the customer's own production lines. Diode or fiber lasers with wavelengths of 980 nm and outputs of up to 500 W are usually used. A new solution uses a fiber laser with a wavelength, which is especially optimized for the joining of transparent-transparent parts. This LPKF system can be used to join transparent plastic components without any absorbent additives, and can achieve a weld seam width down to only 100 µm and a repeatability of only 10 µm.

Fig. 6 This transparent microfluidic wafer was welded without any additives using the new ClearJoining technology.

Typical areas of application

Laser plastic welding boasts a wide spectrum of applications. These range from large components such as car tail lights, to the safe encapsulation of car components, all the way down to the tiny microfluidic applications used in the medical technology sector. The key aspect for microfluidics is that no damage is caused to the fine channels during the welding process (Fig. 6).

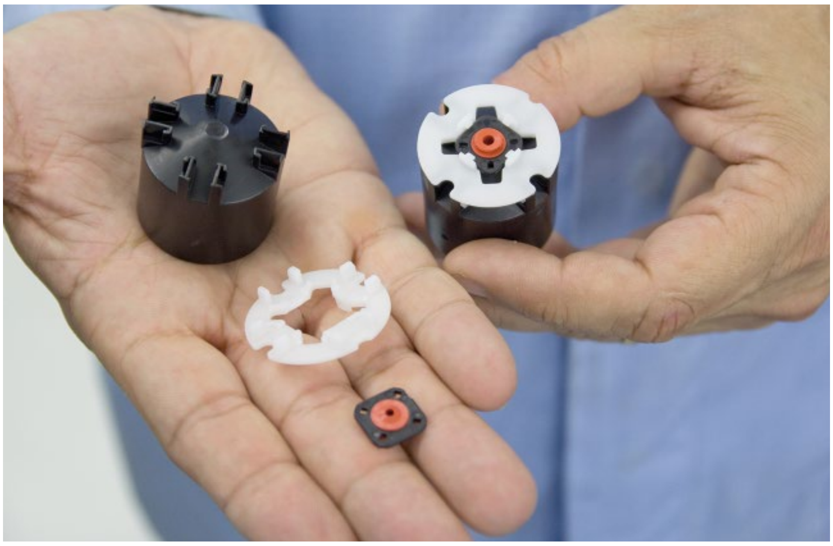


Fig. 7 Laser plastic welding has underpinned many production innovations in the product lines of the automotive subcontractor Alfmeier. In these valves, the laser-transparent upper part (white) has been safely joined to the laser-absorbing lower part (black).

Fig. 8 Alfmeier has trained its own laser welding specialists. The LPKF integration system used here – only the welding head can be seen – can be optimally configured for flexible production.

A good example of the industrial use of laser plastic welding in the automotive industry is LPKF client Alfmeier Präzision AG. This owner-operated company is an internationally oriented manufacturer of precision components. Its portfolio includes valves, actuators and pumps. The company manufactures innovative, fluidic system solutions with a very high level of quality and precision. In the case of car seats, for instance, Alfmeier supplies comfort systems such as lumbar supports, side bolster adjustment, and SMA valves. The seats – and therefore the seating adjustments used – are becoming increasingly smaller and lighter. Automotive manufacturers demand that the pressure loss in air cushions must not be more than ten percent, even after seven days. This in turn means that the plastic components must have very tight joints, and must therefore be made using particle-free manufacturing methods (Fig. 7 & 8).

Alfmeier has been using laser technologies for 16 years. For its co-operation with LPKF, stipulations such as set-up times, cycle times and traceability were defined in a specifications sheet. This resulted in the selection of integration systems which can be incorporated in production lines, but only require a small amount of space, because of the separation between the control/laser source and the processing head.

Initially only used in its headquarters in Treuchtlingen, Germany the laser systems have now been successfully rolled out in its factories in the Czech Republic, USA, Mexico and China.

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