Radial Welding of Polymer Parts under Closed Loop Process Control

Innovative solutions facilitate faster and controlled processes

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One of the key competences of Dilas Industrial Laser Systems is laser based plastics welding. The product range for plastic welding ranges from 10 W output power up to 600 W and are suitable for this application because of beam quality, efficiency and dimensions. Laser based plastic welding is gaining market share not only for automotive parts but also for medical and consumer parts. In order to offer flexible and innovative solutions to their customers, Dilas developed new optical solutions providing distinct process advantages such as increased welding speed and lower handling costs, especially for cylindrical parts and radial welding seams. While there are different radial welding seams for plastic components, all of them are based on the same principle which is laser transmission welding.

Plastic welding: Process comparison and general survey

Welding of plastics is a topic which gains in importance for light weight construction, miniaturized assemblies and parts that require a clean joining process.

Appropriate joining technologies are available and have been developed for decades. However, the requirements on the parts of the assembly have increased in such a way that those conventional technologies have reached their limits. The assembly is sensitive to stress during the joining process and need to be manufactured in high quantity industrial serial production.

Weld joints are common thermal processes besides mechanical joining technologies like screwing or snap joints. Typical welding technologies are friction welding, hot plate welding and ultra-sonic welding. Those are well automated and no additional material is needed like for gluing processes. In ultrasonic machining, sonotrodes create ultra-sonic vibrations and transfer these vibrations into the plastic component under pressure. The welding seam is created where the joining partners are in mechanical contact to each other. The mechanical stress created by the above described process can cause micro cracks inside the assembly which may lead to leakage problems. Ultrasonic welding can damage electronic components or their assemblies and can create loose particles.

What conditions are limitations for welding and gluing technologies?

An assembly containing sensitive and expensive electronics requires a joining method that does not affect the electronics functionality. Such applications are versatile and cover e.g. automotive car keys, sensoric assemblies or sensitive parts in the medical device and consumer industry.

Assemblies that contain or store fluids are further examples. Such components demand high standards to pressure resistance, tightness and cleanliness of the welding process.

The welding process may not flake particles from the plastic material and plug or even destroy the assembly during the later operation. Such requirements are found in the automotive industry and consist of pressure surge tanks, tube systems (like AdBlue lines) or pumps for the medical device industry such as catheters or components that contain micro fluidic channels.
Laser transmission welding is a welding technology for thermal plastics that achieve all requirements mentioned above. It is clean – no grit or particles are generated by the process. The energy input into the welding seam is locally bounded and the laser welding process is contactless. The process is absolutely reliable and allows online process control.

**Laser plastic welding: General process**

Diode lasers generate a monochromatic radiation. Its radiation consists of one single wavelength. Typical wavelengths are 808 nm or 980 nm.

Once the laser radiation impinges on a surface, it is partially absorbed and transformed into heat. During the laser transmission welding the first part to be joined consists of laser absorbing plastic. The second one consists of a plastic material that is permeable for the laser radiation. The parts are arranged on top of each other whereas the top layer is the transparent part and the bottom part is the laser absorbing one – achieving an overlap weld.

The upper laser transparent joining partner is penetrated by the laser radiation without getting damaged, while the lower joining partner absorbs the laser radiation, is heated up and melts. The molten material forwards the heat to the top part and melts this as well. After solidification the welding seam is created. Based on this procedure different assemblies can be welded together. In
In general there are diverse laser transmission welding methods which differentiate in how the laser beam is directed to the work piece. The so-called contour welding is characterized by moving the laser spot (by using a XY-movement or a robot) over the welding contour. Thus allows welding of larger parts or welding of 3D-contours. On the other hand simultaneous welding is realized by melting the complete welding contour instantaneously using special optics.

At quasi-simultaneous welding a so-called Galvo scanner deflects the laser beam around the welding contour by using two mirrors. The contour is freely programmable. A fast scanning speed of the laser beam creates a homogenous temperature profile inside the welding area.

**Equipment for laser plastic welding**

As natural plastic is transparent for diode laser wavelength absorbers with different colors have been developed. Appropriate additives allow colored plastics which are transparent for the laser radiation but impenetrable for the visible light at the same time. For welding such thermal plastic materials mainly fiber-coupled high power diode lasers are used. These lasers are characterized by long life time, low maintenance operation and high electro-optical efficiency. Compact 19-inch rack mountable units can be easily integrated into industrial production lines (Fig. 2). A flexible handling is guaranteed by light transmission through thin fiber cables.

Furthermore there are several focusing optics and processing heads available which guide the laser radiation to the welding zone onto the work piece.

Simple focusing units offer a variety of focal lengths and different spot sizes. In addition such focusing units can be equipped with single color pyrometers for contactless temperature control inside the welding area. This option controls the diode laser output power via a closed control loop dependent on the measured temperature inside the welding plain and can be adjusted rapidly (Fig. 3). The desired temperature can be programmed by software.

Galvo scanners are used for quasi-simultaneous welding and are available with different scanning field sizes in order to weld 2-dimensional parts up to 415 mm × 415 mm. Within certain limits a closed control loop of the welding temperature is also available for such Galvo scanners by using a pyrometer (Fig. 4).

As the number of rotation-symmetric parts are increasing which require a radial weld around their circumference, Dilas has developed optics that offer different possibilities for fast and reliable welding joints.

**Approaches for radial welding**

There are numerous rotation-symmetric plastic parts not only in the automotive industry but also in the medical device industry and other markets.

For the automotive industry tube assemblies like AdBlue lines, supply pumps or pressure tanks should be mentioned. In the medical device industry filter housings, catheters or tube to connector assemblies are typical examples.

A conventional way of welding these parts is by rotating the component and using a fixed optic to focus the diode laser radiation to the welding area.

Usually, these are contour welding processes. The part is rotated by 360 degrees plus an additional overlap of several degrees. Or the part is rotated several times. During this process a pyrometer for process control can be used in order to control the welding temperature, a clear process advantage. Negative aspects to mention are:

1. Process speed slowly
2. Part handling – the component needs to be placed into a rotary axis
3. Rotation of the part is not always possible

These disadvantages have been the main reasons why laser plastic welding projects were difficult to be realized in the past. With optical solutions provided by Dilas it is possible to avoid these problems. The optical solutions allow fast cycle times and reduce the complexity for part handling to a minimum.

**Radial welding optic – simultaneous welding approach**

The radial welding optic is able to heat up the whole radial welding seam simultaneously. This optic is connected to the output side of a standard fiber-coupled diode laser via a SMA or QBH fiber connector. The laser radiation is collimated and transferred into a ring shape intensity distribution (Fig. 5) by using a special optical element inside the collimated beam path. The ring shaped beam is then guided to a reflector mirror at the end of the optic that deflects the beam to the center.

Such radial welding optics are placed into a processing chamber inside a production line. The part is positioned inside the radial optic tube by moving either the part or the optic itself.

Once the part is in correct position, the diode laser is activated via the control interface of the laser and the beam is heating up the welding seam instantaneously. Typically the weld is created within 0.5 – 2 s and the next part can be positioned. Furthermore the radial...
welding optics are designed to the parts dimension as the ring dimension and the associated ring reflector dimension has to be matched to the part size (Fig. 6). Within certain limits, parts with different diameters can be welded with one single radial welding optic because of the focal depth which keeps the beam height constant over a distance of a few millimeters. Fig. 7 shows this effect.

It is not possible to use an online process control with pyrometer in combination with these radial welding optics. Parts that require process control for quality control and documentation cannot be welded with this set up, or a post process quality control like leakage tests need to be put in place.

**LLDROP-P – quasi-simultaneous radial welding optic with process control**

The latest innovation, the LL DROP-P, incorporated one further feature. Besides the features of the radial welding optic like static positioning of the assembly to be welded and easier handling of the parts, the LL DROP-P enables the user to add an online process control. So it combines all features in one optical device.

This optic has been developed by Ro-fin-Lasag in Switzerland for metal welding applications of rotary symmetric metal tanks. Combining this optic together with Dilas process control capabilities a new processing head for plastic welding processes of radial welding seams was designed.

Dedicated for plastic welding applications, this optic is featured by a servo motor that rotates the laser beam.
with up to five rotations per second around the welding seam. This allows a quasi-simultaneous welding which is programmable by a servo control and results in homogeneous temperature distribution inside the welding seam. This temperature can be controlled or monitored by a pyrometer. The laser systems fiber cable can stay in a fixed position at the same time.

The optic is available in two versions. Depending on the required welding spot size the diameter of the part to be welded can vary between 5 mm and 180 mm (Fig. 8). This is possible because of the long imaging ratio and the resulting focal depth. Also different spot sizes are available and hence different welding seam widths can be realized. The spot size depends on the fiber core diameter of the diode laser system used and the collimation focal length.

**Conclusion**

Laser plastic welding is an established process in the automotive, medical device and consumer industry. High flexibility of the process enables new welding approaches. Especially for radial welding seams, Dilas developed optical solutions that enable the customer to improve throughput and to create new production strategies.

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