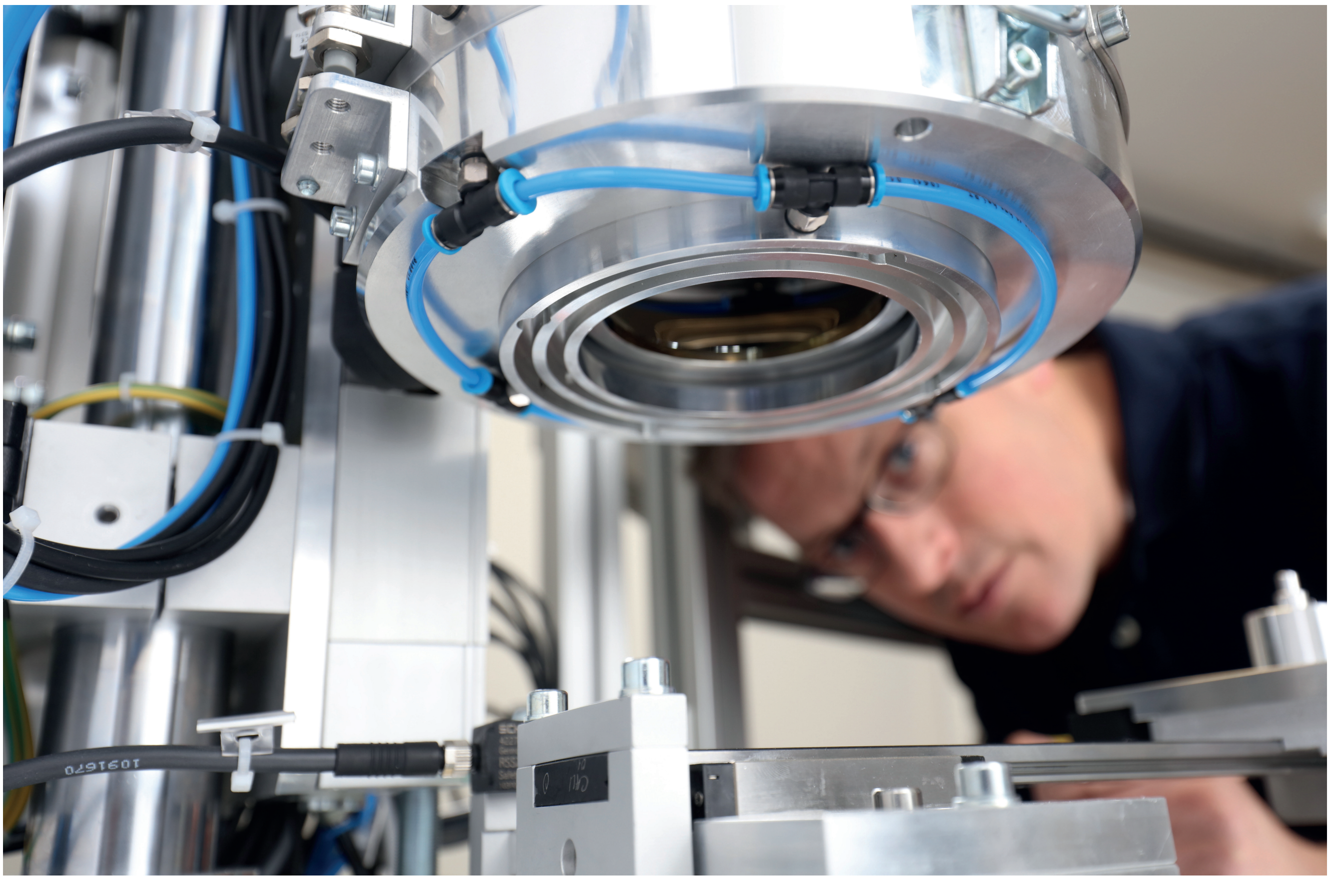
Laser Welding Re-Thought

Increasing Process Efficiency through Advanced Quasi-Simultaneous Welding

Evosys Laser GmbH has patented a new variant of laser welding that combines two laser beam sources and wavelengths. This approach is not limited to contour welding, but is particularly aimed at significantly reducing welding times and extending the process window in quasi-simultaneous welding.



View inside an Evosys laser welding system © Evosys

Laser welding of plastics is an established and preferred joining method in plastics technology due to its numerous advantages. The predominant principle for joining plastics by means of laser radiation is so-called through-transmission welding, in which the parts are joined in an overlapping arrangement using a single laser source. The laser beam is focused through the upper layer onto the contact surface of the laser-absorbing, lower joining partner. The beam energy is absorbed there and converted into heat, causing the lower part to melt. The upper joining partner is also plasticized via heat conduction – the melts join and a material bond is created.

Preferred laser sources are diode lasers that emit in a wavelength range of approx. 800 nm to 1000 nm. In this range, most engineering thermoplastics are transmissive enough in their natural state to be used as transparent joining parts. The absorption properties, on the other hand, are usually adjusted by adding laser-absorbing additives, such as carbon black.

This process principle has various disadvantages. Especially with the variant of contour welding without a welding collapse, the parts must be geometrically very precise in the contact area, as air gaps can only be bridged with difficulty. Furthermore, the temperature gradient between the two components is comparatively high, which can have an unfavorable effect on residual stresses in the weld seam. Overall, these disadvantages limit the process window.

To counteract these effects in laser transmission welding, a more homo- »

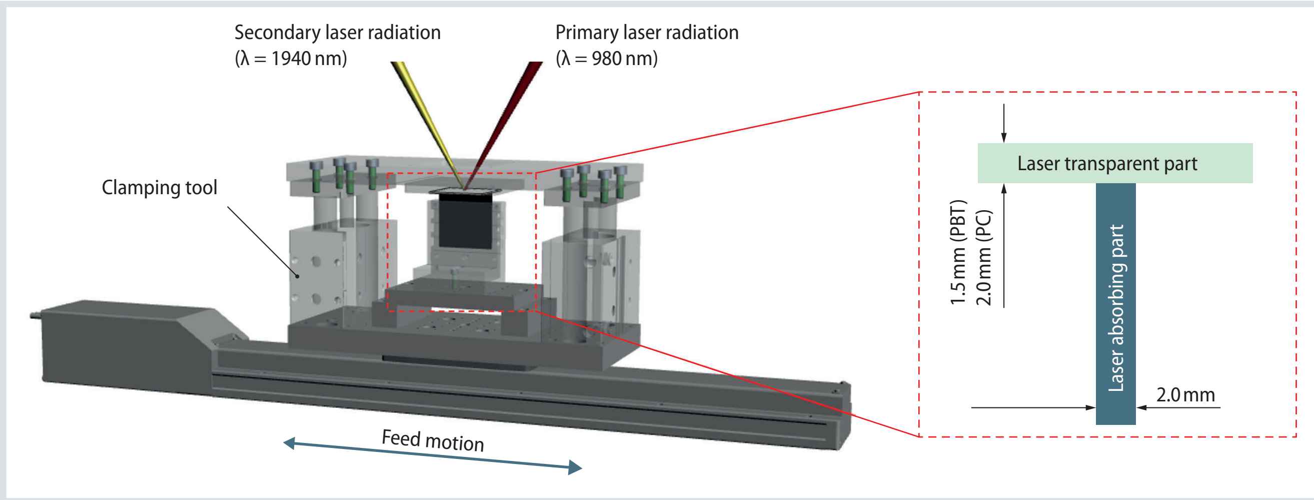


Fig. 1. Test setup and welding configuration for advanced quasi-simultaneous welding Source: Evosys;, graphic: © Hanser

geneous temperature field is advantageous, in which the upper joining partner is not only heated by heat conduction from the joining zone, but also heats up more spatially. One solution for this is so-called hybrid welding, which is already state of the art in contour welding. Here, another radiation source is added to the primary processing laser. Its secondary radiation can, for example, consist of light of several wavelengths, with the aim that certain components are also absorbed in the upper joining part and converted into heat.

Better Process Control through Selective Energy Input

A new approach to laser welding with multiple beam sources is being developed by Evosys Laser GmbH. In contrast to the technique described above, the workpiece is not irradiated simultaneously by the primary and secondary sources, but the radiation is alternately switched back and forth between the two in a specific time pattern. With this irradiation strategy and a targeted selection of the applied wavelengths, the selective introduction of energy into one or the other joining part can be better controlled and matched to the desired process results. Since this development is aimed in particular at a quasi-simultaneous welding process, a laser is used as a secondary radiation source as well, since it facilitates integration into common beam guidance systems, such as a galvanometric scanner.

The focus of this process, called "Advanced Quasi-Simultaneous Welding" (AQW), is on extending current process limits, with the main aim of enabling a more efficient, reliable and faster welding process. To this end, tests were carried out on the materials polybutylene terephthalate (PBT) and polycarbonate (PC) in order to specifically shorten the welding time and increase the quality of the welded joint (the latter characterized by the tensile strength of the weld). The influence on both criteria as a function of certain process parameters was investigated. PBT is a semi-crystalline thermoplastic used, for example, in the automotive industry for assemblies subject to high loads. Due to its high crystallinity and low transparency, the available process window is limited, as the material tends to burn at the surface. In contrast, PC is an amorphous, optically highly transparent polymer that is used especially for displays or lighting applications that require high transparency. The latter favors the high temperature gradient in the joining zone, which in turn can lead to high residual stresses and ultimately stress cracks near the weld seam after cooling.

A widely used 980 nm diode laser was applied as primary source together with a 1940 nm fiber laser as secondary source for the experiments. The two materials exhibit a significantly lower transmission rate near the secondary wavelength of about 2 µm compared to the primary radiation, so that a direct spatial heating of the upper joining partner can be expected by the secondary radiation.

Test Setup with Two Plates

In the test setup, the typical joining geometry of a quasi-simultaneous welding process is realized, in which two flat sample plates are arranged to form a T-joint. They are fixed with a clamping tool and pressed onto each other, ensuring thermal contact in the joining area. The laser beams of the primary and secondary sources are focused on the same spot of the component by a suitable optical and mechanical setup, and the T-joint specimens together with the clamping tool are moved several times and at high feed rates under the laser spots (**Fig. 1**).

This relative movement between the lasers and the joining part creates the weld contour (in this case a line), with the multiple overruns leading to the characteristic (quasi-) simultaneous plasticiz-

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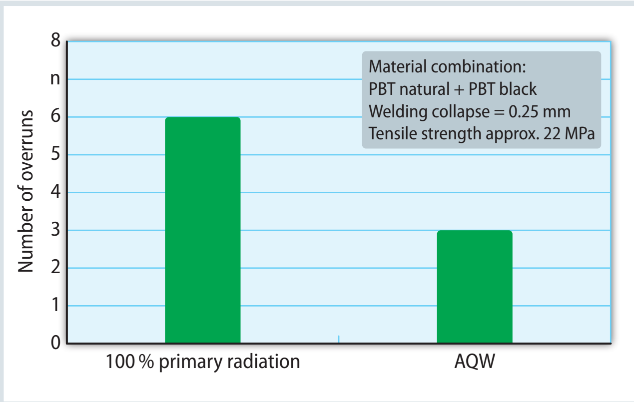

Fig. 2. The number of overruns can be halved with AQW, thus ensuring a shorter welding time Source: Evosys;, graphic: © Hanser

ation of the entire weld. The completely melted weld contour allows the laser transparent part to move under the clamping force towards the absorbing joining partner, which is called the welding collapse. It is a parameter that can be sensed and is often used for process control. During the welding process, the two laser sources are switched back and forth at high frequency. Short switching intervals ensure that the parts to be joined are exposed to both radiation wavelengths in just one overrun.

Experiment to Reduce the Welding Time with Plates Made of PBT

The investigations into the possible reduction of the welding time are carried out on the sample plates made of PBT. As a welding time reference, the number of overruns necessary to achieve a welding collapse of 0.25 mm with 100% primary continuous radiation is determined (this corresponds to the conventional quasi-simultaneous process). The feed rate is kept constant and the laser power is selected so that just no surface burns occur. Thus, this resulting weld time reference represents the shortest time possible with a single beam source at 980 nm. The next goal is to add secondary laser radiation to reduce the number of necessary overruns, again with the requirement of not causing any burns on the component surface.

PC in Practical Test for Weld Seam Strength

The tests to increase the weld strength are carried out on the material PC. For this purpose, the number of overruns (and thus the welding time), the feed rate and the weld path are specified; the laser power of primary and secondary radiation are the variable parameters and are combined with each other in various ways. Starting from 100% primary radiation, this is reduced in various steps and supplemented with secondary radiation to the extent that an equal welding collapse of 0.2 mm is always achieved. All specimens are tested in a tensile strength test to determine the tear-off force of the weld.

Welding Time Is Halved, Tensile Strength Increases by One Third

Through the additional use of secondary radiation, the number of overruns and thus the welding time can be halved for the same welding collapse (**Fig. 2**). No burns occur on the surface of the transparent component. The tensile strengths are comparable for both process variants, so that no impairment of the weld seam quality is to be expected.

In **Figure 3**, the tensile strengths of the T-joints made of PC are plotted against the proportion of primary radiation, starting from the left with 100% to the right with 0% (100% secondary radiation). The graph shows that the tensile strength of the specimens increases by using the AQW method. The highest strength value is obtained by welding the parts with 75% primary radiation combined with secondary radiation. This means that the strength increased by more than one third compared to the standard process with only one laser source. Using the same amount of primary and secondary radiation, the strength is similar to the standard process. A further increase in the proportion of secondary radiation reduces the strength of the weld, so there is an optimum ratio of the two radiation proportions.

The Advanced Quasi-Simultaneous Welding (AQW) process trials show that a significant improvement in process time and weld strength is possible compared to the standard single laser source process.

Due to the wavelength of the secondary laser radiation, more energy is absorbed in the transmissive joining partner during the entire process. This increases the plasticized and melted material volume of the laser transparent part. By switching between the two beams, the total energy introduced into the joining area can be increased without damaging the absorbing or the transparent joining partner. This results in faster plasticization and thus a faster and more efficient welding process. ■

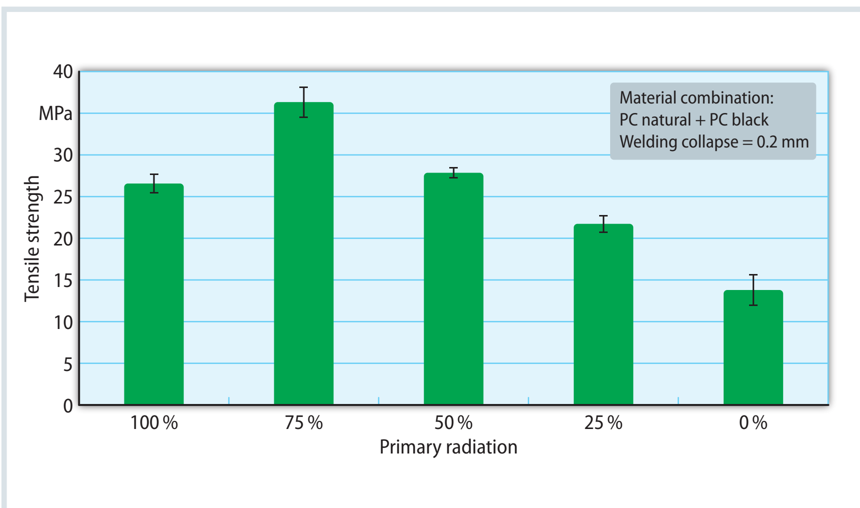

Fig. 3. The highest tensile strength with AQW is achieved at 75 % primary radiation – and is one third higher compared to the standard process Source: Evosys;, graphic: © Hanser