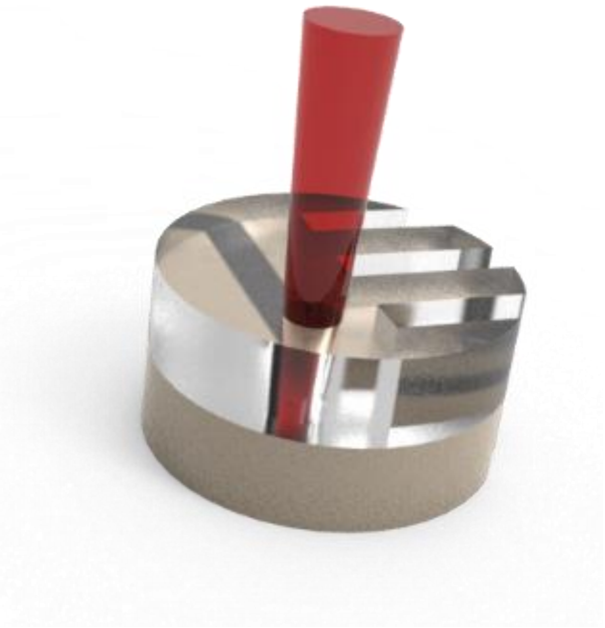

GUIDELINE –

LASERWELDING OF PLASTICS

Evosys Laser GmbH, Schallershofer Straße 108, 91056 Erlangen

Content

1. Foreword

The information listed below about the design of plastic moldings for laser welding is based on our long-standing experience. We have tried through the proper selection of the most important issues to ensure a brief overview and quick introduction to the technology. On your request, the EVOSYS application experts are happy to support you personally in the design of your assembly.

2. Procedural principle

When laser transmission welding, the two parts to be joined are placed in the lap joint and affixed in this position already before welding by means of a suitable clamping device. The laser beam passes through one of the two joining partners, which is largely transparent to the laser radiation, through to the second joining partner (Figure 1).

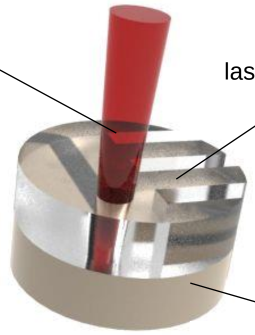

Figure: Principle of laser transmission welding

This absorbs the laser radiation on the surface and is melted. The heating and melting of the transparent joining partner is largely done by thermal conduction from the absorbent to the transparent joining partner. The weld seam is produced due to the relative movement between the laser beam and the component to be welded.

3. The process variants

Depending on the relative movement between the laser beam and joining assembly as well as the type of the energy input, the laser welding of plastics is divided into different process variants.

3.1 Contour welding

In contour welding, the weld seam is traversed once or several times with a focused laser beam. When passing over a portion of the weld seam by the laser beam, this is heated up to the melting temperature range and then immediately re-solidifies so that a fusion of the two joining partners immediately results.

Contour welding is always to be used when melt flash is to be avoided for aesthetic or functional reasons. In addition, you are only limited with respect to the component dimensions by the traversing range of the kinematics used in contour welding so that even components with dimensions > 1 m can be processed.

Figure: Principle of contour welding

Contour welding also offers advantages over other welding processes if a temperature control is to be realized through pyrometer.

Furthermore, contour welding is used for radially symmetrical components where the laser beam must meet the component radially, because of the joint geometry. In such cases it makes sense to either move the component by means of a rotational axis and to keep the laser stationary or to move the laser by means of a suitable optical configuration around the component.

3.2 Quasi-simultaneous welding
With quasi-simultaneous welding, the weld seam is repeatedly traversed with a focused laser beam at a high speed. All areas of the weld seam are heated and melted at nearly the same time (i.e. quasi-simultaneously).

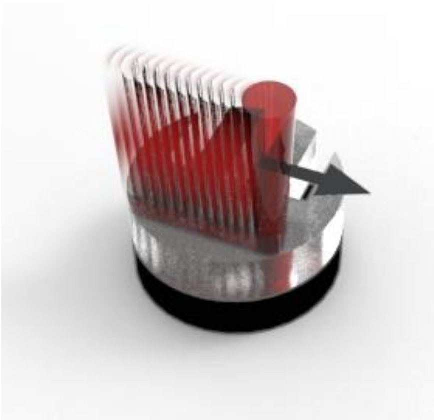

Figure: Principle of quasi-simultaneous welding

Through the simultaneous melting of the entire welding contour and the clamping force applied by the clamping technology, the two components to be joined move toward one another and the melted mass is laterally expelled at the weld seam. This collapse serves to compensate for component unevenness and can be used simultaneously for process control.

5.3 Simultaneous welding
With simultaneous welding, the entire weld seam is simultaneously heated and melted by one or more laser sources. The arrangement of the beam sources and beam formation by means of suitable optical elements must be carried out so that the energy input per unit length introduced during the welding process is as even as possible over the entire weld seam.

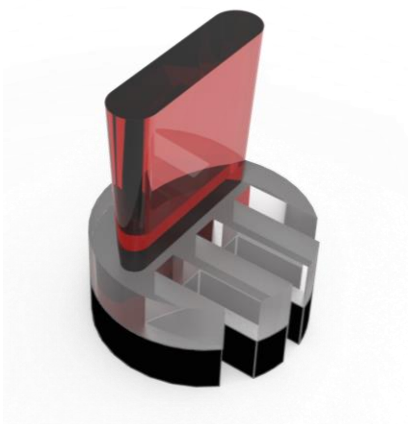

Figure: Principle of simultaneous welding

Due to the simultaneous melting of the entire welding contour and the force applied by the clamping technology, the two components to be joined move towards each other just like with quasi-simultaneous welding and the melted mass is laterally expelled at the weld seam. The collapse serves on the one hand to compensate for component unevenness and on the other hand it can be simultaneously used for process monitoring. A weld seam produced in the simultaneous welding process is basically the same in appearance as a weld seam produced in quasi-simultaneous welding processes.

4. Materials

4.1 Material selection
Thermoplastics take a special position among polymer materials due to the molecular structure and the associated thermal properties. They are both fusible and malleable. This behavior allows the

welding of two thermoplastic polymers. The prerequisite for this is a chemical and thermal minimum compatibility of the two materials. In addition, the melting ranges of the two materials to be welded must overlap. This is the case especially when connecting similar thermoplastics. The selection of the individual polymers in mixed-material welding is much more difficult and usually requires intensive inspections. Here we strongly recommend getting in touch with our experienced EVOSYS application experts.

4.2 Molecular order and transmission

Amorphous thermoplastics only absorb a small portion of the incident laser radiation at specific wavelengths. In contrast, the optical properties of semi-crystalline thermoplastics differ significantly from those of the amorphous thermoplastics. The crystalline superstructures present there cause multiple undirected reflection of the laser radiation (scattering). The absorption coefficient rises with an increasing degree of crystallization. The reflection of infrared radiation by the material itself is larger with semi-crystalline thermoplastics than with amorphous thermoplastics.

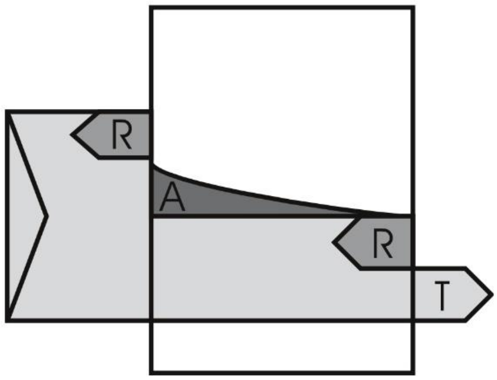

Figure: Radiation portions for the material passage (beam direction from left to right)

The wavelengths usually used for the laser welding are also partly absorbed (A), reflected (R) and scattered (T) in an uncolored and unfilled plastic.

transparent material (columns) / absorbing material (rows)

	ABS	ASA	COC	EVA	LCP	MABS	PA 11	PA 12	PA 6	PA 66	PBT	PBT/ ASA	PC	PC/ ABS	PEEK	PE-HD	PEI	PE-LD	PES	PET	PI	PMMA	POM	PP	PPS	PS	PSU	PUR	PVC	SAN	SB	TPE
ABS	++	++				++					++	+	++	++					+	++		++				+	+		++	++		++
ASA	++	++									++	++	++	++								++							++	++		
COC			++																													
EVA				++																												
LCP					++																											
MABS	++					++																										
PA 11							++																									
PA 12								++																								
PA 6									++	++																						
PA 66									++	++																						+
PBT	++	++									++	++	++						+	++		+					+			++		
PBT/ASA	+	++									++	++	++						+			+					+					
PC		++									++	++	++	++					++	++		++							++	++		+
PC/ABS		++											++	++								+										
PEEK															++																	
PE-HD																++		++														
PEI																	++															
PE-LD																++		++														
PES	+										+	+	++						++								++					
PET	++										++		++							++										++		
PI																					++											
PMMA	++	++									+	+	++	+								++				+			++	++		
POM																							++									
PP																								++								++
PPS																									++							
PS	+												+									+				++				++		
PSU	+										+	+							++								++					
PUR																												++				
PVC	++	++											++									++							++	+		
SAN	++	++									+		+							++		++				++			+	++		
SB																															++	
TPE	++										+		+											++								++

++ good weldability // + weldable - tests necessary // 0 poor weldability

Figure: Overview of weldability of different materials

Plastics are rarely put to use in their pure form. Mostly mechanical and thermal as well as optical adjustments of the polymer are made.

In addition to the possibilities of chemical modification of the monomers, additives, fillers or reinforcing materials are often used today.

4.3 Additives or functional additives

Additives are mixed with the polymer in small amounts and thus cause a change to the appropriate properties. As the additives are usually very different in size, shape and color compared to the basic material, in addition to the desired properties, other properties of the plastic can also be changed. The most commonly used additives are listed in the following:

- Flame retardant
- Solid lubricants
- Nucleating agent
- Metals
- Plasticizers

Due to the high variety of different additives on the market, we recommend consulting an EVOSYS application expert in any case regarding influencing the behavior of the laser radiation welding.

4.4 Fillers

The term 'fillers' is generally used for powder, organic or inorganic substances. Their addition to the base polymer is usually intended to increase the volume and weight as well as to improve the technical usability in terms of strength, elongation and elasticity.

Polymers modified with organic fillers can usually not be processed with the joining method of laser welding due to the very strong absorbance of additives and the low decomposition temperatures of the organic particles.

Much more relevant for the laser welding of plastic materials is the use of inorganic fillers (calcium carbonate, talc, glass beads). However, as a number of different versions also exist on the market here and the filler proportion has a huge impact, the exact impact for the specific application case should be metrologically clarified in advance.

Specifically, consultation with an EVOSYS application expert will provide quick information.

4.5 Reinforcing materials

Another technically important method for modifying the mechanical properties of a plastic is the use of reinforcing materials. Reinforcing materials are generally understood as filler particles that serve to increase the mechanical strength. Characteristic is the fiber-like geometry with a large length to diameter ratio. Today, synthetic inorganic substances, such as glass, carbon and aramid fibers, are used for polymer reinforcement.

Glass fibers are used these days for most technical applications with high mechanical loads. The impact on laser radiation welding lies on the one hand at varying transmission properties with varying fiber content. On the other hand, the influence on the seam strengths must be considered. Despite the high transparency of glass in a natural state in any form, the addition of glass fibers significantly affects the transmission properties of thermoplastic materials. Nevertheless, polymers with a fiber content of up to 50% can be welded by laser radiation with suitable process control.

It is possible to use carbon fibers for applications in which the stiffness and strength of glass fibers are insufficient. Since C-fibers are made of graphite, these types of reinforced materials have an extremely high absorption of radiation in the near infrared range. The absorption properties of carbon fiber-reinforced polymers are very similar to those of carbon black filled polymers. The use in laser plastic welding applications is only possible as absorbing joining parts due to this property.

Specifically, consultation an EVOSYS application expert will provide quick information.

4.6 Coloring

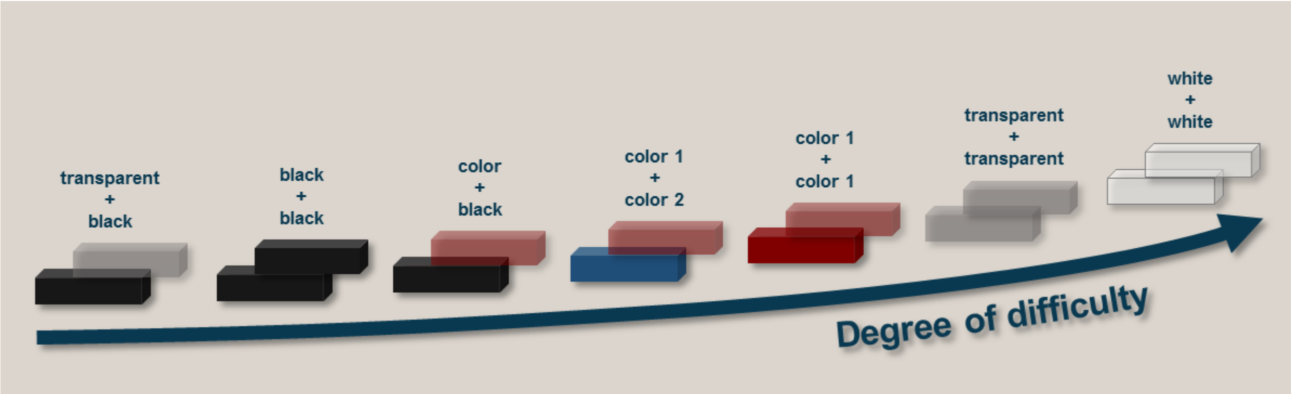

Figure: Degree of difficulty of color combinations

Seldom are plastics processed in the uncolored state into a final product. Aesthetic perspectives and requirements must be taken into account for consumer products or visible components in the automotive sector, for example. However, functional colorations, such as signal colors, are also required in certain areas.

For this reason, colorants are added to the plastics during processing, which change the outer appearance according to the specifications. Creating a color matrix of laser-transparent and laser radiation absorbing color settings is not possible due to the large number of variables, such as paint, plastic, section thickness, laser wavelength, speed of processes, approvals, etc. Therefore, a degree of difficulty of the color combinations has been created (see chart) with which an initial indication for the use of color can be made for laser plastic welding.

Color additives can be distinguished between pigments insoluble in plastic and soluble colorants. Both groups have a strong influence on the laser radiation welding of plastics, since they affect the visual properties of thermoplastics in the near infrared range.

In contrast to the colorants, the pigments in the plastic are almost insoluble. The pigments can be inorganic or organic in nature, whereby the inorganic pigments are completely insoluble.

The most important group among the inorganic pigments is made up of the black pigments. The most important representative is carbon black, which besides being financially attractive also has a positive impact on the properties of the plastic. Carbon black already provides sufficient coverage at very low concentrations from 0.5 to 1%. It is ideal for coloring the laser-absorbing joining partner, as it is absorbed in nearly the entire wavelength range.

An equally significant group among the inorganic color pigments is white pigments. The most significant representatives today include titanium dioxide TiO_2, zinc white ZnO and zinc sulfide ZnS. Since white pigments are highly reflective and scattering in response to the radiation used in laser plastic welding in the near infrared range, very white-colored components are very difficult to weld.

Due to the specific requirements of laser radiation welding for coloration regarding transmission and absorption for wavelengths in the near infrared range, special additives and colorings have been developed by the plastics manufacturing industry and colorant producers that meet the set requirements. The now likely most well-known coloring, which was specially developed for the laser welding of plastics, is the IR-transparent black. Superimposing different, conditionally laser-transparent pigments creates an opaque, black color impression of a component in the range of visible light. Unlike other black colors, the coloring thus produced is transparent to wavelengths in the near infrared range.

The use of carbon black is not possible for color settings that are bright and brilliant. However, nearly all colors can be set with the use of alternative NIR absorbers.

Transparent combinations are possible by means of a series of transparent NIR absorbers. Another possibility for the joining of transparent components is the use of laser wavelengths between 1.6 to 2 microns. In this range, absorption takes place through the plastic itself so the weld can be done without the addition of additives

Specifically, consultation with an EVOSYS application expert will provide quick information.

5. Design layout of the joining zone

An essential component of a robust process is the design of the joining zone. Basically, one can distinguish between process-independent and process-related criteria.

5.1 Process variant-independent criteria

The following criteria and statements are generally applicable to all process variants.

Material thickness

Depending on the material used for the laser-transparent joining partner, the material thickness in the area where the laser radiation passes through the transparent component should not be designed to be excessively thick. A good rule has been proven that the material thickness is chosen similarly to the planned width of the weld seam. However, as a general rule of thumb: the thinner the better! Due to the variety of different materials and color and filler variants, it is always recommended that you consult with an experienced specialist from the company EVOSYS as well as perform a transmission measurement to assess the weldability.

Accessibility for the laser beam

Due to the characteristic beam shape for the typically focused laser beam, it is necessary to ensure a shadow-free accessibility in the area above the joining zone.

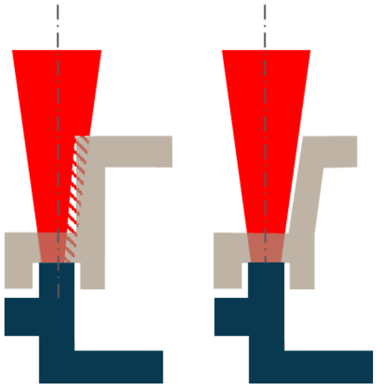

Figure: Beam shadow of laser beam

Clamping device bearing surface

An essential component of the laser welding process is the joining force between the two joining partners. It is necessary to use a clamping device in order to introduce this force into the components to be joined.

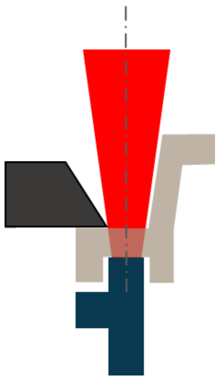

Figure: Application of clamping force

Typically an application of force is required in the immediate vicinity of the entire weld seam. To support the corresponding clamping device, sufficient space must be provided in the area of the joining zone and accessibility must be ensured for the laser beam. The force used usually is thereby in a range of 2-5 N / mm^2 with respect to the weld seam area.

Also a corresponding counter surface must be provided for receiving the applied force. In the majority of cases, this is done directly via the component and a component jig, which follows the shape contour of the overall assembly.

5.2 Process variant-specific criteria

The following criteria are especially relevant for the process variants mentioned.

Contour welding - tolerances

Since no relative movement of the joining partners to each other can take place in a contour welding process, but thermal contact between the two joining partners is also necessary, the requirements for the molded part tolerances are higher than for the other process variants.

As an example of the magnitude of the required tolerances, the flatness tolerance of a joining part with a flat weld geometry and lateral dimensions in the range of 100 mm x 100 mm should be mentioned at this point. For such an assembly, a flatness tolerance of no more than 0.08 mm would be applied.

Minor differences can be compensated for by higher clamping forces, but these lead to stresses within the assembly after the welding process.

The application engineers from EVOSYS are happy to help you with the proper choice of tolerances for your application.

Quasi-simultaneous - collapse

Unlike with a contour welding process, a relative movement of the assemblies to each other occurs during simultaneous and quasi-simultaneous welding. Usually a so-called weld rib is provided on the laser-absorbent molded part, which is melted off during processing. The laser-transparent molded part moves towards the laser-absorbent part. If the laser is switched off at the end of the process, this is followed by a cooling phase in which the cooling causes a shrinkage of the material.

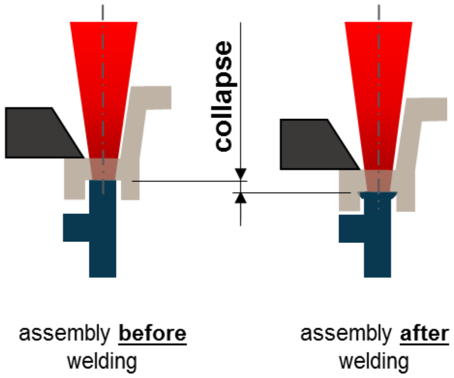

Figure: collapse

It is important in this context to take into account the relative movement and the contraction during the cooling phase

Usually the collapse for components with dimensions in the range 100 mm x 100 mm is about 0.1-0.5 mm.

Specifically, consultation with an EVOSYS application expert will provide quick information.

Quasi-simultaneous melt flash space and melt coverage

For simultaneous and quasi-simultaneous welding, melt material is displaced from the joining zone in the process due to the afore-described melting of a collapse. It is important to provide sufficient space for the displaced melted mass in the adjoining regions of the joining zone.

Since this melted mass usually interferes aesthetically or - in the case of glass-fiber reinforced materials - poses a risk of injury during subsequent manual processing, it is recommended to provide an additional structural cover.

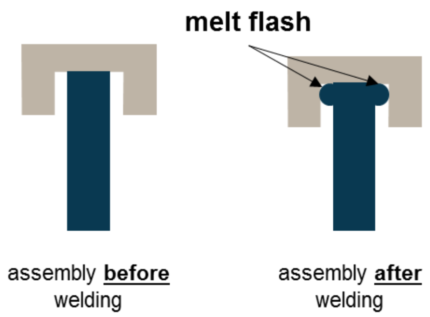

Figure: Melt flash cover

Specifically, consultation with an EVOSYS application expert will provide quick information.

Checklist

Assembly Part	
Selected process variant?	☐
Is the material selection of the base material weld able?	☐
Laser-absorbing molded part pigmented in an absorptive manner?	☐
Laser-transparent molded part colored in a laser-transparent manner?	☐
Accessibility for the laser beam ensured?	☐
Bearing surface of clamping technology available?	☐
Direction of contact pressure of clamping technology correctly designed?	☐
Receiving of lower component half possible?	☐
Positioning of the component halves to each other ensured?	☐
Collapse considered, if necessary?	☐
Flow space available for melt flash?	☐
Cover for melt flash available?	☐
	☐

Note

All information about the laser beam plastic welding process mentioned in this document is to be understood as a rough overview of the requirements of the process. Due to the many different influencing factors, we recommend including the specialists from Evosys Laser GmbH at the earliest possible stage. All information in this document is not binding and does not claim to be exhaustive.

Creation Date December 2016

Evosys Laser GmbH
Schallershofer Straße 108, 91056 Erlangen
Tel. +49 9131-81497-0
info@evosys-laser.com, www.evosys-laser.com