Laserwelding of plastics

Ir. Luc Janssen - 2008

1 Laserwelding - How it works

Laserwelding is a very versatile process and is suitable for both small-series and mass-production. The laserwelding technique is based upon the polymers *transmitting* and *absorbing* characteristics for the used electromagnetic (EM) radiation (*i.e.* laserlight wavelength). The key-requirement for success is therefore a suitable combination of optical properties of the joining partners.

The welding joint should always be made from an IR-transparent part and an IR-absorbing part (see part 1 and part 2 in Figure 1). The first part will be made from a plastic with high transmittance properties for the used laser radiation. The laserbeam will pass through part 1.

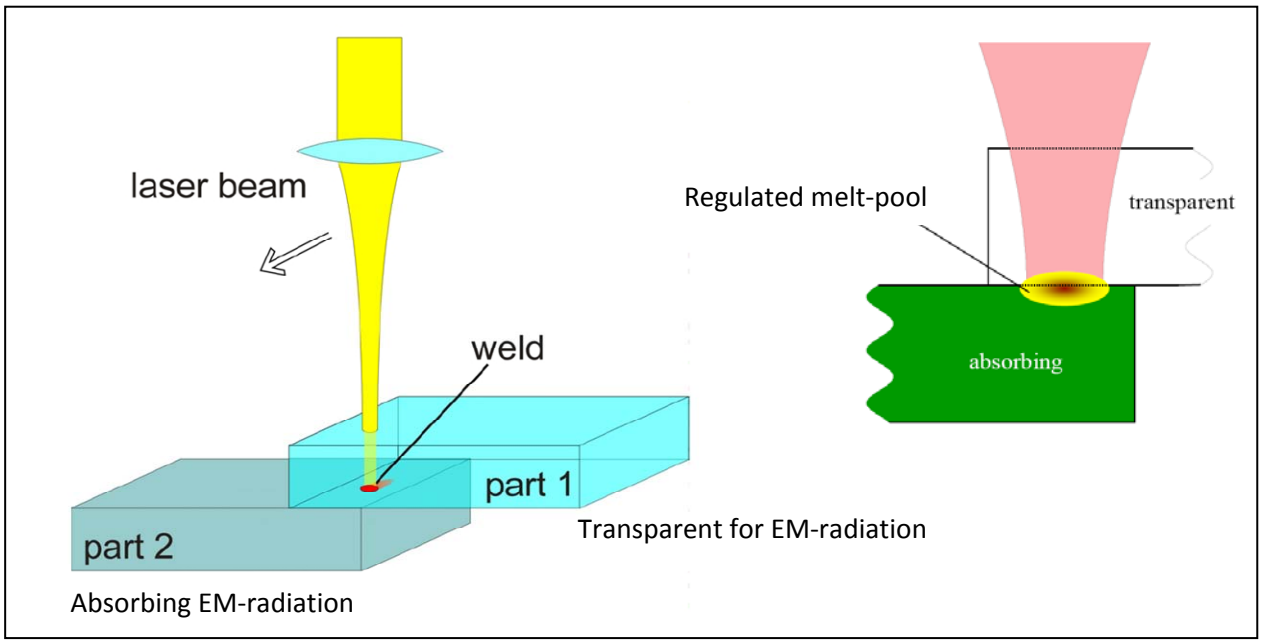

Figure 1: principle of transmission laserwelding of plastics (Philips CFT et al.[1], Bachmann and Russek [4]).

At the interface of both parts, the transmitted laser energy will be absorbed by part 2.
The absorbed beam energy is converted into heat, leading to local plasticization of the polymer. A regulated melt-pool arises in the contact interface of the two parts which, after cooling down, results in a high-graded and strong connection.

Mareco can offer her customers the two main methods for laserwelding, namely:

A. Contour welding
B. Quasi-simultaneous welding

A - Contour welding

Contour welding is a sequential welding process in which either the laser beam is guided along a freely programmable weld profile or the component is moved relative to a fixed laser. Since the melting of the weld takes place sequentially no melt flow-out is possible, and therefore only a small joint gap is permissible. As the weld length increases the resultant process times are several seconds.

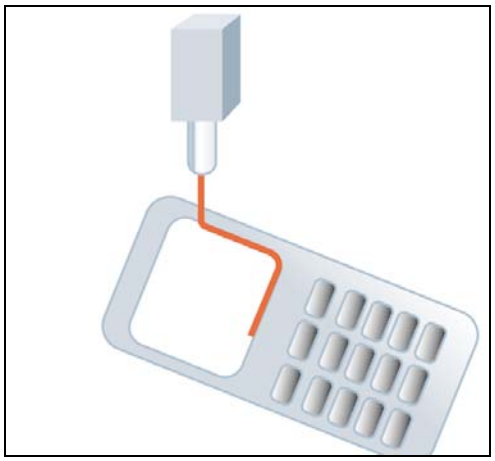

Figure 2: Contour welding (BASF Plastics [5]).

In contour welding, the laser beam is run along the joining seam so that only local plasticization results. Since plasticization takes place on a highly localized basis, the accuracy of the parts to be joined is particularly important. With this process variant, only very small gaps can be bridged with the heat-conditioned volume increase that results in the absorbing part.

B - Quasi-simultaneous welding

Quasi-simultaneous welding is a combination of contour welding and simultaneous welding. Galvanometric mirrors (scanners) are used to guide the laser beam along the weld profile at very high speeds. The high speed of transit gives progressive heating and melting of the region to be welded. Unlike with simultaneous welding, there is high flexibility for changes in weld profile (BASF Plastics, [5]).

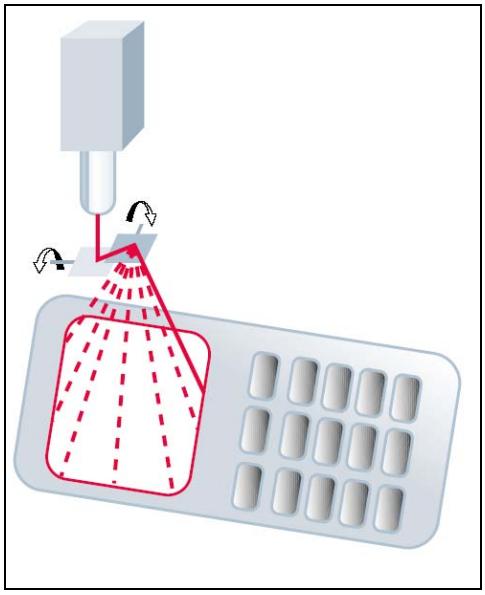

Figure 3: Quasi-simultaneous welding (BASF Plastics, [5]).

With quasi-simultaneous welding, the entire joining surface is similarly plasticized at “quasi” the same time, with the laser beam being guided over the surface to be joined with deflection mirrors. Virtually uniform heating of the absorbing material then results.

2 Advantages of laserwelding

Laserwelding is an advanced technique to create a lasting and high-graded connection between plastic parts. By integrating robotic movements 2D and 3D contours are perfectly laser weldable. Compared to the more traditional assembly methods (like glueing, ultrasonic welding and vibration welding), laserwelding offers significant benefits.

Major benefits of laserwelding:

★ **Excellent visual part apperance**
- o 'hidden' overlap joints can be made without affecting part surface
- o high-graded and clean seal : no or hardly any weld-flash is formed
- o no damage to part exterior as only limited mechanical (welding) load is applied

★ **No temperature stress on the product**
The heat affected zone is very small.

★ **No need for 3rd component (e.g. glue)**

★ **Liquid-tight and gas-proof sealing**

★ **Non-contact process**

★ **Sensitive parts or components (like electronics) are not affected**
No electrical fields or mechanical vibrations are generated during the welding process.

★ **Accurate and reproducable welding**
Precise positioning of the weld contour and controllable energy (heat) supply.

★ **Series production**

★ **Flexible**
Flexible welding of 2D and 3D shaped contours.

3 General boundary conditions for laserwelding

Some boundary conditions as to materials and product design have to be fulfilled in order to make quality laserwelding joints. Mareco can offer her customer assistance in this trajectory by physical experiments (see laserwelding test-strip) and weld-designs suggestions/optimizations.

Boundary conditions are:

→ **OPTICAL PROPERTIES**

Important optical aspects which influence the weldability and quality of welding joint are

- transmittance of laserenergy (*i.e.* transparancy for laser radiation)
- absorbancy of laserenergy
- reflectivity (amount of incident laserbeam reflected back)

Please note that the above mentioned optical properties may change with:

- *part thickness*
- *colour (see also Section 5)*
- *pigment concentration*
- *pigment supplier*
- *polymer reinforcements (glass-fibres etc.)*
- *flame-ratings*

→ **CHEMICAL COMPATIBILITY**

In order to create a strong bond between the joining partners have to be chemically compatible

→ **THERMAL COMPATIBILITY**

- welding temperature must be above the melting temperature for both parts.
- welding temperature should be less than the decomposition temperature of both polymers.

(Boundary conditions continued)

→ **PART DESIGN: GEOMETRICAL ACCURACY OF PARTS TO BE JOINED TOGETHER**

At the welding interface the geometrical accuracy of the part (*i.e.* part flatness) is very important. In order to get an uniform melt-pool, heat conduction to the IR-transparent part is very important. Small gaps act like heat-insulators preventing good heat-conduction.

→ **PART DESIGN: GEOMETRICAL CONSTRUCTION OF WELDING AREA**

For example is the welding area reachable for the laser and are there any sharp weld edges in Z-direction.

→ **PART DESIGN: CLAMPING PRESSURE**

The ability to apply homogeneous pressure on the welding area of the part during welding. Both joining partners have to be in optimal contact with each other (heat conduction). In general the necessary clamping force is lower than with other welding techniques.

4 Laserwelding test-strip

If a customer wants to investigate and/or test the actual quality of a laserwelding bond between two specific polymers, Mareco can offer to mould and laserweld special test-strips.

For this Mareco has manufactured a tooling for injection moulding these strips. The test-strips are used for laserwelding experiments and have proven to be an efficient and practical method for determining whether two polymer types or grades can be laser welded to each other (see figure below). It also gives a very good impression of laserweld quality and appearance.

Figure 4: laserwelding test-strip Polycarbonate/Polycarbonate (source: Mareco Kunststoffen 2006)

Main advantages of using laserwelding test-strips:

1 **PRACTICAL AND EFFICIENT TEST TO INVESTIGATE THE LASER WELDABILITY OF TWO SPECIFIC POLYMERS.**

2 **ACTUAL WELDED SAMPLES OUT OF THE SPECIFIED POLYMER CAN BE SUPPLIED TO THE CUSTOMER.**

3 **SAMPLES FOR TESTING LASERWELD QUALITY / STRENGTH.**

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5 Polymer matrix

The idea of the polymer matrix (see Figure 5) is to give a rough overview of thermoplastic polymers welded to the contributers.
Please note that the polymer matrix is not at all complete. Specific polymer combinations not listed in the matrix below may still be laser weldable. The most efficient method to test not listed combinations is by making laserwelding test-strips (see previous chapter).

Transparent	"Black"	ABS	PA	PBT	PC	PE	PEEK	PEK	PES	PET	PMMA	POM	PP	PPS	PS	PSU	PVC	SAN
ABS	Acrylnitril-Butadien-Styrene	+	+									+/-	-					+
PA	Polyamid		+															
PBT	Polybutylene-Terephthalate			+/-	+													
PC	Polycarbonat	+		+	+						+							+/-
PE	Polyethylen					+												
PEEK	Polyetheretherketone						+/-											
PEK	Polyetherketone							+/-										
PES	Polyether-Sulfone								+/-									
PET	Polyethylene-Terephthalat									+								
PMMA	Polymethyl-Methacrylat	+			+						+							
POM	Polyoxymethylene											+/-						
PP	Polypropylene												+					
PPS	Polyphenylene-Sulfide													+				
PS	Polystyrene														+			
PSU	Polysulfone															+		
PVC	Polyvinyl-Chloride																+/-	
SAN	Styrene-Acrylonitrile	+			+/-													+

Figure 5: Polymer matrix (Philips CFT et al. [1]).

Laserwelding is an optical process. The weld properties are thus governed very considerably by optical parameters such as absorbancy and scattering.

6 Influence of colour pigments

Laser tranmittance can be greatly affected by colour pigments. The colour pigment of the components is a key factor contributing to the weldability and getting a high-quality polymer weld.

The colour pigment has to fulfill two key aspects simultaneously:

1) THE ACTUAL COLOUR SPECIFICATION (AESTHETIC OR FUNCTIONAL)
2) TRANSMISSION AND ABSORPTION CHARACTERISTICS FOR THE LASERBEAM

The influence of colour pigments on laser transmittance is shown in Figure 6.

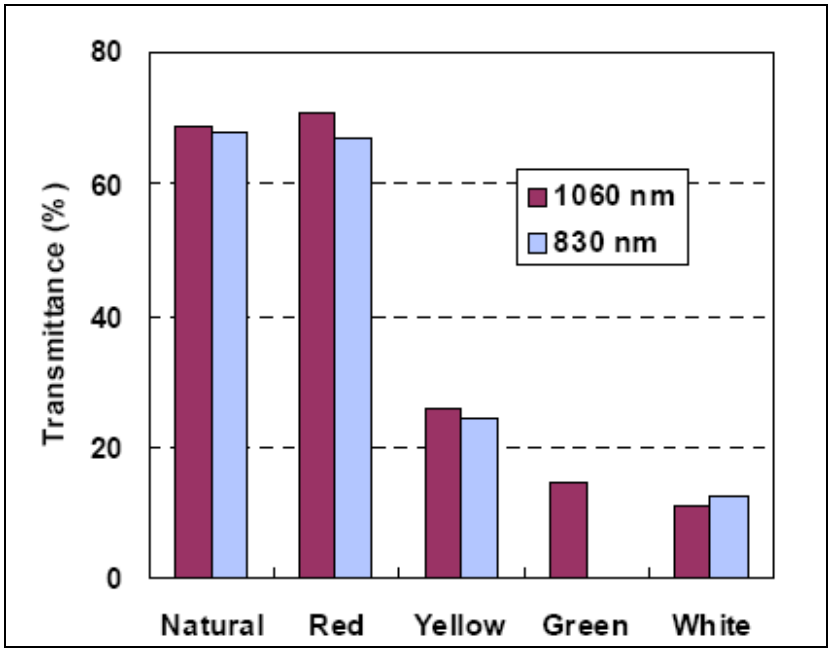

Figure 6: Influence of laserenergy transmittance for following versions of coloured nylon: natural, red, yellow, green and white (BASF [6]).

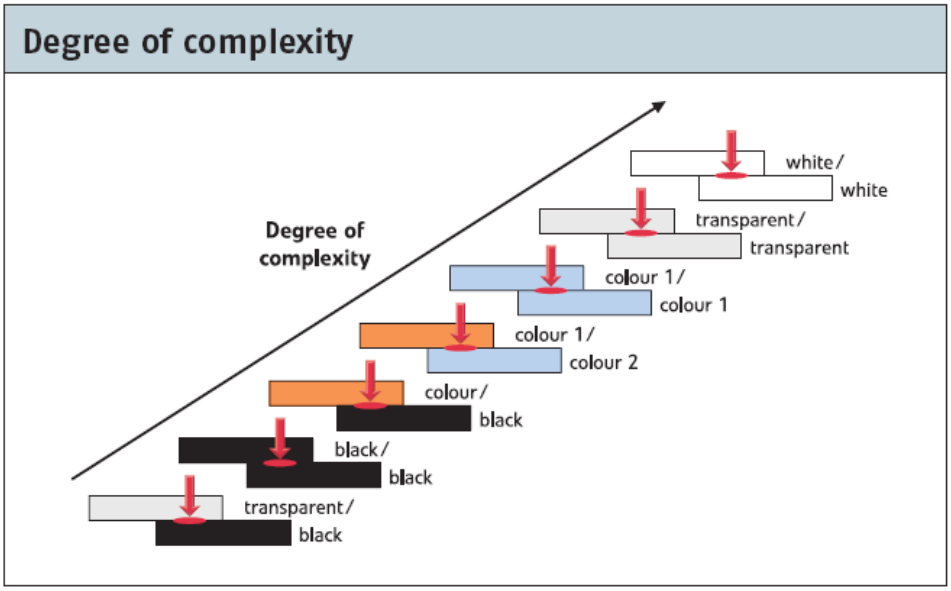

Figure 7: general level of difficulty with overlap welding of plastics in different colour combinations (Renner & Sieffert, [3])

7 Contact information

If you should have any questions or need additional information, please feel free to contact:

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References:

[1] Philips CFT and others,
New advances in polymer laser welding

[2] Ir. L.J.P. Janssen
Laserlassen van kunststoffen
Presentation for Kunststoffenbeurs Veldhoven, 2007

[3] Thomas Renner and Michel Sieffert
Laser-adapted construction for plastic welding
Laser Technology, Kunststoffe 2/2004, pp 30-36

[4] Friedrich G. Bachmann and Ulrich A. Russek
Laser Welding of Polymers Using High Power Diode Lasers
Photonics West 2002 Conference , 2002

[5] BASF Plastics
Transmission laser-welding of thermoplastics
Technical Information for Experts 02/00e

[6] BASF Corporation
Relationship between optical properties and optimized processing parameters for throughtransmission laserwelding of thermoplastics
BASF, 2003

List of Figures

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