Lasers in Manufacturing Conference 2015

Laserwelding of transparent polymer films

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1. Abstract

In the field of packaging technology in many cases transparent polymer films are used for food but also for goods packaging. The polymer based packaging protects the goods in transit from the environment but also against transportation typical stresses such as shocks, etc. Conventionally the polymer films are sealed by a heat sealing jaws method or ultrasound. So far, the use of laser sources could be realized only for very thin or specially modified absorbing films. Polymers have a wavelength dependent absorption coefficient. Most polymers, which a relevant to the packaging technology, have in the spectral range from 1500 nm to 2000 nm an absorption peak or areas of increased absorption. Newly especially for polymer welding developed diode laser modules emit laser radiation precisely in these areas of higher absorption. Therefore it is possible with the aid of an adapted beam shaping to laserseal directly commercially available packaging films without any modification. On the basis of thin sections and tensile tests the suitability of laser-based sealing process is demonstrated on representive samples directly from the packaging industry.

Keywords: Lasertransmissionwelding; Packaging technology; Multilayer Films; Polymer

1. Motivation

In the field of packaging technology in many cases transparent polymer films are used for food but also for goods packaging. The polymer based packaging protects the goods in transit from the environment but also against transportation typical stresses such as shocks, etc. The polymer films are usually made up of several different layers. Each of these individual layers satisfies a specific function. These are for example, barrier function against oxygen and water, printable function or sealing function. The film composites are built and assembled for the purpose. The packaging good is then enclosed in the packaging process from all sides with this film.Conventionally the polymer films are sealed by a heat sealing jaws method or ultrasound. A significant trend in the packaging industry is towards ever smaller lot sizes and high flexibility. Packagings are designed more and more individualized. Therefore, the format of the package has to be changed often during the packaging process. Through the use of laser radiation as a geometry-free tool, high format flexibility can be achieved. Initial approaches pursued the use of a carbon dioxide gas laser as a radiation source for joining [Gillner, 2009]. However, due to the absorption length films only up to a certain thickness can be joined. In addition, complex beam delivery systems are necessary. Another approach is to add to the market provided packaging films an additional absorber layer in order to realize the use of highly available laser sources in the range of 1000 nm [Russek 2009]. The introduction of an additional absorber layer is associated with additional costs and effort and especially in the field, for example of medical technology undesirable. Therefore in this paper the use of wavelengths adapted diode lasers for joining market multilayer polymer films without modification is investigated.

2. Lasertransmissionwelding with adapted wavelength

In the process of laser transmission welding, the two films are positioned in an overlapping arrangement. In order to achieve a technical zero gap a joining pressure is applied via a clamping system which also fixes the sheets during the joining process. The laser beam is then passed over by a moving system along the welding contour (Figure 1, left). For beam shaping a laser optic with a high numerical aperture is used. This provides a more favorable energy per area ratio on the surface.

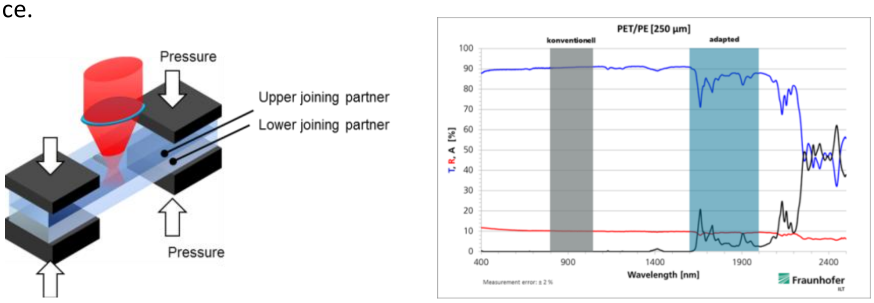

Fig. 1. Principle of lasertransmissionwelding (left), Optical Spectrum of Polyethyleneterephthalate PET (right) [3]

Polymers have a wavelength-dependent absorption coefficient (Figure 1, right, black). The absorption coefficient increases with increasing wavelength and has so-called areas of higher absorption / absorbance peaks [Mamuschkin, 2013]. The conventional laser sources used for laser welding of plastics emit radiation in the range of 800 to 1100 nm. In this area, transparent plastics have no or only a low absorption. To achieve a sufficient energy input the plastics must be modified by the addition of absorbers for example carbon black to become weldable. With newly developed laser sources which emit laser radiation in the range of 1500 - 2000 nm areas of higher absorption or direct absorption peaks can be reached. The location (wavelength) and the size (percentage) of the absorption peak are dependent on the polymer (Figure 2, left).

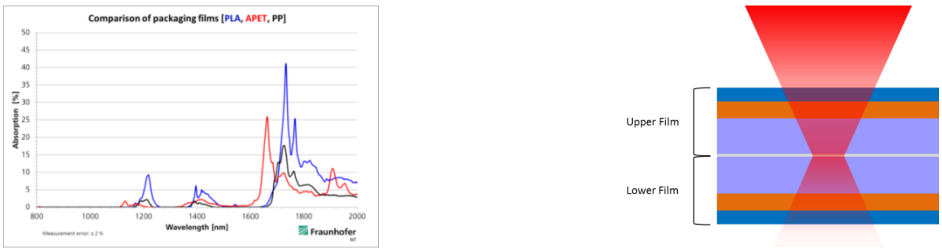

Fig. 2. Optical Spectrum of polymer packaging films (left) Laserbeam penetration of multilayer polymer films (right)

Commercially available polymer films for the packaging sector usually consist of several layers. The individual layers in turn consist of various plastics. An often used combination is, for example, a polyethylene terephthalate /polyethylene [PET / PE] multi-layer film. PET is the basic substrate and PE the applied low-melting sealant layer. In the joining process the PE layer is then sealed with the opposite PE layer. Depending on the application additional layer such as barrier layer for example EVOH are added. During the laser transmission welding process, the laser radiation irradiates all layers (Figure 2, right). Each layer consists of a different polymer and has its own absorption coefficient. The absorption coefficient of the entire multi-layer film is the sum of the absorption coefficients of the individual layers (1) (Figure 1, right). Depending on the used laser wavelength different energy levels are deposed into the individual layers. By selecting a suitable laser wavelength, it is possible to depose energy only in the required layer.

$$1 = T + R + A, \quad A_{Total} = A_{Layer1} + A_{Layer2} + \ldots \qquad (1)$$

3. Welding results and analytics

To investigate the suitability of wavelength adapted diode laser system for joining market packaging films a test setup is realized. This consists of a diode laser with a wavelength of 1.7 microns and an optical power of 30 W at the work piece surface, and a laser optic which shapes the laser radiation to spot diameter of 280 microns in the focus is used. The films are positioned in an overlapping arrangement and clamped with a pneumatic clamping device. The laser optics is moved via a 3-axis system through the sample on the desired welding contour. The diode laser module and the laser optics are connected to each other via an optical fiber. Various typical packaging films including a PET / PE film are examined. The PET / PE film is however considered in the following in more detail. After the joining process, the weld seams are analyzed by the following test methods:

- Incident light microscopy
- thin sections
- transmitted light microscopy
- tensile tests.

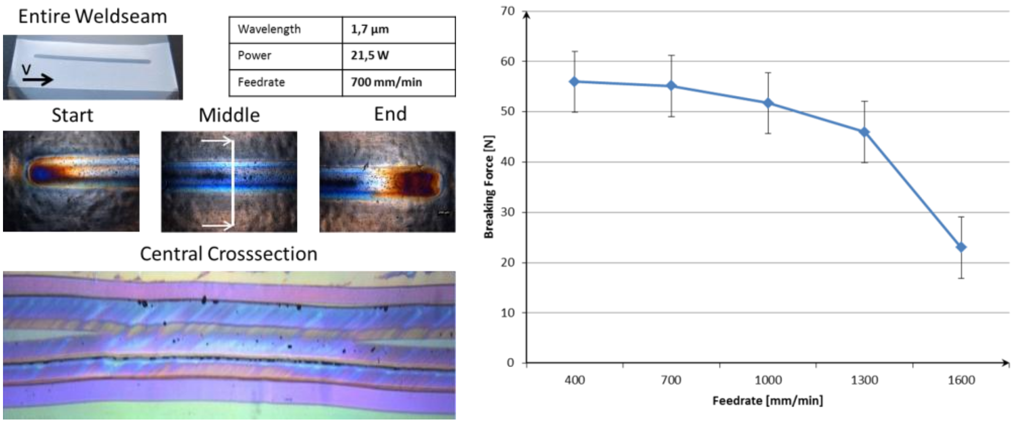

Fig. 3. Weld seam analytics of PET/PE vs. PE/EVOH/PET (left) breaking force of PET/PE vs. PE/EVOH/PET (right, sample size for each test point: 3)

The microscopic analysis, especially in the thin cross-sectional view, shows that the two films can be welded together in the desired range and width (Figure 3, left). The heat affected zone is limited to the joining area. There are no surface defects. A melt outlet as it is known by using sealing jaws is not observed. Damage or mixing of the surrounding layer cannot be identified. The top view shows a visually appealing homogeneous seam. To investigate the influence of the feed rate and thus the heat input into the material tensile tests in accordance with DIN 527-1 and DIN 55529 are carried out. With DIN 527-1 the maximum tensile shear strength of a polymer connection is tested. DIN 55529 determines the peeling forces in a T-arrangement. The results of the tensile test in accordance with DIN 527-1 are in industry-standard range for typical connection of packaging films (Figure 3, right) [Buchner, 1999]. With higher feed rate decreases the maximum tensile strength. By the deposited energy, the tensile strength can be flexible set. This can affect for example how easily the package can be opened by the consumer.

4. Conclusion and outlook

The experimental results and analysis demonstrate that commercially available transparent polymer packaging films can directly be welded by a wavelength adapted diodes laser system. The weld seams have a visually appealing look and also show in the analysis, a homogeneous distribution. By changing the deposited energy the maximum tensile forces can be influenced and adjusted. Through the use of a laser system any contours also may be welded flexible.

Fig. 4. Laser welded packaging for coffee, peelable

In the current work the suitability of the process for multilayer plastic films in addition to various plastic layers which also contain metallic layers is examined (Figure 4). Future research will address the maximum possible feed rate by using new laser beam sources with higher optical power.

Acknowledgements

This research carried out in cooperation with the Fraunhofer IVV, Branch Lab for Processing Machinery and Packaging Technology, Dresden.

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