Available online at www.sciencedirect.com

ScienceDirect

Physics Procedia 83 (2016) 472 – 482

Physics Procedia

9th International Conference on Photonic Technologies - LANE 2016

Improvement of energy deposition in absorber-free laser welding through quasi-simultaneous irradiation

Viktor Mamuschkin[a,]*, Christoph Engelmann[b], Alexander Olowinsky[b]

[a]*Chair for Technology of Optical Systems (TOS), Steinbachstraße 15, 52074 Aachen, Germany*
bFraunhofer Institute for Laser Technology (ILT), Steinbachstraße 15, 52074 Aachen, Germany

Abstract

Laser transmission welding is usually known to put little thermal stress on the joining partners, indicated by a small heat affected zone (HAZ). However, this only applies when the joining partners have adapted optical properties. When it comes to welding of optically equal thermoplastics without absorbers, the main issue is the HAZ extending far from the interface. To enable welding without absorbers, lasers emitting within the polymer's intrinsic absorption bands are used. So far, different beam shaping approaches have already been investigated to achieve a selective energy deposition at the interface but, with little success to date. The approach presented in this paper is irradiating the welding path quasi-simultaneously to exploit the poor heat conductivity of polymers. Therefore, the influence of the irradiation regime on the seam formation is considered in detail. Another aspect investigated is the length of the irradiated contour which is a crucial factor in quasi-simultaneous welding. The results show that the energy deposition can be significantly improved when the welding contour length does not exceed a critical length determined by the capability of the welding system. However, by welding in segments the approach can also be applied to longer contours without any noticeable loss in welding time. The ideal irradiation regime obtained in the trials corresponds to an effective welding speed of 37 mm/s and reduces the vertical extent of the HAZ by 30 %.

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH

Keywords: Thulium fiber laser; quasi-simultaneous; absorber-free; polymer welding

1. Introduction

Since its industrial introduction in the mid-nineties laser transmission welding spread into many application areas and has meanwhile become a state of the art joining technique for plastic parts [1]. Unlike competing technologies

* Corresponding author. Tel.: +49-241-8906-8198 ; fax: +49-241-8906-121.
E-mail address: viktor.mamuschkin@tos.rwth-aachen.de

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH
doi:10.1016/j.phpro.2016.08.049

such as ultrasonic and hot plate welding, laser welding offers the possibility of a selective and contactless energy deposition which predestines it for welding of plastic components sensitive to thermal and mechanical stress [2].

The principle of classic laser transmission welding is based on different optical properties of the joining partners. One part has to be laser-transparent whereas the other has to possess a high absorption capability. Thus, with the laser-transparent part facing the laser beam the radiation is able to penetrate to the underlying part where its electromagnetic energy is converted into heat. Through the contact, the generated heat is spread in the interface area fusing both parts locally (Figure 1) [3].

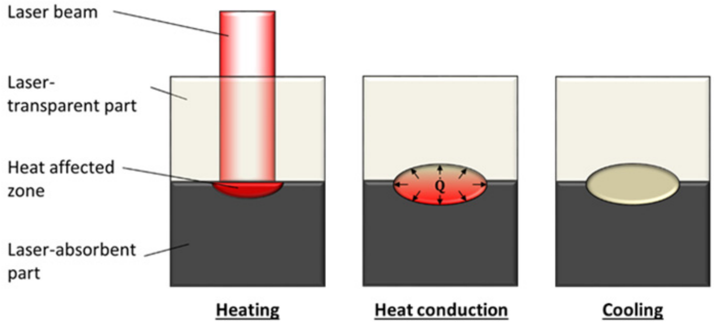

Fig. 1. Process phases in laser transmission welding.

Most thermoplastics feature a high transparency in the spectral range of classic beam sources used in polymer welding (800-1100 nm). In order to sensitize them to laser radiation absorbers are used which is considered as the main drawback of laser transmission welding [4]. Absorbers not only require an additional process step for application but also affect the optical properties of the component. In the early days carbon black was used exclusively due to its outstanding absorption properties at low cost. Over time new absorbers were developed to satisfy the increasing demand for a larger color variety of laser-weldable parts. Today, laser-absorbent parts can have almost any color or even be transparent [5].

Despite the great industrial success of laser transmission welding there is still a large potential for further application fields. One of those is undoubtedly the microfluidic device market with an expected average annual growth rate of 23% within the next years. For the production of microfluidic devices thermoplastics are increasingly used due to their several process and material related advantages (easy/cheap to process, nontoxic, etc.) compared to typical materials like glass and silicon [6]. Typically, a microfluidic device consists of a substrate containing flow channels and reaction/mixing chambers. Capping of the microfluidic structures is an essential process step in the production of microfluidic devices posing high demands on the joining method. Laser welding with its characteristics could be an appropriate method, but in many cases fails because of the required absorbers which may affect the functionality or even pose a risk to the biocompatibility of the device [7]. Without the need for absorbers laser transmission welding could not only raise its attractiveness for manufacturing of microfluidic devices but also find access to further application areas.

2. Absorber-free laser transmission welding

2.1. Fundamentals

The optical conditions in classic and absorber-free laser transmission welding differ greatly from each other. A suitable measure to characterize the optical properties and the attenuation of the incident laser radiation within the polymer respectively is the absorption coefficient α. Without taking scattering into account, a small absorption coefficient indicates high transparency for the considered radiation wavelength. However, with increasing absorption