Available online at www.sciencedirect.com

ScienceDirect

Physics Procedia 78 (2015) 272 – 284

Physics Procedia

15th Nordic Laser Materials Processing Conference, Nolamp 15, 25-27 August 2015, Lappeenranta, Finland

Laser welding of transparent polymers by using quasi-simultaneous beam off-setting scanning technique

Saara Ruotsalainen[a], Petri Laakso[a], Veli Kujanpää[a*]

[a]VTT Technical Research Centre of Finland Ltd

Abstract

Traditionally laser polymer welding has been done by using lasers with wavelength of c. 1 μm wavelength. With this wavelength one of the pair of polymers to be joined needs to be transparent and one absorbing, usually clear and black, respectively. Joining of two transparent polymers with laser has been possible only by using absorbing additive between the samples or by doping the polymer with absorbing additive. During the last years lasers with new wavelengths between 1.4 to 2 μm have been developed. With this wavelength range welding of the transparent polymer to another transparent one without any absorbing additives is now possible. In this paper joining of transparent to transparent polymers with quasi-simultaneous laser welding (QSLW) technique and fibre lase with wavelength of 1.94 μm is studied. Also a new scanning technique for QSLW is introduced. In this technique laser beam path is off-setting to a different place in every scanning round. This way the Gaussian beam shape of fibre laser can be smoothened to be more suitable for polymer welding and more flexibility on laser welding of polymers is achieved without losing the benefits of quasi-simultaneous laser welding.

Peer-review under responsibility of the Lappeenranta University of Technology (LUT)

Keywords: laser polymer welding; transparent polymers; new wavelengths

1. Introduction

Laser welding of polymers have been studied and used in industry for a long time, Bachmann and Russek (2002), van Engen et al (2001) and Boglea et al (2010). Traditionally trough transmission laser welding (TTLW) with ~1 μm lasers has been used. In TTLW one joining partner needs to be transmissive and the other absorbing for laser wavelength used. Usually samples to be joined are clear and black. Many polymers are highly transmissive for ~1μm wavelength in their natural state. Polymers doped with black pigment, normally with carbon black are highly

* Corresponding author. Tel.: +358405762479
E-mail address:veli.kujanpaa@vtt.fi

Peer-review under responsibility of the Lappeenranta University of Technology (LUT)
doi:10.1016/j.phpro.2015.11.038

Nomenclature

QSLW	Quasi-simultaneous laser welding
TPE	Thermo-plastic elastomer
TTLW	Through transmission laser welding
TWIST	Transmission welding by incremental scanning technique

absorptive for ~1 μm wavelength. In TTLW laser beam goes through the top transmissive polymer and absorbs to the surface of the lower absorptive one. Special optical properties of polymers are needed in TTLW so material properties and pigments have been developed to be suitable specially for laser welding. Nowadays different transmissive and absorptive colour polymers at ~1 μm are available, Basf and Treffert (2013). Joining of two transparent polymers with ~1 μm laser is possible only by using laser absorbing additive between the samples or by doping the polymer with absorbing additive.

There are different welding methods to weld polymers with TTLW technique. One of those is quasi-simultaneous laser welding (QSLW) process which means that the laser beam is scanned with a high speed several times along the welding path so that the entire weld seam is melted almost at the same time. Many advantages can be achieved with this process. One of the most important advantages is the lower sensitivity for joint air gaps because of the almost simultaneous melting, Jansson et al (2004).

During the last years lasers with new wavelengths between 1.4 to 2 μm have been developed, Westphäling (2013), Limo (2013). With this wavelength range welding of the transparent polymer to another transparent one without any absorbing additives has become possible. The process is based for the volume absorption of transparent polymers with these wavelengths. Only a few studies of joining transparent polymers with new wavelength lasers are published, Roesner et al (2008), Boglea et al (2010a), Mungareev et al (2012), IPG (2012). In these studies welding techniques have mainly been contour welding or transmission welding by incremental scanning technique (TWIST). In this paper joining of transparent to transparent polymers with QSLW technique and 1.94 μm fibre laser have been studied.

Nowadays fiber lasers are often used for TTLW of polymers due their low price and high flexibility. Fiber laser beam is Gaussian beam shaped and the size of the spot is small and the power density is high. This type of beam is not optimal for laser welding of polymers where a more even power distribution is better. Polymers have relatively low melting temperatures and the temperature difference between overheating and melting is low. If Gaussian beam is directly used the middle of the weld may be over heated before the edges of the weld are melt. Also in many applications the wanted width of the weld is higher than achieved with Gaussian beam of fiber laser. Different strategies have been developed to overcome this issue. For example, optical beam shaping elements can be used to produce the intensity profile and the spot size wanted, Vogler (2012). There are also scanning methods which can be used for widening the weld width and smoothen the heat input like in TWIST, Boglea et al (2010b). By using a scanning method more flexibility can be achieved due the weld width can be varied only by changing the program of the scanner. In some applications it is advantageous to use QSLW process and this why the QSLW process needs to be developed more. In QSLW Gaussian beam can be smoothened with beam shaping optics. Incremental scanning method during QSLW process is not possible to use due to the speed and accuracy limitations of the scanners. In this study a scanning method for QSLW was developed to overcome the effects of Gaussian beam and to achieve the process flexibility with scanning technique. In this new QSLW technique laser beam path is off-setting to a different place in every scanning round. This way the middle point of the beam, where the intensity is highest, is in a slightly different place in every round and whole weld area will be heated evenly. Also, if beam is scanned in different place after ever scanning round, the weld should become wider. This way wider weld and smaller heat input in weld area compared to simply Gaussian beam can be achieved. Beam off-setting technique is used with 1.94 μm laser to weld the transparent samples to each other.

2. Experimental Procedure

Welding tests were done by using IPG Thulium fiber laser TLR-120-WC with a wavelength of 1.94 μm. Laser beam was guided by Scanlab IntelliCube10 scanhead to working field. Scanning optic used was f100 f-theta optic. The samples were pressed against the optical glass with the pneumatic clamping fixture during welding.