Optics and Laser Technology 106 (2018) 215–221

Contents lists available at ScienceDirect

Optics and Laser Technology

journal homepage: www.elsevier.com/locate/optlastec

Full length article

A non-destructive optical experimental method to predict extinction coefficient of glass fibre-reinforced thermoplastic composites

Benoit Cosson *, André Chateau Akué Asséko, Myriam Dauphin

IMT Lille Douai, Institut Mines-Télécom, Polymers and Composites Technology & Mechanical Engineering Department, 941 rue Charles Bourseul, 59508 Douai, France
Université de Lille, 59000 Lille, France

ARTICLE INFO

Article history:
Received 24 November 2017
Received in revised form 5 April 2018
Accepted 8 April 2018

Keywords:
Thermoplastic composites
Light scattering phenomenon
Extinction coefficient
Ray tracing method
Photographic experimental set-up

ABSTRACT

The aim of this paper is to develop a cost-effective, efficient and fast experimental optical method to predict the optical properties (extinction coefficient) of semi-transparent glass-fibre-reinforced polymer composites. The extinction coefficient takes into account the effects due to the absorption and the scattering phenomena in a semi-transparent component during the laser processes, i.e. TTLW (Through-Transmission Laser Welding). A laser as light source and a reflex camera equipped with a macro lens as a measuring device are used in the present method. It is based on the measuring of the transmission of light through different thicknesses of samples. The interaction between the incident laser beam and the semi-transparent composite is examined. The results are presented for the case of a semi-transparent composite reinforced with unidirectional glass fibre. A numerical method, ray tracing, is used to validate the experimental results. The ray tracing method is suitable for characterizing the light-scattering in semi-transparent materials.

© 2018 Elsevier Ltd. All rights reserved.

1. Introduction

Within the global composite materials market, which now exceeds 10 million tons, glass fibre-reinforcements still remains the largest market segment, accounting for more than 90% in volume, whereas the fastest growth is noticed for thermoplastic matrices [1]. Continuous glass fibre thermoplastic composites are actually wildly used in transportation and in the sports and leisure industries. While many parts can be manufactured in one shot, the completion of some complex technical functions often requires the assembly of several parts.

Various techniques are available to achieve the assembly: adhesive bonding (often used for thermoset composites), welding or mechanical fastening (screwing, riveting) [2–4]. Welding is often used to assemble two thermoplastic parts, at least in the case of non-reinforced polymers. The extension and applicability of this assembly method to glass/thermoplastic textile composites (i.e. thermoplastics reinforced with continuous glass fibres) is consequently of huge industrial interest even if rather tricky because of the presence of the fibres. Welding can be done in several ways: ultrasonic welding, friction wilding, resistive welding, infrared welding or laser welding. In particular in Through Transmission Laser Welding (TTLW) [5], the power of the laser is transmitted through the part to be welded. TTLW is a clean and fast bonding technique. It is contactless and there is no need of special expensive tools. However, the part must be transparent to the wavelength of the emitted light [6,7].

In the TTLW, two parts are involved: a semi-transparent and an absorbent. During the TTLW process, the energy of the laser beam is transmitted and diffused through the semi-transparent part and is absorbed by the surface of the second absorbent material and causes an increase in temperature (Fig. 1) [6,7]. The rise of the temperature in the transparent part is induced by conduction. The welding occurs when the temperature at the interface reaches the melting temperature of the thermoplastic. During this process, macroscopic diffusion of the laser beam is observed in the first part. It is due to the refraction, at the microscopic scale, of the beam at each matrix-fibre interface. At the macroscopic scale, this phenomenon leads to the light scattering of the laser beam in this heterogeneous media. Due to the anisotropic structure, especially for unidirectional composites, the scattering is not the same in all directions. Optical characterization allows the interaction between the incident beam and the semi-transparent material to be understood. The Fig. 2 outlines the mechanism of light transmission in the semi-transparent composite part [6].

* Corresponding author at: IMT Lille Douai, Department of Polymers and Composites Technology & Mechanical Engineering, 941 rue Charles Bourseul, CS 10838, F-59508 Douai Cedex, France.
E-mail address: benoit.cosson@imt-lille-douai.fr (B. Cosson).

https://doi.org/10.1016/j.optlastec.2018.04.009
0030-3992/© 2018 Elsevier Ltd. All rights reserved.

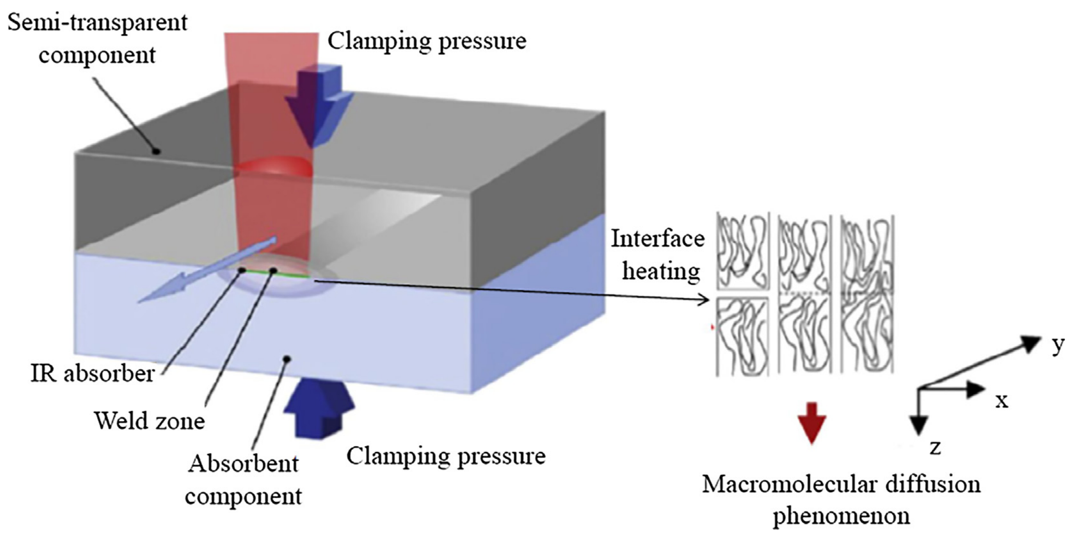

Fig. 1. Through Transmission Laser Welding [6,7].

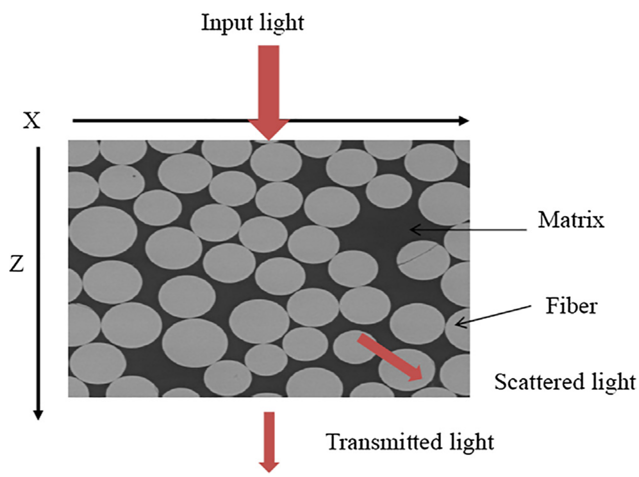

Fig. 2. Light transmission in semi-transparent composite part (microscopic observations of a polycarbonate containing 66 vol% glass fibres) [6].

Knowledge of the extinction coefficient ($\beta = \mathrm{A(absoption)} + \mathrm{S(scattering)}$) is of paramount importance for a better understanding and optimization of the TTLW process of heterogeneous materials. These properties play an important role in the simulation of the welding process. The computation of the temperature field at the welding interface can be obtained by using numerical simulations of the laser welding process of thermoplastic composites.

Two techniques can be used to determine the extinction coefficient. A first one, called the direct method, is based on the study of the interaction between a reinforced structure, like a fibre and a beam, via the solution of Maxwell's equations [8–12]. The resolution is done with Mie's theory and allows the radiative properties of a single fibre to be obtained. Then, the optical properties of the medium are given by averaging properties of the fibre on size and orientation distributions in the medium. The second technique, used to determine optical properties of a medium, is an inverse method based on the inversion of the radiative transfer equation from reflection and transmission measurements using a Fourier transforms infrared spectrometer as in [6,12–15].

The purpose of this paper is to propose an alternative non-destructive experimental method based on image processing to determine the optical properties (extinction coefficient) of glass fibre-reinforced thermoplastic composites required to optimize their Through-Transmission Laser Welding. In this method, the images are taken with a digital camera equipped with a macro lens in order to characterize the interaction between the incident laser beam and the semi-transparent glass fibre-reinforced composite structure. After describing the experimental setup, the associated method will be presented to identify the extinction coefficient. Then, a numerical identification of the optical parameters will be performed with the ray tracing technique as described in [16]. Finally, experimental and numerical results will be compared to validate the novel non-destructive alternative method proposed.

2. Experimental method description

The experimental setup that is described in the Fig. 3 is maintained in a darkroom to eliminate any external light that may be parasitic and affect the captured signal in the image.

Semi-transparent thermoplastic composite samples, of different thicknesses, are exposed to a laser beam, in static mode (nominal power: 1 mW, the wavelength of the laser is $\lambda = 650$ nm), on their front face. Three images with three different exposure levels (under exposure, normal exposure and overexposure) are needed to determine the light transmission through the transparent part. The spot, with surface energy distribution, of the laser beam on the back side of the sample is captured using a digital camera (Canon EOS 750D) in manual mode equipped with a macro lens (Canon EF 100 mm f/2.8 USM Macro, 24.2 mega-pixels for image resolution). The manual mode is required to impose the same settings, except the exposure time, for all pictures.

The used concept is the Exposure Bracketing in photography [17–19]. Bracketing is a general technique of taking multiple images of the same subject using a different exposure time and keeping all other parameters unchanged (aperture, white balance, ISO or sensor gain, depth-of-field and focus). Changing the exposure time gives a brighter and a darker image. These pictures are used to determine the equivalence between the grey scale and the energy received by the camera.

3. Material

Materials used in this study for the composition of thermoplastic composites are a polycarbonate (PC, Macrolon® 2405, Bayer

Download English Version:

https://daneshyari.com/en/article/7128509

Download Persian Version:

https://daneshyari.com/article/7128509

Daneshyari.com