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Effect of infrared laser surface treatment on the microstructure and properties of adhesively CFRP bonded joints

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ABSTRACT

Adhesive bonding is considered to offer advantages over the connections of the aircraft composite structures. The infrared laser surface processing of various laser process parameters and peel ply treatment are performed in this study. To investigate the microstructure and properties of adhesively bonded composite single-lap joints obtained by infrared laser surface treatment and peel ply processing, the examinations of microstructures, surface free energy and shear strength of the joints are conducted. The results indicate that the adhesively bonded joints acquired by infrared laser treatment have lower average shear strength of 20.158 MPa, comparing with the joints of 32.574 MPa in average shear strength treated by peel ply processing. In addition, the surface roughness test is conducted and the surface roughness of 4.926 μm of the specimen after peel ply treatment is higher than that of the specimen after infrared laser treatment.

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1. Introduction

With the properties of high specific strength, high specific modulus, good corrosion resistance and excellent fatigue resistance, the carbon fiber reinforced plastics (CFRP) have been generally considered as the valuable composite material with extensive application in aerospace field [1]. As an implication, the single-lap jointing of CFRP laminates could have a major application in the aviation and aerospace industries where high-strength, concurrent low-weight and cost reduction are desirable. For example, the CFRP has been employed in the fuselage and engine of Boeing 787 [2].

Due to the anisotropy of CFRP, conventional connection techniques are difficult to be popularized and applied in the connection of CFRP laminates. The mechanical connection techniques have the characteristic of poor fatigue resistance. The weight of the overall structure will increase on account of the use of mechanical fasteners. It will not meet the requirement of the lightweight aircraft structure. Aiming to achieve low-weight and avoid the holes produced in the traditional connection processes of composite materials including riveting and bolting, the adhesive bonding technology has already been employed [3]. The adhesive bonding structures of composite materials have been applied in the aircraft manufacturing industry widely, due to good weight loss, high specific strength, small stress concentration and good crack resistance [4,5].

Therefore, it is necessary to mention that the adhesive bonding technology on composite materials has been investigated for years and numerous research results have been proposed. He et al. [6] completed the latest work about finite element analysis of the adhesively bonded joints integrating the static loading analysis, environmental behavior, fatigue loading analysis and the dynamic characteristics of adhesively bonded joints. Sahoo et al. [7] adopted the plastic area size standard to predict the strength of the bonded joint and employed NASTRAN software for geometric and material nonlinear finite element analysis to establish the failure criterion of the plastic zone size. The examination of adhesive bonding strength and numerical analysis were conducted in the same configuration. Moya-Sanz et al. [8] studied the effect of the geometrical structure of single lap joints on the bonding strength of composite laminates during uniaxial tensile loading. Das et al. [9] adopted a finite element analysis simulation technique to study the onset and growth of delamination damages in laminated bonded tubular single lap joint made of fiber-reinforced polymer composite. Melo et al. [10] completed the different surface treatments and accelerated artificial aging to assess the bond strength of composite resin repairs. Guo et al. [11] analyzed the effects of debond flaws on the mechanical properties of adhesively bonded single lap joints. And the three-dimensional progressive damage finite-element models were adopted to simulate the tensile

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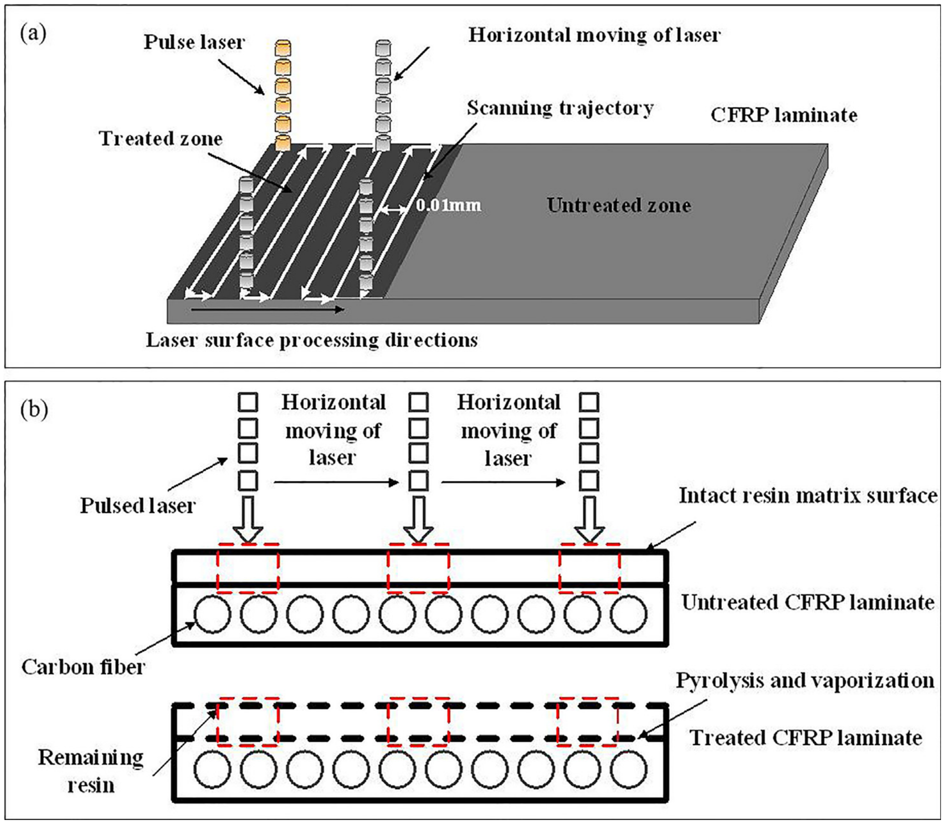

Fig. 1. Schematic diagram of laser surface treatment: (a) laser processing path; (b) the lateral view of laser processing.

Table 1
The laser processing parameters of experiments.

Number	Speed (V, mm/s)	Power (P, W)	Frequency (f, kHz)
1	7000	7.4	50
2	7000	11.1	50
3	7000	16.65	50
4	7000	18.5	50
5	7000	22.2	50
6	7000	24.05	50
7	8000	100	20

behavior of single lap joints. In addition, the surface of the material need be pretreated before the bonding of the composite materials. Mechanical polishing surface treatment process, the conventional surface pretreatment technology for composites, had a high labor cost [12,13]. And the effect of artificial mechanical polishing was difficult to control. In contrast, the laser surface treatment method had a series of advantages such as high efficiency, good cleaning effect and automatic operation [14,15]. It could be adopted for surface pretreatment before composites adhesive bonding.

Furthermore, the laser surface pretreatment of composite materials has attracted particular attention and many researchers have investigated this process and obtained some significant conclusions. Palmieri et al. [16] studied the laser surface pretreatment of carbon fiber reinforced epoxy resin composites prior to adhesive bonding and shear strength tests of the lap samples were conducted. Reitz et al. [17] analyzed the effects of infrared and ultraviolet lasers on the bonding strength of aluminum and CFRP materials respectively. Oliveira et al. [18] investigated the surface treatment of carbon fiber reinforced polymer composites using femtosecond laser radiation. The results showed that the selective removal of the epoxy resin could be achieved and the carbon fibers

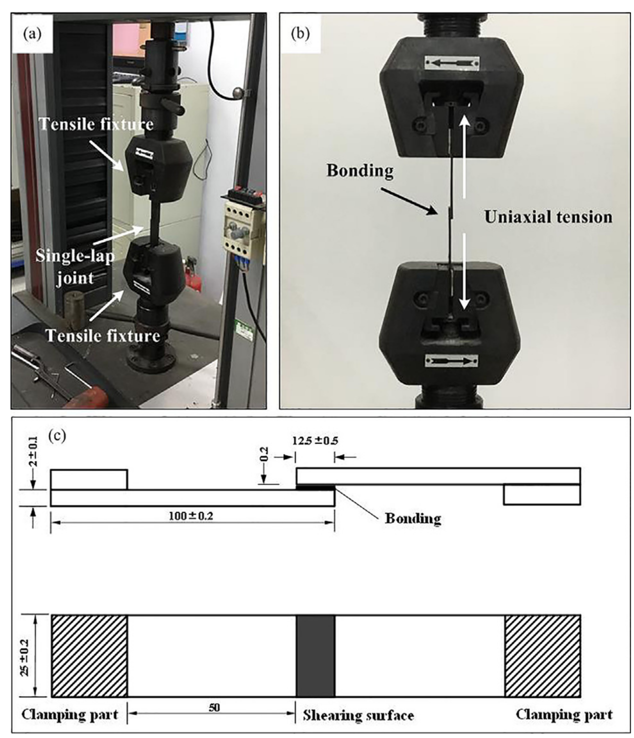

Fig. 2. (a) The equipment of uniaxial tensile test; (b) uniaxial tensile test of sing-lap specimen; (c) schematic diagram of single-lap specimen structure.

were exposed by employing the appropriate processing parameters. Liu et al. [19] studied the interlaminar damage effects of continuous wave laser irradiation for the carbon fiber reinforced

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