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Effect of several gas ambiences on HAZ suppression in CFRP cutting with nanosecond laser

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Abstract

The laser cutting for a carbon fiber reinforced plastic (CFRP) is one of suitable way because of contact-free and high speed processing. However, a matrix material composed of CFRP was quickly decomposed before the carbon fiber deformation, which caused to form a heat affected zone (HAZ) which composed matrix evaporation zone (MEZ) and resin alteration zone (RAZ). The improvement of HAZ is the most important task in the laser cutting for CFRP. In this study, we have demonstrated that the CFRP plates were cut with a pulse fiber laser at pulse width of 0.4 ns, wavelength of 1064 nm and average power of 100 W under air and nitrogen (N_2) gas flow.

Keywords: CFRP, pulse fiber laser, HAZ,

1. Introduction

A carbon fiber reinforced plastic (CFRP) has characteristics of light weight, weather resistance and dimensional stability. Many industries such as automobile and aircraft hope on use of CFRP as a new metal substitution material. The CFRP is composite material composed of two parts; one is carbon fiber as reinforcement and another one is a binding polymer as an epoxy resin, polyester, vinyl-ester or nylon. The processing of composite material is difficulties. Recently, the laser cutting and drilling for CFRP have attracted attention for high speed and high quality processing by J.Stock et., Klotsbach et al., C. Emmelmann et al, and so on. Based on these reports, the pulse width, wavelength, repetition rate for pulse laser and

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processing ambience are important factor for laser cutting for CFRP. In our previous study, the wavelengths for laser were evaluated for CFRP processing with a high speed video camera and a Fourier-transform infrared spectroscopy. The heat affected zone (HAZ) for IR (wavelength: 1064 nm) laser was larger than that for UV (wavelength: 266nm) laser, although the cutting speed for IR laser was faster than that for UV laser.

In this report, we demonstrated that the CFRP was cut using a pulse fiber laser operated at wavelength of 1064 nm, average output power of 100 W, a repetition rate of 1 MHz and a pulse width of 0.4 ns in air and nitrogen (N_2) gas flow. In order to evaluate ambience effect, a Raman spectroscopy analysis was conducted to measure the heat affected zone quantitatively.

2. Experimental set up

A cross type of CFRP plate (thickness: 2.2 mm) was employed composed of PAN type carbon fiber and epoxy resin. Fig.1 shows the schematic diagrams of the experimental setup for pulse fiber laser irradiation on the CFRP plates. The pulse fiber laser, which has Yb-doped photonic crystal fiber rod fibers, was employed at wavelength of 1064 nm, output power of 100 W, repetition rate of 1MHz and pulse width of 0.4 ns. The CFRP was put on stage; the laser scanned the CFRP plate with galvanic mirror passing the attenuator for adjusting the laser intensity. All the experiments were performed with same conditions, as shown in Table 1. A beam profile of the Gaussian laser beam had a diameter of 65μmϕ at the $1/e^2$ intensity points on the CFRP.

Table.1 Experimental condition

Laser condition	
Output power, W	100
Spot diameter, μm	65 ($1/e^2$)
Pulse width, ns	0.4
Repitation rate, MHz	1
Scanning speed, m/s	2.75

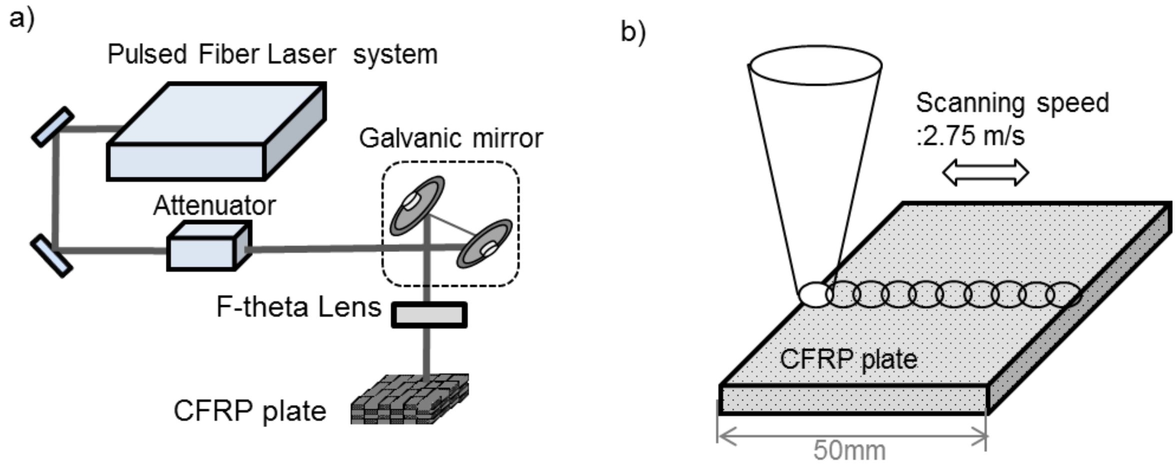

Fig.1 Schematic diagram of a) experimental set up for CFRP processing, and b) scanning strategy

3. Results and discussion

Fig.2 shows the optical microscope images after laser cutting in air and N_2 gas flow at the laser intensity of 1.0 x 10^9 W/cm^2. HAZs were confirmed to form near the kerf on the CFRP. In our previous study, we clarified that the HAZ had a two parts, as shown in Fig. 2, one is a matrix evaporation zone (MEZ), and another one is a resin alteration zone (RAZ). The MEZ means that the resin is only evaporated by the laser irradiation since the evaporation temperature of resin was lower than that of carbon fiber. Carbon fiber was exposed on the CFRP. The RAZ means the resin is altered by the heat conduction during the laser cutting. In order to measure the HAZ, MEZ and RAZ quantitatively, Raman spectroscopy analysis was conducted. As the results, MEZ, RAZ and HAZ in air were 60, 180 and 240 µm, respectively. In case of N_2 gas flow, the MEZ, RAZ and HAZ were obtained 25, 95 and 115 µm, respectively, as shown in Table 2. The CFRP cutting speed under both ambiences were same, at 0.42 cm/s. From the results, although it was found that cutting speed for CFRP was not depended on processing ambience, the HAZ was depended on processing ambience of oxygen concentration.

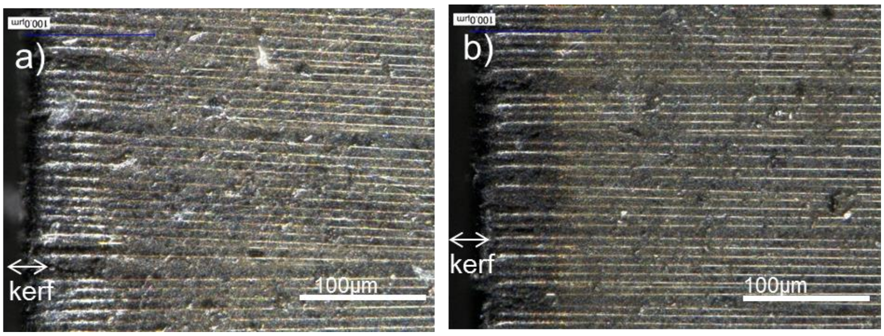

Fig.2 Optical microscope images of CFRP surface in (a) air and (b) N_2 gas ambience.

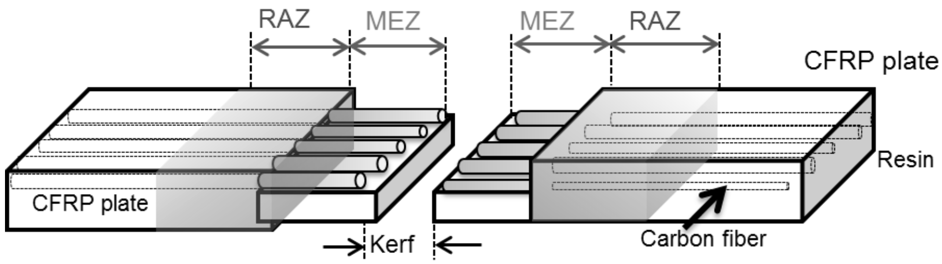

Fig.3 Schematic diagram of HAZ, MEZ and RAZ formation on CFRP after laser irradiation.

Table.2 Results of cutting speed and HAZ measurements by Raman spectroscopy analysis.

	Air ambience	N_2 gas flow
Cutting speed cm/sec	0.42	0.42
MEZ, µm	60	25
RAZ, µm	180	95
HAZ, µm	240	115

4. Summary

The CFRP plate was demonstrated to cut with pulse fiber laser in air and N_2 gas ambience. The emission spectra and cutting surface were evaluated by spectroscopic analysis and a confocal laser microscope. The results revealed that the laser cutting of the CFRP in Ar gas ambience might be a useful method to reduce the HAZ to suppression of the oxidization of the carbon fiber.

Acknowledgements

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