

Study on Non-Destructive Evaluation of Fiber Content for Advanced Quality Assessment of Recycled CFRP

-Thermal Diffusivity Measurement Using Active Thermography-

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Recently, recycled carbon fiber reinforced polymer (recycled CFRP) composites, which are made from recycled carbon fibers, have attracted increasing interest. To advance the quality assessment of recycled CFRP composites, the non-destructive evaluation of the fiber content uniformity is useful. As an indicator reflecting the through-thickness fiber content in CFRP composites, we focused on their out-of-plane thermal diffusivity. In this study, active thermography using a flash lamp, which is a non-destructive method for measuring the out-of-plane thermal diffusivity, was employed and applied to various CFRP composites. Furthermore, the feasibility of non-destructively evaluating the fiber content using the out-of-plane thermal diffusivity was investigated.

In this study, three types of specimens of CFRP composites, composed of a thermosetting resin and continuous carbon fibers (CFs), were used. The first was a virgin carbon fiber unidirectional laminate (vCF-UD), fabricated via autoclave molding by stacking prepregs with virgin continuous CFs such that their fiber orientation was unidirectional. The second was a virgin carbon fiber cross-ply laminate (vCF-CP), fabricated via vacuum assisted resin transfer molding (VaRTM) by stacking substrates with virgin continuous CFs such that their fiber orientation was alternately orthogonal. The third was a recycled carbon fiber cross-ply laminate (rCF-CP), fabricated via VaRTM by stacking substrates with recycled continuous CFs, which had been recovered from CFRP composites used in hydrogen storage tanks through a solvent-based recycling process, such that their fiber orientation was alternately orthogonal.

Figure 1 shows the experimental setup for the employed active thermography. In the figure, the specimen is instantaneously heated using a flash lamp, and its temperature response on the specimen surface opposite the heated side is measured using an infrared camera. From the measured temperature response data, the out-of-plane thermal diffusivity is calculated [1]. The power output of the flash lamp and the frame rate of the infrared camera were set to 3200 Ws and 60 Hz, respectively. Figure 2 shows the distributions of the out-of-plane thermal diffusivity for vCF-UD, vCF-CP, and rCF-CP. In the figure, the regions of low thermal diffusivity at the four corners of each specimen correspond to the areas extending beyond the reflector of the flash lamp, where the out-of-plane thermal diffusivity cannot be measured. As shown in Fig. 2, the out-of-plane thermal diffusivity is approximately uniform in vCF-UD and vCF-CP, whereas it is non-uniform in rCF-CP. These distributions are considered to reflect differences in the fiber content uniformity between CFRP composites with virgin and recycled continuous CFs. In Fig. 2(a), the average out-of-plane thermal diffusivity within a 10 mm × 10 mm area at the center of the specimen is 0.453 mm²/s. In Ref [2], the out-of-plane thermal diffusivity of vCF-UD fabricated under the same manufacturing process was measured by the conventional flash method, and the average value was 0.462 mm²/s. Since the relative error between these two methods is only -1.9%, the employed active thermography can measure the out-of-plane thermal diffusivity with an accuracy comparable to that of the conventional flash method. The conventional flash method requires samples to be cut into smaller pieces (e.g., a sample was cut into a 10 mm × 10 mm piece in Ref [2]) to measure the out-of-plane thermal diffusivity, whereas the employed active thermography requires no such cutting. Overall, the possibility of non-destructively evaluating the fiber content uniformity in CFRP composites by the employed active thermography is confirmed.

[1] T. Kostroun, M. Dvořák, doi : 10.3390/ma14030533.

[2] A. Akai, Y. Hamada, Y. Sato, A. Mikuni, doi : 10.11351/jsaeronbun.57.549.

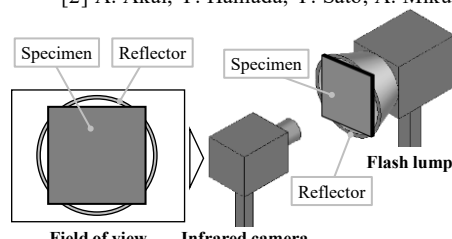


Fig. 1 Experimental setup.

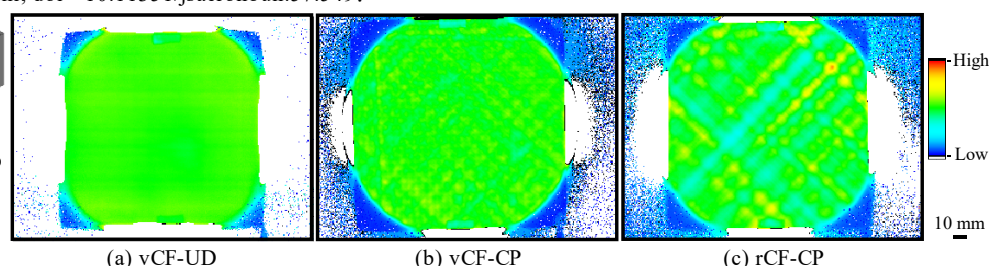


Fig. 2 Distributions of out-of-plane thermal diffusivity for vCF-UD, vCF-CP, and rCF-CP.