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Application News

No. N139

Microfocus X-ray CT System

Observation of Carbon Fiber Reinforced Thermoplastic (CFRTP) with inspeXio™ SMX™-225CT FPD HR Plus

Introduction

Carbon fiber reinforced plastic (CFRP) is a composite material which is produced by strengthening a thermosetting resin with carbon fibers, and offers strength and rigidity equal to or greater than that of steel, together with significantly lighter weight. Although CFRP is relatively expensive in comparison with conventional metal and resin materials, use in industrial applications is increasing, particularly in the automotive field, owing to its excellent mechanical properties.

As a material which improves the productivity, processability, and recyclability of CFRP, development of carbon fiber reinforced thermoplastic (CFRTP) has progressed in recent years. Because CFRTP is also suitable for mass production, as the time required for molding is short in comparison with CFRP, expanded application is expected, centering on the automotive industry.

While both CFRP and CFRTP have higher mechanical properties than conventional resin materials, the fact that internal voids and cracks that occur in the manufacturing process cause product defects is unchanged. Furthermore, the mechanical properties of both materials are controlled by the orientation of the carbon fibers. In order to stabilize the product quality of CFRP and CFRTP products, it is necessary to investigate whether voids and cracks exist in the resin, and whether the fiber orientation is as designed. X-ray CT systems are used to investigate these points, as nondestructive observation of the 3-dimensional structure of the investigation target is possible.

This article introduces an example of observation of voids and the fiber orientation in CFRTP by using the Shimadzu inspeXio SMX-225CT FPD HR Plus microfocus X-ray CT system (Fig. 1).

T. Hashimoto

Fig. 1 inspeXio™ SMX™-225CT FPD HR Plus Microfocus X-ray CT System

Observation of CFRTP

Fig. 2 shows the external appearance of the CFRTP sample scanned in this experiment. This is a multilayered laminated material with overall dimensions of 30 mm × 3 mm × 1 mm.

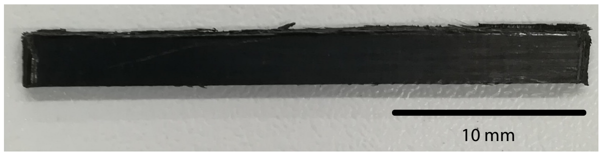

Fig. 2 External Appearance of CFRTP Sample

Fig. 3 shows an MPR (Multi Planar Reconstruction) screen, in which cross sections seen from multiple angles are displayed on the same screen after a portion of the sample is scanned by CT system. The numbers at the upper left of each screen and the lines drawn in the screens show the location of each cross section in the sample. In the cross-sectional images, higher density areas are shown as whiter as the density increases, while lower density areas are shown as blacker, making it possible to observe voids, cracks, resin, and carbon fibers from the screen. Looking at the various sections, it can be understood that the structure of the CFRTP consists of densely-arranged carbon fibers with a width of several µm, which form layers oriented in a certain direction in the composite material, and the orientations of the fibers are orthogonal in each layer.

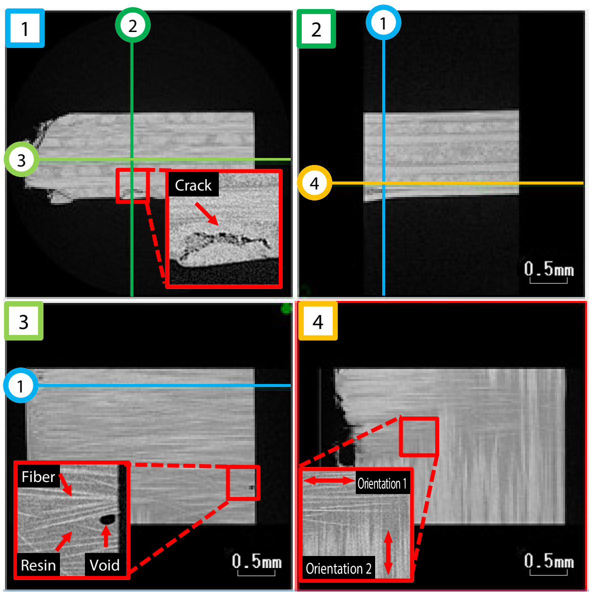

Fig. 3 MPR Screen Showing Cross-Sectional Images of CFRTP

Next, as shown in Fig. 4, the CT data are displayed on screens showing 3-dimensional representations for easier understanding of the structure of the scanned sample. Screen ① is the result of observation mainly near the sample surface, and Screen ② is an enlarged view of Screen ①. In Screen ②, a particulate piece of foreign matter with a higher density than the fibers and delamination, which is thought to have occurred because force was applied, can be observed at the sample surface. Screen ③ is a screen in which the interior of the sample was observed by cutting away a portion of the sample surface in the CT data, and Screen ④ is an enlarged view of Screen ③. Here, the laminated structure formed by the orthogonally-arranged layers of carbon fibers and a crack near the surface can be observed.

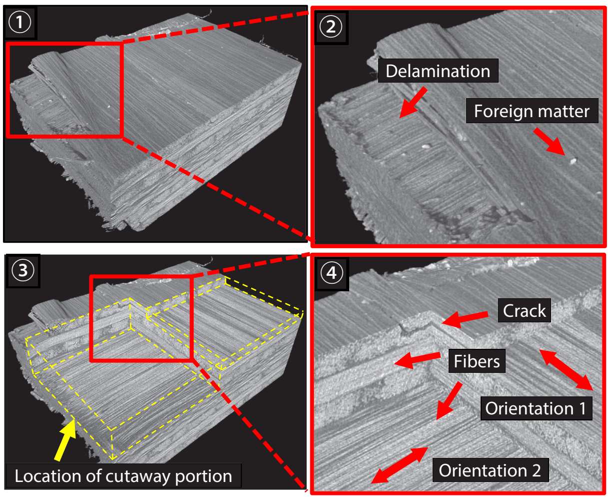

Fig. 4 Screens Showing 3D Representations of CFRTP

Fig. 5 is a screen in which the voids detected in the sample interior were colored corresponding to their volumes. In order to extract only voids that affect the quality of the product, it is possible to select detection targets based on information such as the void volume, XYZ coordinates, and diameter.

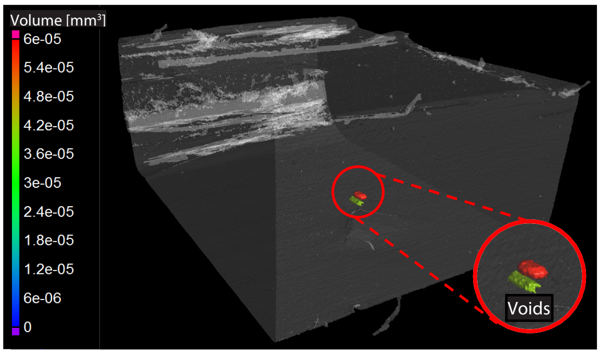

Fig. 5 Screen Showing 3D Representation of CFRTP: Void Analysis

Fig. 6 is a screen showing the result of an analysis of the fiber orientation. The standard orientation is set to 0° in the data, and the fibers in the CFRTP are colored corresponding to their deviation angles. The histogram in Fig. 7 expresses the analysis results in Fig. 6 in the form of a graph, where the x-axis is the deviation angle with respect to the standard orientation of the fibers, and the y-axis shows the frequency*1 of each deviation angle. The condition of fiber orientation can be grasped easily by showing the deviation in colors and numbers, as in Fig. 6 and Fig. 7. These results show that many of the fibers are oriented at 90° to the standard orientation.

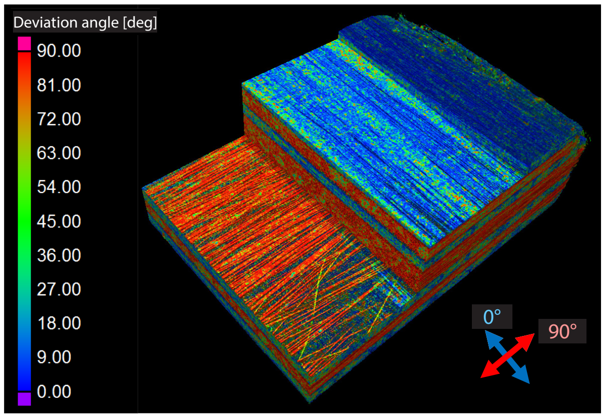

Fig. 6 Screen Showing 3D Representation of CFRTP: Fiber Orientation Analysis

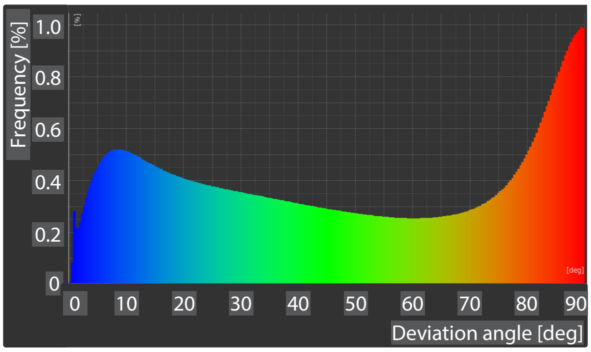

Fig. 7 Histogram Showing Fiber Orientation Angles of CFRTP

Conclusion

As demonstrated by this experiment, it is possible to analyze the size and location of voids contained in CFRP and CFRTP and the orientation of the carbon fibers in the resin matrix by using the inspeXio SMX-225CT FPD HR Plus microfocus X-ray CT system. This system is used in development and quality control of products in which fiber composite materials are used.

*1 Frequency: Percentage of pixels of each deviation angle, where the total number of pixels in the CFRTP image is 100 %.

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