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Determination of 3D Fiber Orientation Distribution in Thermoplastic Composites without Ambiguity Using SAM Image of Elliptical Mark and Interference Fringe

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Three-dimensional fiber orientation distribution in composite materials has a significant effect on the mechanical and thermal properties of the materials. The material properties modeling and design of short fiber composites need 3D fiber orientation distribution with material properties of fiber and matrix. Recently, efforts have been made to simulate quantitative relationships between processing conditions and fiber orientation. It is also necessary to measure accurate 3D fiber orientation distribution for the verification of this simulation accuracy. In order to design and control favorable orientation states, the best possible manufacturing process conditions are decided by the simulation results.

In the previous paper, 3D fiber orientation is determined by measuring the fiber direction and the interval of interference fringes using scanning acoustic microscopy. The nondestructive measurement in skin layer with scanning to depths of about 12.25μm is possible for this technique, but it is impossible to obtain 3D fiber orientation distribution in core layer without cutting. Another limitation of this technique indicates that the out-of-plane angle cannot be measured larger than 71.92°.

In this study, a new technique to determine the 3D fiber orientation distribution using SAM image of the elliptical mark and the interference fringe is proposed. Since interference fringe in the direction of a fiber is observed by SAM, the in-plane angle without ambiguous by adopting this information of interference fringe is determined. Procedures of determining the in-plane angle and the out-of-plane angle using SAM image of the elliptical mark and the interference fringe are explained. Comparison of the errors measured by present method and previous method is conducted, and it is found that this technique carries out the measurement with higher accuracy. This technique is applied to the 3D fiber orientation determination in the plaque of short-fiber reinforced polyamide 66 and the cylindrical part of short-fiber reinforced liquid crystalline polymer.