PS-OCT를 이용한 유리 섬유복합재료의 비파괴 검사

Nondestructive inspection of glass/epoxy composites with PS-OCT

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Composite materials are widely used in industry because of its high ration of strength vs. weight, and consequently many nondestructive methods have been developing to find stress or subsurface defects like crack, and delamination inside composite material. Among them, optical inspection methods have been widely neglected because of translucent or opaque nature of composite. Recently, Dunkers et al. first adapted OCT(Optical Coherence Tomography) and showed some possibility of OCT as a nondestructive inspection tool for a glass/epoxy composite.(1) Basically, OCT is low-coherence Michelson interferometer, and it selects only specific backscattering light from certain depth by time gating, and discriminate optically different layers. Currently, OCT in biomedical area is developing very fast and lots of applications are being reported.(2) In addition to investigating morphological map and defect inspection of the composite materials, noncontact optical remote sensing of actual stress distribution inside composite may be important for composite inspection. So far, transmissive photoelasticity are used to find stress distribution for composite, but it was limited to almost transparent and tenuous fiber composite.(3) In case of commercial glass/epoxy composite with densely packed glass fiber whose diameter is 10 um or smaller, conventional photoelasticity, like half wavelength photoelasticity, can't reveal stress induced birefringence due to low transparency and poor fringe quality due to multiple light scattering inside composite. Along with this scattering problem, transmissive type photoelasticity can't be applied to closed form glass/epoxy composite structure because it is not a practical way to put analyzer and detector inside structure.

In order to realize noncontact optical remote sensing of stress distribution and defect inside glass/epoxy composite, we adapt polarization sensitive OCT(PS-OCT)(4), which is also emerging for its ability to find polarization change unique for specific tissues and disease. Using scattering model and measured 4 elements full Stokes parameter from backscattered light, we extract internal stress birefringence distribution. By doing so, nondestructive inspection for subsurface defect and true 3-dimensional photoelasticity are made at the same time. Unlike previous research, we try commercial translucent composite comprised of densely packed glass fiber whose diameter is 9 um, which is challenging because of its multiple scattering. Since fibers inside composite have high volume ratio and large scattering cross section, we first identify scattering model for given sample composite and signal models for PS-OCT based on known theories and experiment.

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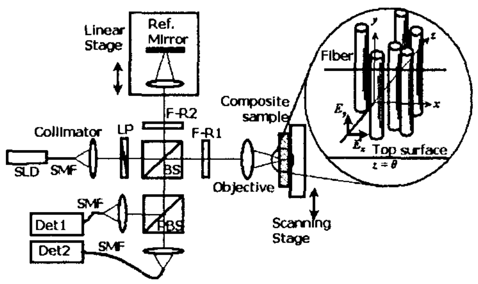

Figure 1: Schematic of the PS-OCT system configured for testing composites. SLD: super-luminescent diode, LP: linear polarizer, F-R: Fresnel-Rhomb prism, BS: non-polarizing beam splitter, PBS: polarizing beam splitter, SMF: single-mode fiber, Det: detector. Top right circle: Orientation of the composite structure to be examined.

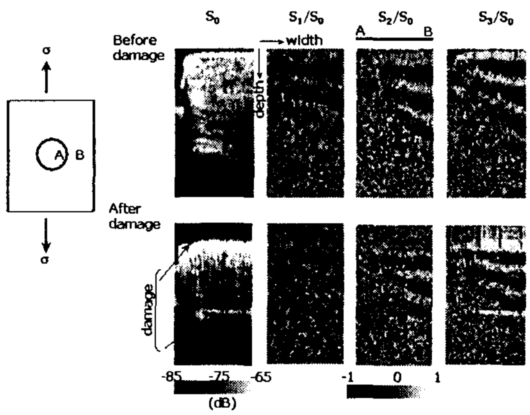

Figure 2: Comparison of two-dimensional images of Stokes parameters taken before and after failure by excessive loading. Upper four images were taken before failure and below four images after failure. Arrows in S0 image indicate delaminations. The physical size of each image is 1.0 mm(depth) x 0.5 mm(width), and the pixel resolution is 8 x 10 mm.