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FIBER-OPTIC-BASED

FIBER-OPTIC-BASED IN-PROCESS MONITORING OF CFRP STRUCTURES FOR MATERIAL QUALITY ASSURANCE

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ABSTRACT

Although carbon fiber reinforced polymer (CFRP) composites have been used extensively in many aerospace structures such as Boeing 787 and Airbus 350, low-cost and high-rate production CFRP are highly demanded for next-generation single-aisle commercial aircraft. Competition has been increasing between CFRP and light-weight metals and quality assurance methods are the key technologies for CFRP to be used in such applications.

High-fidelity process simulation codes are useful tools for quality assurance of CFRP structures but needs appropriate in-process material property data. We have been developing optical fiber sensor based process monitoring methodology to obtain in-process material property data which cannot be provided by conventional material characterization methods. Such data have been successfully fed into the process simulation code for better prediction of CFRP structures to avoid many trials and errors in the development of new CFRP materials for high-rate production.

This presentation includes the following research items from the author's recent papers.

Composite cure simulation scheme fully integrating internal strain measurement [1]: Fiber Bragg grating (FBG) strain sensors are embedded in a composite laminate and the two key parameters for simulation, composite shrinkage strain and stiffness change during curing, are simultaneously determined from in-situ measurements by the embedded FBG sensors. Furthermore, the simulation is validated using internal strain change during curing.

Process-induced strain and distortion in curved composites [2]: L-shaped CFRPs are fabricated and the internal strains (out-of-plane normal and shear strains) states are monitored during the fabrication. The deformation changes from shear dominated to bending dominated as cure proceeds. Thickness effects are particularly studied to show the advantages of the process-induced strain monitoring.

Cure-induced strain and failure in deltoid of composite T-joints [3]: Three types of deltoid structures with differently oriented interlaminar toughened layers are used, and the relationship between the strain distribution and the failure pattern of the deltoid are examined. Based on the experimental results, finite element analysis is conducted and a failure index for the process-induced failure of deltoids is developed.

References

[1] S. Minakuchi, S. Niwa, K. Takagaki, N. Takeda, "Composite cure simulation scheme fully integrating internal strain measurement," Composites Part A, Vol. 84, pp. 53–63 (2016)

[2] K. Takagaki, S. Minakuchi, N. Takeda, "Process-induced strain and distortion in curved composites. Part I: Development of fiber-optic strain monitoring technique and analytical methods" Composites Part A, 103, 236-251 (2017)

[3] S. Hisada, S. Minakuchi, N. Takeda, "Cure-induced strain and failure in deltoid of composite T-joints," Composites Part A, 141, 106210 (2021)

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BIO

Dr. Nobuo Takeda, is currently Chairman, Japan Transport Safety Board (JTSB) and Professor Emeritus, the University of Tokyo. His research includes experimental micromechanics of composites and smart composite structural health monitoring (SHM) and process/life cycle monitoring (LCM). He has led several Japanese national projects on structural health and process monitoring of aerospace composite structures mainly based on optical fiber sensors. He was President of International Committee of Composite Materials (ICCM, 2015-2016) and Japanese Representative of International Committee on Aeronautical Fatigue (ICAF, 2009-2017). He is currently Asian Editor of Composites Part A. He is World Fellow of ICCM and Fellow of SAMPE.

He graduated from the University of Tokyo with BEngr and MEngr (Aeronautics), from University of Florida with PhD (Engineering Mechanics). Then he also graduated from the University of Tokyo with DEngr (Aeronautics). After working at Japan Atomic Energy Research Institute (JAERI) and Kyushu University, he joined the faculty at the University of Tokyo in 1988. He was Dean, Graduate School of Frontier Sciences in 2013-2015, and Vice President in 2015-2017.