

# The Role of Embedded Sensors in Damage Assessment of Composite Laminates

Chun Park, Kara Peters, Mohammed Zikry

Department of Mechanical and Aerospace Engineering, North Carolina State University, Raleigh, NC 27695

## ABSTRACT

Various densities of optical fibers are embedded into a total of eighty woven, graphite fiber-epoxy composite laminates, for which the response to low velocity impacts are evaluated. The goal of this work is to determine the role of host-sensor interaction on the lifetime of the host material system. The woven composites are subjected to multiple impacts at 14.5 J until perforation of the specimen. We obtain the energy dissipated by the laminate and the maximum contact force between the impactor laminate for each strike.

## I. INTRODUCTION

Fiber reinforced polymer composites have become widely used as replacements for traditional metallic materials in aerospace applications. Their use has produced lightweight, high performance airframe skins, stiffeners and structural joints. As the failure mechanisms of these laminated structural components are significantly different than those of homogenous materials new, in-situ damage assessment methods must be implemented to assure the reliability of these components. Internal damage in the form of delaminations, fiber breakage and matrix relaxation can interact and rapidly lead to catastrophic failures. One of the most promising techniques to assess internal damage in these composite laminates is the embedment of an array of sensors directly into the laminate [1]. Recent advances in signal processing techniques for fiber Bragg grating (FBG) sensors have permitted unique damage signatures to be determined from their spectral response.

In general, the more sensors that are available within a given structural volume, the higher the fidelity of the damage state reconstruction from the sensor information and therefore the more accurate the remaining lifetime prediction for a given structural components. However, this increased fidelity is not without additional costs. When designing a surface mounted sensor

network, increasing the number of sensors increases the hardware costs, installation costs and data collection requirements of the system. While the same is true for embedded sensors, a more critical penalty from an increased number of sensors is the potential negative impact of the network on the material properties of the host material system the network is intended to monitor. In order to properly design an embedded sensor network one must therefore be able to accurately quantify this penalty for a given structural component.

In this article we perform an experimental study of the global response of woven graphite fiber-epoxy laminates subjected to multiple low velocity impacts with various densities of embedded optical fibers. The goal is to quantify the role of optical fiber density on the degradation of global material properties of the host material system. A large number of specimens are experimentally tested at various embedded optical fiber densities to measure the changes in the statistical distributions of the maximum contact force and total dissipated energy of the laminates. These results are then interpolated to yield a model of these properties as a function of embedded optical fiber density. While the resulting numerical values of the model would be different for another material system or impact loading history, the goal of this work is to derive the testing protocol and data analysis method to apply to any laminate configuration.

## REFERENCES

1. R. Garrett, K. Peters and M. A. Zikry, "In-situ impact-induced damage assessment of woven composite laminates through a fiber Bragg grating sensors network," *Journal of the Royal Aeronautical Society*, Vol.113, pp. 357-370, 2009.