ADVANCED STRESS SENSING

An aerospace structure manufactured using a certain hybrid carbon fiber composite with embedded nano stress-sensors can reinforce the material and introduce inherent advanced stress-sensing capabilities.

OBJECTIVES

- Experimentally measure stress-sensing capability introduced in a carbon fiber composite with embedded alumina nanoparticles through piezospectroscopy
- Characterize particulate dispersion through photo-luminescent mapping.

PIEZOSPECTROSCOPIC COATINGS

Piezospectroscopy (PS) is a laser based stress sensing technique, which involves monitoring the spectral emissions of photo-luminescent materials as they change with stress. Through the piezospectroscopic effect, previous work utilized aluminum oxide (alumina) epoxy nanocomposites as stress sensing materials [1].

The composites used in this work include unidirectional carbon fiber and an epoxy matrix loaded with alumina nanoparticles. This composite, which includes both a fibrous filler as well as a particulate filler, is commonly referred to as a hybrid carbon fiber reinforced polymer (HCFRP). The alumina HCFRP was manufactured at Imperial College London using a resin infusion under flexible tooling (RIFT) technique [4].

In order to determine the HCFRP’s stress sensing capabilities, the samples were loaded in tension using a mechanical testing system. Therefore, Aluminum end tabs were adhered to the ends of the samples through a quick setting epoxy; this allows for the course-textured testing grips to latch onto the sample without damaging it.

The Portable Piezospectroscopy System [5] was used to conduct the photoluminescence piezospectroscopic maps of the HCFRP’s surface.

STRESS SENSING RESULTS

Particulate Dispersion

In the 20wt% Static Hold Piezolevel Scan, a positive (or tensile) peak shift can be seen increasing in each map, represented by the increasing red color.

Non-Contact Stress Mapping

A similar tensile biaxial strain trend can be seen increasing in the 20 wt% Simultaneous Digital Image Correlation (DIC) data, also represented by the increasing red color.

The average peak shift of each map at its respective stress and strain are plotted to the right, and a linear ramp-up behavior can be observed in both, the slope of which quantifies the PS coefficient (stress sensitivity). The PS error bars are representative of the non-uniformity of the surface, and the DIC strain data also reflects this surface non-uniformity.

HYBRID COMPOSITES & STRESS MAPPING METHODS

The final samples are of dimensions 10 mm by 100 mm by 3 mm, fitted with aluminum end tabs. There were four varying HCFRP, each with a different amount of alumina nanoparticles: 5, 10, 15, and 20 weight percent alumina. In the manufacturing of the 10 weight percent alumina, difficulty in achieving comparatively uniform dispersion was experienced.

DISCUSSION

This study showed that the piezospectroscopic effect provides sensing capabilities in a hybrid composite that includes unidirectional carbon fiber and alumina nanoparticles. In general, with increasing alumina content, a more significant peak shift was observed (with exception of the 10wt%) indicating increased sensitivity to stress. However, methods outside of a linear slope representing the PS coefficient must be explored to adequately capture and represent the non-linear response.

FUTURE WORK

One area of future work is the complete mechanical characterization of this new hybrid composite, including composites with lower alumina contents, as well as the development of non-contact sensing of fatigue and creep behavior.

REFERENCES & ACKNOWLEDGMENTS


This material is based upon work supported by the National Science Foundation under Grant No. CMMI 1130837 and the Innovation through Institutionalized Integration (ICube) program. This work was also supported by an Undergraduate Research Grant provided by the UCF Office of Undergraduate Research. Thank you also to the Research and Mentoring Program (RAMP) for their support.