Hybrid Carbon Fiber Composite Characterization via Piezospectroscopy

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MOTIVATION
The aerospace industry puts in operation new materials which properties are continually enhanced and must be kept for ensuring safety. Controlling these properties with precision is essential in order to prevent formation of cracks and anticipate repairs. A developing technology, that allows non-contact stress quantification, known as piezospectroscopy, is occupying an even more prominent place. However, its use still have to be improved (portability, efficiency, accuracy).

The University of Central Florida has developed a portable system that is regularly placed under probation at Boeing, in Seattle. Previous work has shown great hopes in the use of this equipment more broadly in industry.

TECHNIQUE : PIEZOSPECTROSCOPY
The principle consists in shining a material in order to get back the reflected radiation that is characteristic of the stress on the surface. However, the material has to contain or to be topped with photoluminescent Cr3+ ions, so the considered peaks can show up in the spectrum.

MATERIAL : HCFRP
Hybrid Carbon Fiber Reinforced Polymer is the material used in this project. This material could find applications in aerospace structures. The HCFRP samples were made at Imperial College London with 4 different proportion of alumina 15, 10, 15 and 20 weight percent. Alumina nanoparticles were mixed with epoxy and then loaded into a stack of carbon fibers.

OBJECTIVES
- Characterize residual stresses created during the manufacturing process in the alumina embedded in HCFRP.
- Measure stress sensing capabilities of the HCFRP for high tensile loadings (around 600 MPa, which is close to the failure of the samples).

RESIDUAL STRESSES DUE TO MANUFACTURING
The challenge with manufacturing HCFRP was the non-uniform distribution of particles through the thickness, which occurs as a result of the epoxy’s viscosity at the start of the curing process, resulting in the settling of the alumina nanoparticles to the bottom surface of the specimens. Using piezospectroscopy by measuring the intensity of the signal on each face, previous work highlighted that, at low particle contents, dispersion is uniform while at high particle contents it is not.

NON-CONTACT STRESS SENSING MAPPING
In order to determine the HCFRP’s stress sensing capabilities, the samples were loaded in tension using a mechanical testing system.

CONCLUSIONS AROUND MANUFACTURING
Using piezospectroscopy, sedimentation of alumina on the bottom of the samples, due to manufacturing, was observed and quantified by measuring the intensity of the R-peaks. On the other hand, the shifts of these R-peaks were calculated and a link between sedimentation and residual stress has been highlighted.

DISCUSSION ON THE HIGH TENSILE TEST
The preparation of the samples and the way to set up a high tensile test has direct consequences on how far it is possible to go. For these experiments, improvements have been made to go up to the failure of HCFRP samples. However, all the experiments but one were stopped because failure happened in the adhesive.

FUTURE WORK
Further characterization of the current HCFRP samples could be achieved like determining bending fatigue properties. Fracture toughness testing is currently being done at Imperial College London.

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