Hybrid Carbon Fiber Composite Characterization via Piezospectroscopy

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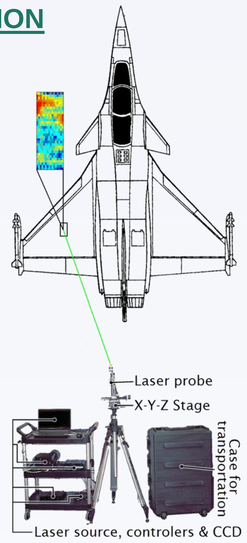
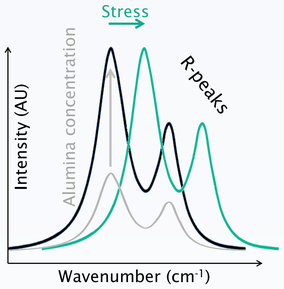
MOTIVATION

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 ever 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.

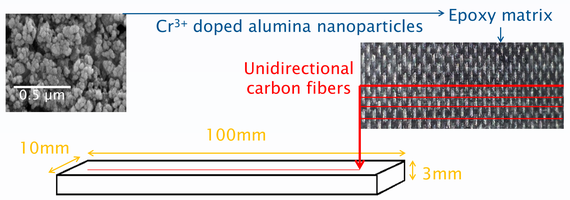
TECHNIQUE : PIEZOSPECTROSCOPY



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 Cr^{3+} 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 : 5, 10, 15 and 20 weight percent. Alumina nanoparticles were mixed with epoxy and then loaded into a stack of carbon fibers.



OBJECTIVES

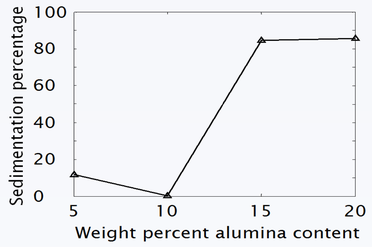
➡ Characterize residual stresses created during the manufacturing process in the alumina embedded in HCFRP.

➡ Measure stress sensing capabilities of the HCFRP for high tensile loadings (around 600 MPa, which is close to the failure of the samples).

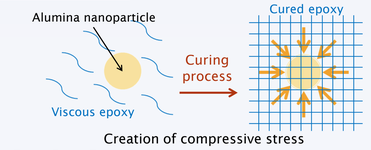
RESIDUAL STRESSES DUE TO MANUFACTURING

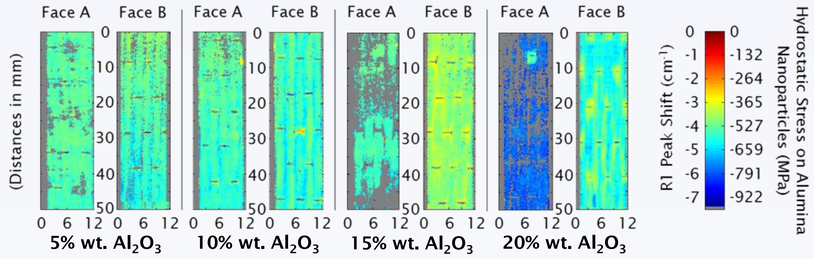
The challenge with manufacturing HCFRP was the non-uniform distribution of particles through the thickness, which occurs as a result of the epoxy's viscosity at the start of the curing process, resulting in the settling of the alumina nanoparticles to the bottom surface of the specimens.

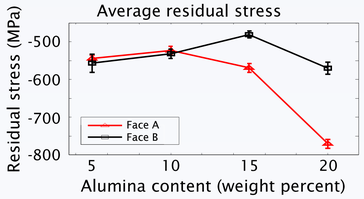
Using piezospectroscopy by measuring the intensity of the signal on each face, previous work highlighted that, at low particle contents, dispersion is uniform while at high particle contents it is not.



Compressive residual stresses present in the HCFRP samples were determined, by using the shifts of the R-peaks from a reference point which has been taken from the average position of these R-peaks on an unprocessed alumina nanopowder.



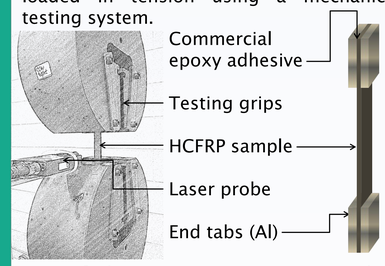




On the top and bottom of the 5% and 10% samples, residual stress is homogeneous. However, there are significant differences between the top and bottom of the 15% and 20%.

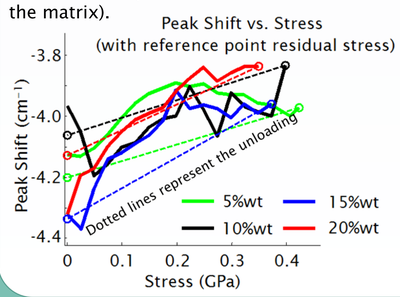
NON-CONTACT STRESS SENSING MAPPING

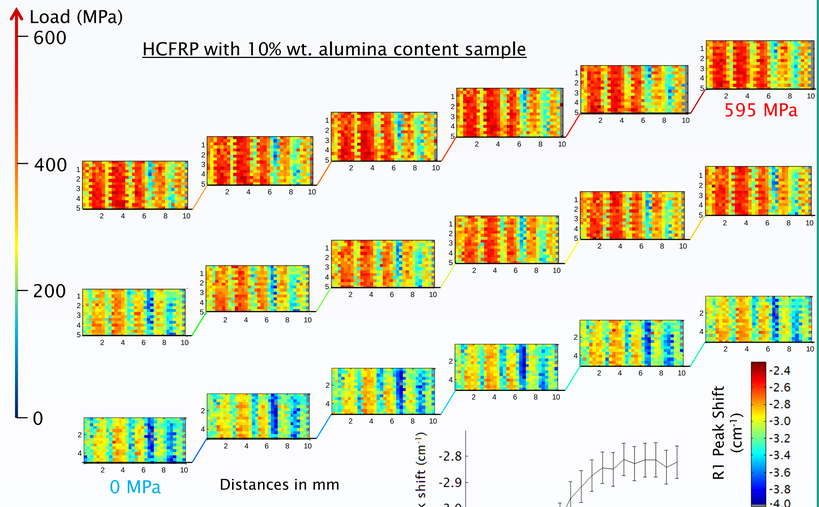
In order to determine the HCFRP's stress sensing capabilities, the samples were loaded in tension using a mechanical testing system.



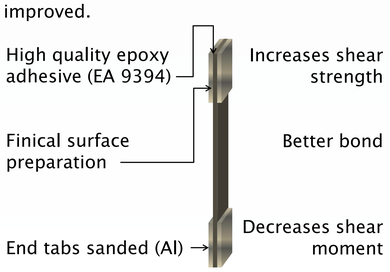
One of the main issues encountered in previous work was concerning end tabs required for the course-textured testing grips to latch onto the sample without damaging it. High tensile values were not reached because end tabs adhesive failed at around 350 MPa.

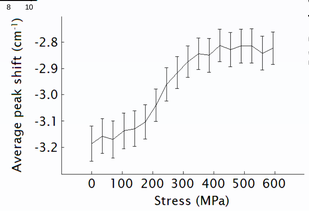
Taking into account residual stresses it is possible to see a positive trend between 50 and 200 MPa (then alumina unbonds from the matrix).



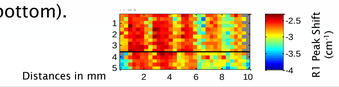


To make possible a high tensile test (around 600 MPa), specimen had to be improved.



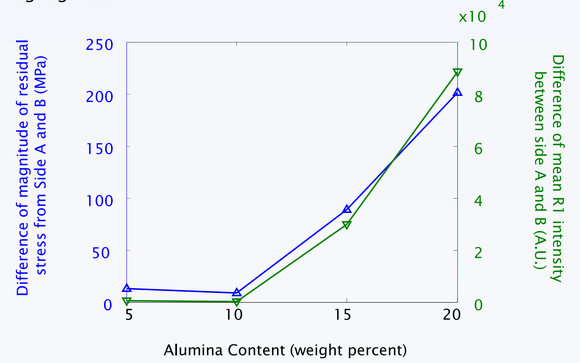


These improvements allow for maps to be taken closer to the failure. For the 10% wt. alumina content sample, 630 MPa was reached but the adhesive failed while the map was being recorded so the last quarter of the map shows relaxation (on the bottom).



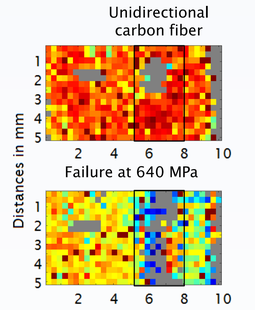
CONCLUSIONS AROUND MANUFACTURING

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.



The delamination of one of the fibers of the 15%wt. alumina content sample was observed at 640MPa. All the tensile stress of this region seems to relax to more compressive values and grey pixels indicate that, because the fiber went away, the laser is not focusing anymore.

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.

Future work could include improvement of the manufacturing process and/or characterization of HCFRP samples that utilize multidirectional carbon fibers.

REFERENCES & ACKNOWLEDGMENTS

[1] Hanhan, Imad *Hybrid Carbon Fiber Alumina Nanocomposite for Non-Contact Stress Sensing Via Piezospectroscopy*. Diss. University of Central Florida, Orlando, Florida, 2015

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