X-Ray tomography investigation on the effect of diffuse damage on transverse cracking in carbon fiber reinforced laminates CFRP

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Industrial context

Carbon Fiber Reinforced Plastics (CFRP) are an essential and prevalent materials for many industries (automotive, wind industry, shipbuilding, sports …) especially for aircraft industry:

- High performance FRP for primary aircraft components: High strength and low weight.
Damage induced in carbon fiber pre-preg laminates $[0, 90]_s$

- A key point is to better understand their complex mechanisms of degradation, from the process to the final failure.
- This requires the development of multiscale models and methods that can capture fiber/matrix debonding, transverse cracking, delamination, and all potential interactions between these damages.
An important material parameter in composite design is the fracture toughness to transverse cracking that is commonly identified on multi cracking testing with cross-ply laminates.

The primary objective is to identify the effect of pre-existing diffuse damage on this fracture toughness.
Sample preparation: CFRP pre-preg laminates $[0, 90]_s$

(a) Master plate (MP)  
(b) Shear Loading (SL) sample tested on Instron 8552  
(c) Transverse Cracking (TC) sample tested on Deben tensile stage
Mechanical tensile cyclic test

(a) Instron 5882 load frame
(b) Deben 5 kN tensile stage
(c) X-Tek XT H 225 tomograph

$d = 1 - \frac{G_{12}^n}{G_{12}^0}$
Strain field evolution: $\varepsilon_{yy}$
Modeling the interaction between diffuse damage and transverse cracking

\[ G(\rho) = \frac{h < \tilde{\sigma}_{22} > +^2}{2 \tilde{E}_2} f(\lambda \rho) \]

\[ G_c^0(1 - \eta(\tilde{d})) = \frac{h < \tilde{\sigma}_{22} > +^2}{2 \tilde{E}_2} f(\lambda \rho) \]

Fracture toughness, \( \tilde{G}_c (\text{J/m}^2) \)

![Graph showing the interaction between diffuse damage and transverse cracking]
Conclusion

- The results presented here establish that there is a strong connection between diffuse damage and microcracking in the evolution of damage in carbon fiber composites.

- In carbon fiber composite samples that experience diffuse damage, the evolution of transverse cracking is modified, and this modification can be accurately described by a change in the effective fracture toughness.

- Despite requiring an extensive experimental campaign for its characterization, the strong coupling between the two mechanisms is essential to the accurate simulation of transverse cracking. The results presented here offer a first insight into this coupling phenomenon.
Conclusion

- Our future investigations will focus on similar effects in fatigue crack propagation. Indeed, we suspect that the development of transverse cracks under fatigue loading is a direct result of diffuse damage. Extensive characterization of both mechanisms under cyclic loading will make possible the identification of a similar coupling function and unified static and cyclic descriptions of transverse cracking.
Thank You