- Project proposal -
Microscopic observation and statistical analysis of initiation and propagation of the fiber/matrix interface crack

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1. Introduction

Although microscopic observations have been performed since , only few works ([1, 2]) have attempted to statistically characterize the size of fiber/matrix interface crack in FRP UD and cross-ply laminates. Current methods allow for feasible and reliable measurements only in 2D, by observing the specimen on each side and eventually the two sides of a central longitudinal cross-section obtained after cutting and polishing. Coupled with numerical and analytical estimations of ERRs at the crack tips, a statistical analysis of debonds' geometry for different combinations of material configurations and loading could provide valuable insights into the mechanisms underpinning the onset of transverse cracks in FRP laminates.

2. Objectives

1. Determine the statistical distribution and statistical descriptors (mean, mode, median, variance) of

    a debond size,

    b angular position of debond's crack tips,

    c angular position of debond's mid-point,

    d angular position of kinks' start,

e kinking angles,

parameterized with respect to

a fibers' material,

b laminate lay-up,

c level of applied strain.

2. Investigate correlations between the quantities defined in 1 and the distribution of

a fibers' radii,

b angular position of closest fiber to debonded one,

c distance of closest fiber to debonded one,

d material,

e lay-up,

f level of applied strain.

3. Measure the reduction in stiffness.

4. Measure the linear density of transverse cracks.

5. Measure the areal density of debonds.

3. Materials

Glass-fiber and carbon-fiber cross-ply $[0^{\circ}_{m\cdot n}, 90^{\circ}_{n}]$ with $m = 1, 10$. 6 specimens for each lay-up and material combination, for a total of 24.

4. Methods

1. Manufacturing of laminates through manual lay-up, cutting and polishing of specimens.

2. Tensile tests in quasi-static conditions at 2 $[mm/min]$ reaching different levels of applied strain: $[0.4\%, 0.6\%, 0.8\%, 1.0\%]$.

3. Once a target level of strain is reached:

    a unload the specimen and then load again at 0.3% to evaluate the reduction in stiffness;

    b count the transverse cracks visually and then with the optical microscope, with which measure the distance between cracks;

    c for each debond visible with the aid of the optical microscope, measure its fiber's radius, its angular size, crack tips' position, kinks' starting position, angular position and distance of the closest fiber.

4. Analyse the data in Python, R, Excel or Matlab.

5. Expected outcomes

6. Audience

2-3 students for Project Course or Master thesis.

References

[1] E. Correa, M. I. Valverde, M. L. Velasco, F. París, Microscopical observations of inter-fibre failure under tension, Composites Science and Technology 155 (2018) 213–220. doi:10.1016/j.compscitech.2017.12.009.

[2] P. L. Zumaquero, E. Correa, J. Justo, F. París, Microscopical observations of interface cracks from inter-fibre failure under compression in composite laminates, Composites Part A: Applied Science and Manufacturing 110 (2018) 76–83. doi:10.1016/j.compositesa.2018.04.004.