In situ observation of crack initiation and propagation in CFRP using X-CT

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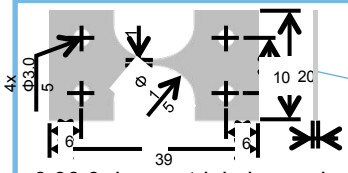
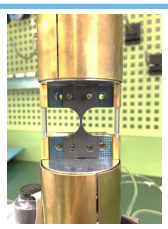
Introduction

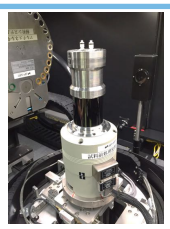
- Carbon fiber and carbon fiber reinforced plastic (CFRP) composite are promising material for application for aircraft and spacecraft by their light weight and high strength and toughness.
  Determination of a crack initiation and its propagation mechanism develops innovative application.
- In this study, *in-situ* X-ray computed tomography (X-CT) was applied for damage visualization during tensile testing of multi-layered uni-directional CFRP composite, where damage initiation and propagation mechanism can be observed with a spatial resolution.

Experiment



0,90,0 degree triple layered uni-directional CFRP, HYEJ25-36.





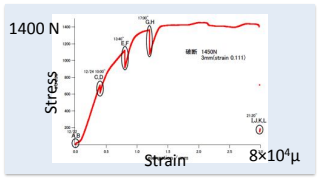
Tensile strain was applied to the specimen with cylindrical pins inserted into four holes of the specimen

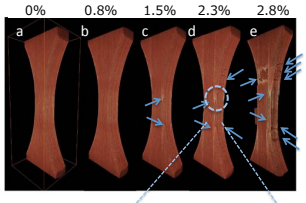
X-CT observations were carried out with mechanical testing .

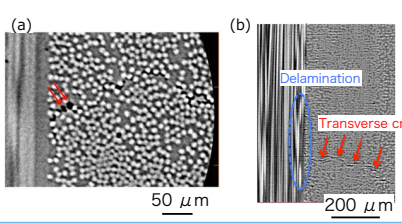
Results

Crack initiation and propagation under tensile stress

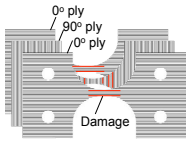
> Spatial resolution down to 0.6 μm
> Clear identification: 90° ply cracks, 0° ply splits, and delaminations



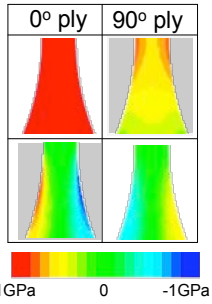




Strain analysis with FEM



ASSUMPTION
0° ply (fiber direction)
Tensile strength: 2200MPa
Young's modulus: 128GPa
90° ply
Tensile strength: 69MPa
Young's modulus: 8GPa



Longitudinal tensile stress

In-plane shear stress

> Initiation of cracks occurs in areas where high tensile and shear stress are expected.

Segmentation of crack-types

> Segmentation of crack-types were carried out by image-processing. (including manually)

> Change of crack-types were clearly shown:
  0° ply splits
  → 90° ply cracks
  → ply delaminations

Segmentation of X-CT volume data

	×10⁻³ Volume/mm³	Area/mm²
Purple: 0° ply splits	18.3.	3.60
Blue : 0° ply cracks	16.3	5.89
Red : delaminations	4.8	1.63

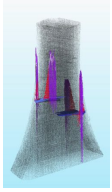


Fig. An example of segmentation.

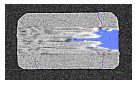


Fig. Change of crack-types during tensile loading.

Summary

- It was shown that in situ 3D X-CT provided us the information on crack initiation and its propagation.
- Further observation, including uni-directional CFRP, and its analysis proceeds in order to predict damagesin CFRP components.

This work was supported by Cross-ministerial Strategic Innovation Promotion Program - Unit D66 - Innovative measurement and analysis for structural materials (SIP-IMASM)