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

T. Ishii¹, R. Kitazawa¹⁺, H. Kawabe¹, Y. Takeichi¹,², Y. Niwa¹, M. Kimura¹,²

¹ High Energy Accelerator Research Organization (KEK)
² Dept. Mater. Structure Sci., School of High Energy Accelerator Sci., SOKENDAI (The Graduate University for Advanced Studies)
⁺ Present: Katayanagi Advanced Research Laboratories, Tokyo University of Technology

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

---

**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**

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: 2200 MPa
  - Young’s modulus: 128 GPa
  - 90° ply
    - Tensile strength: 69 MPa
    - Young’s modulus: 8 GPa

- In-plane shear stress
  - Damage
  - Longitudinal tensile 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.
  - Change of crack-types were clearly shown:
    - 0° ply splits
    - 90° ply cracks
    - Delaminations

> Segmentation of in-situ crack-type observations

- Purple: 0° ply splits
- Black: 90° ply cracks
- Red: Delaminations

---

**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 damages in CFRP components.