Composite healing – A new perspective base on Bio-inspired helicoidal structure

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Summary

1. Introduction
- Healing of CFRP composites
- Bio-inspired helicoidal laminate

2. Methods and results
- CFRP/CFRTP hybrid
- CFRP with PA6 toughening/healing particles

3. Conclusion

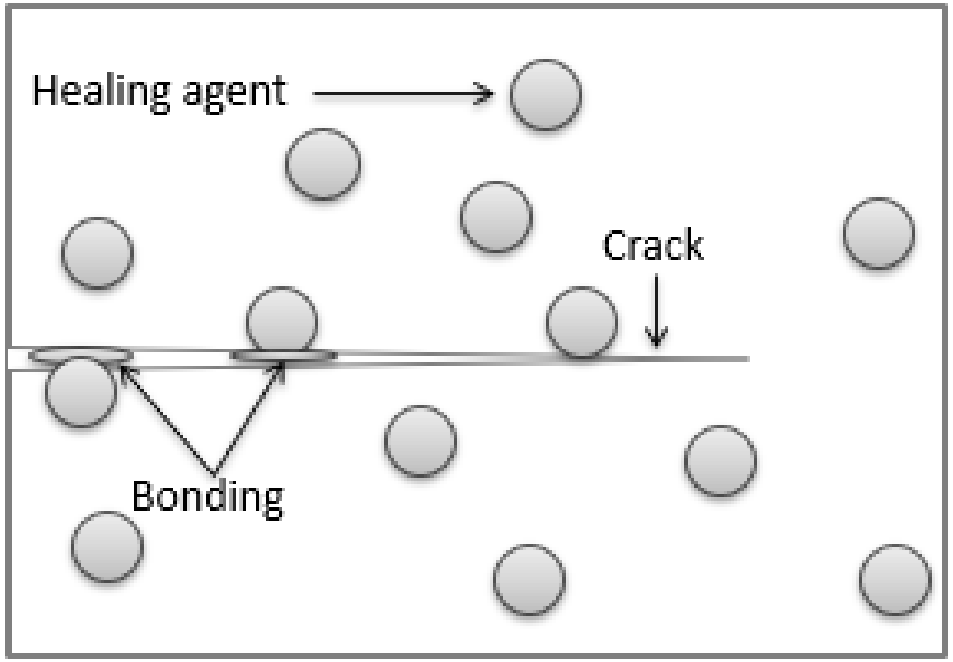
Healing of CFRP composites

Composite healing approaches:

- Embedding liquid healing agents contained in micro-capsule or vascular system in the composite.
- Embedding solid thermoplastic microparticles in the composite.

The challenge:

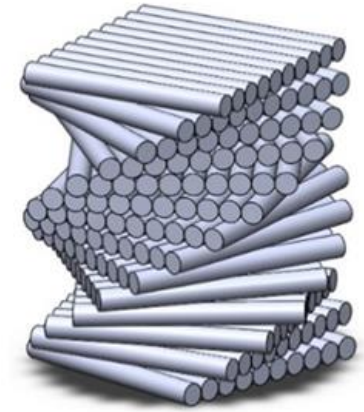
- Unable to heal damaged carbon fiber
- Impact-induced carbon fiber fracture is generally severe
- Carbon fibers are the main load carrier of CFRP

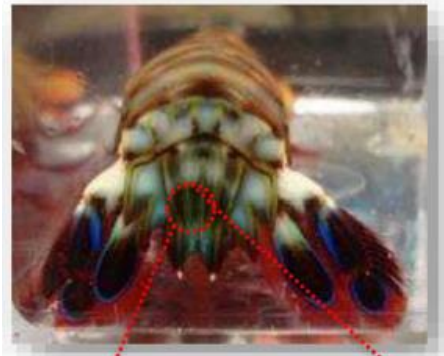


Helicoidal laminate

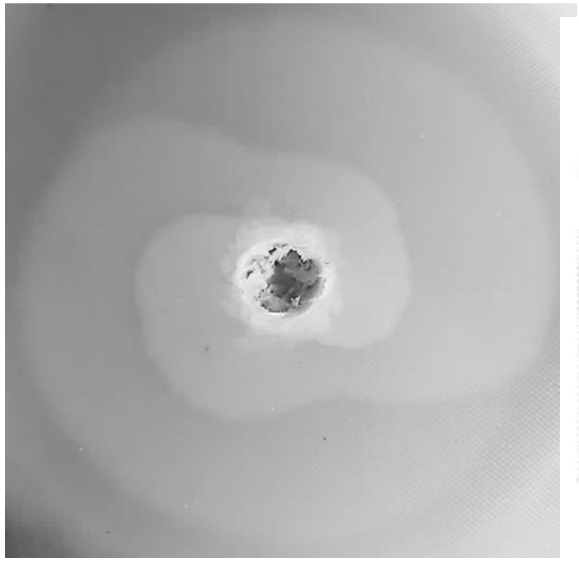
Bio-inspired helicoidal structure for CFRP laminate

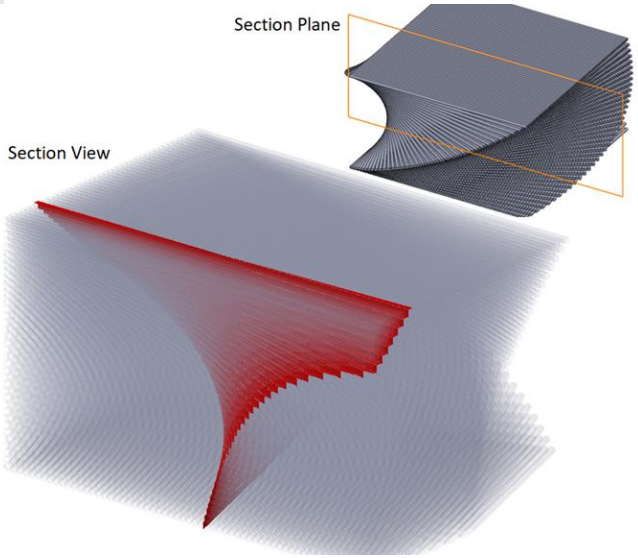
- [0/10/20/30/40/……330/340/350/0]s
- Higher out-of-plane strength
- Higher impact resistance

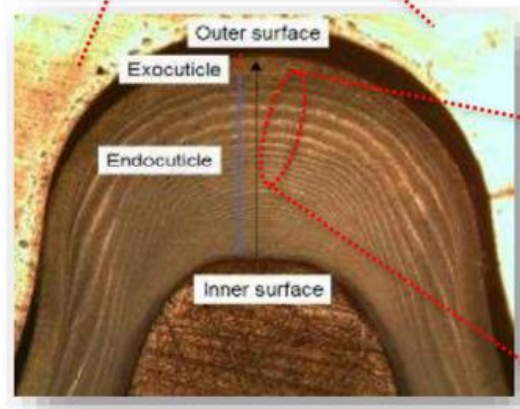


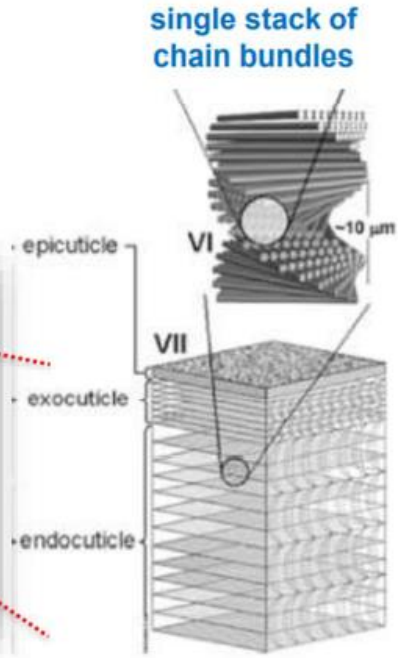


- Unique damage pattern



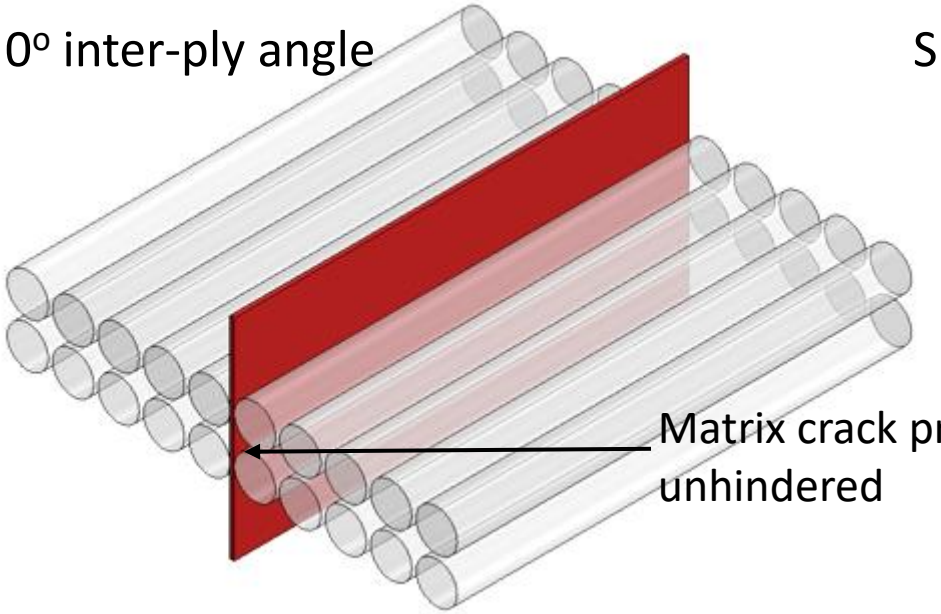




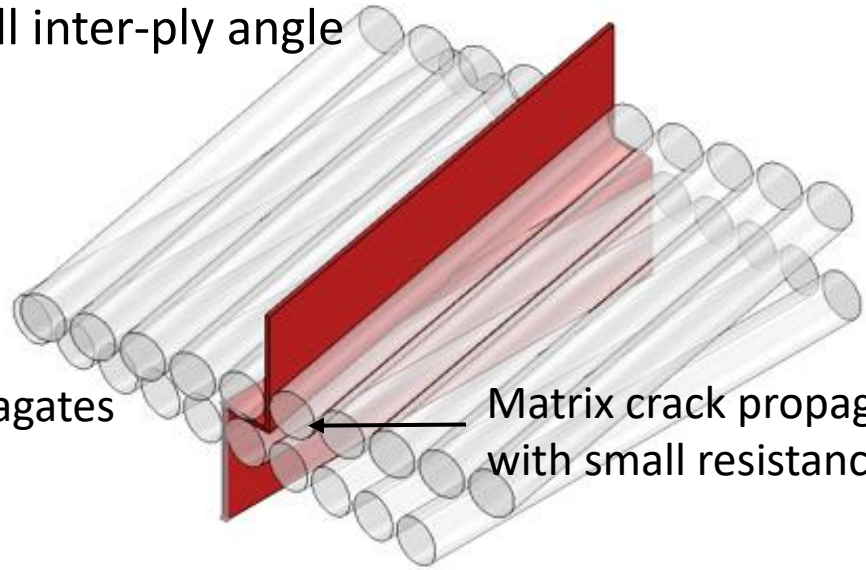


Unique damage pattern of helicoidal laminate

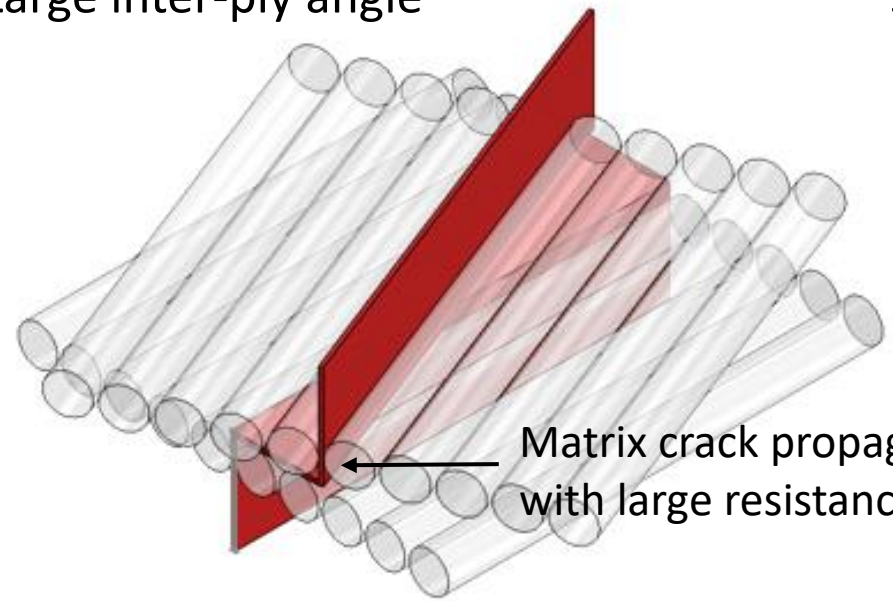
0° inter-ply angle



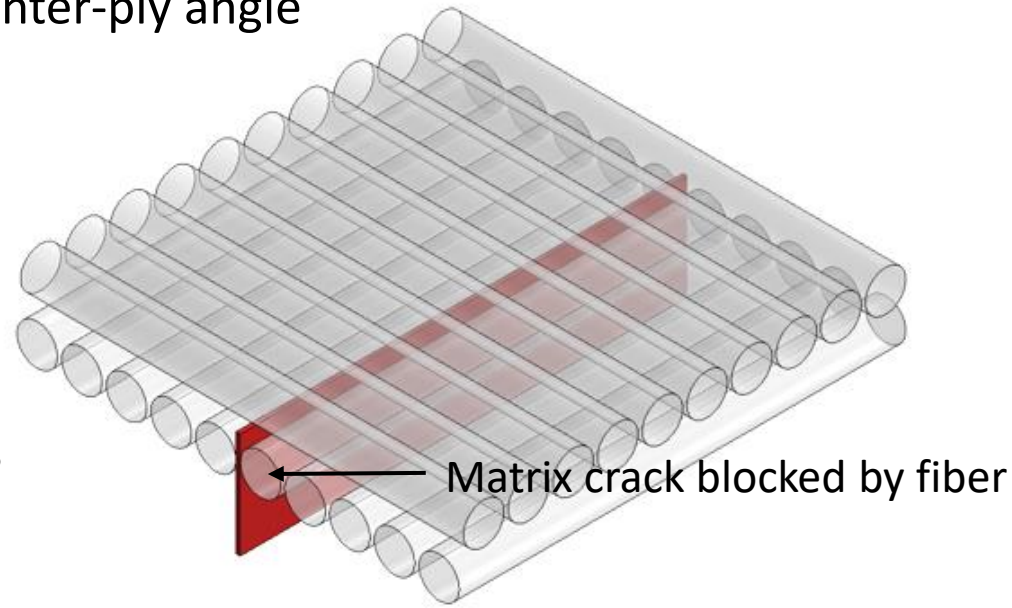
Small inter-ply angle



Large inter-ply angle

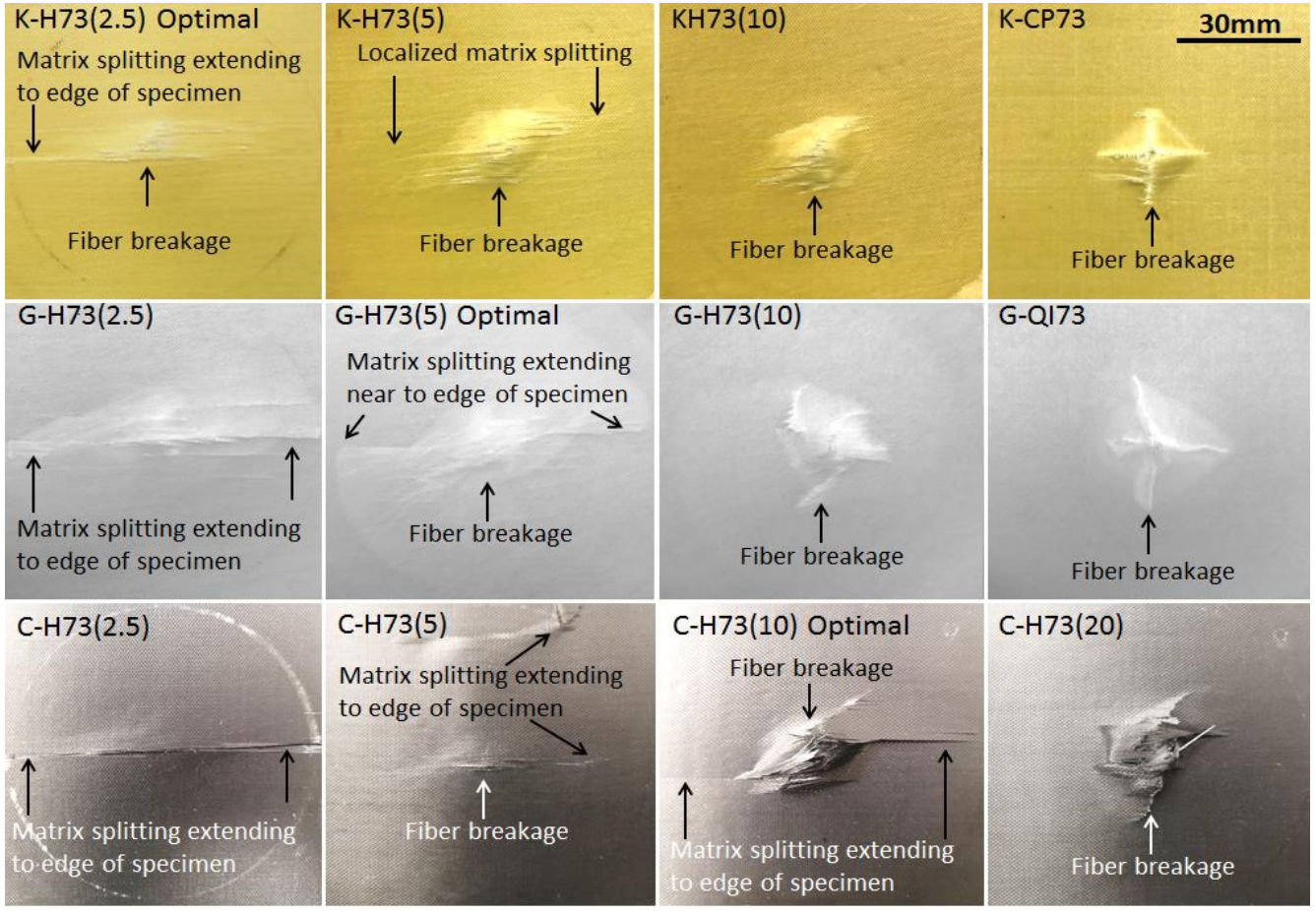


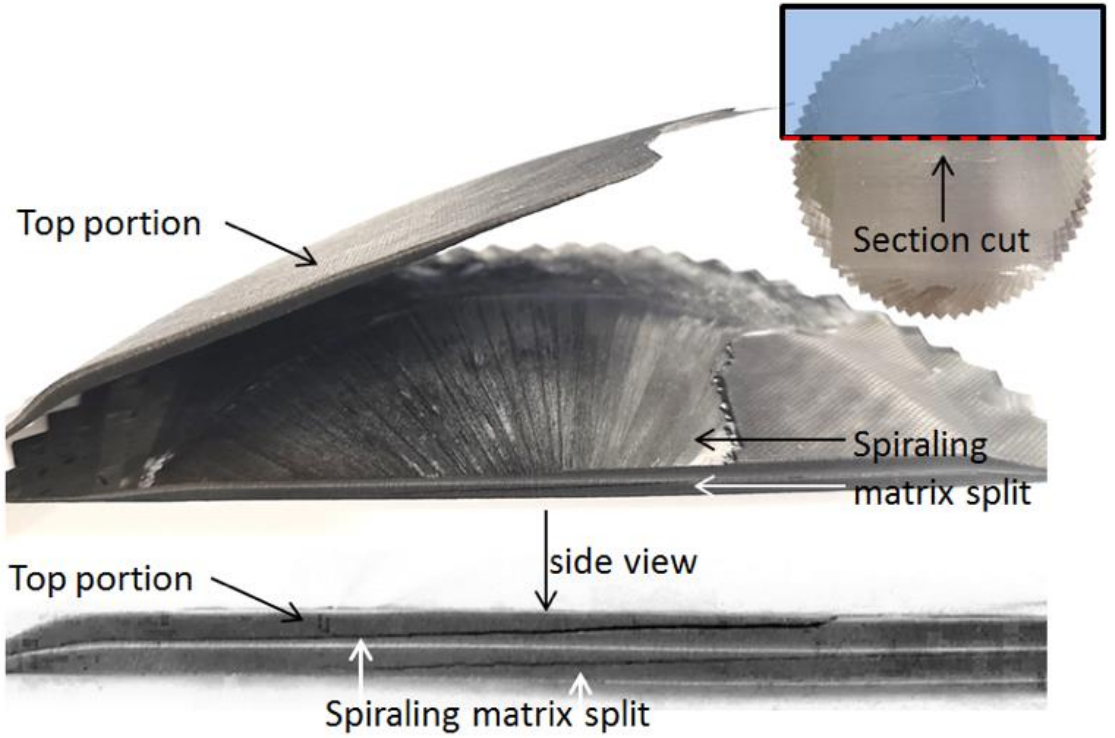
90° inter-ply angle

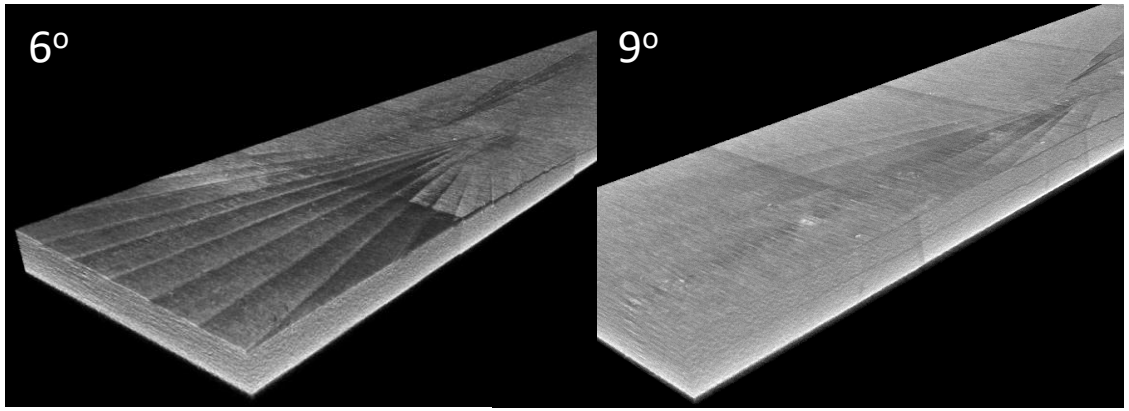


Unique damage pattern of helicoidal laminate

- Spiralling matrix splitting
- Significant decrease in fiber damage
- Angle, ply thickness, matrix property dependant

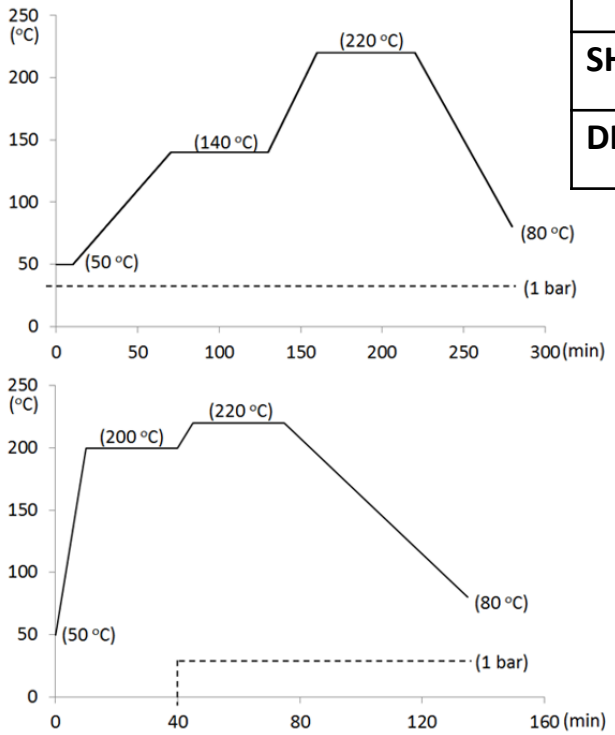


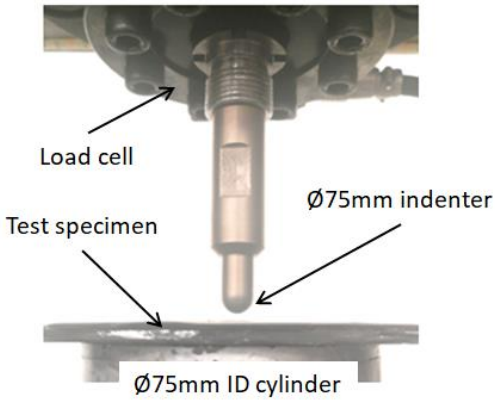


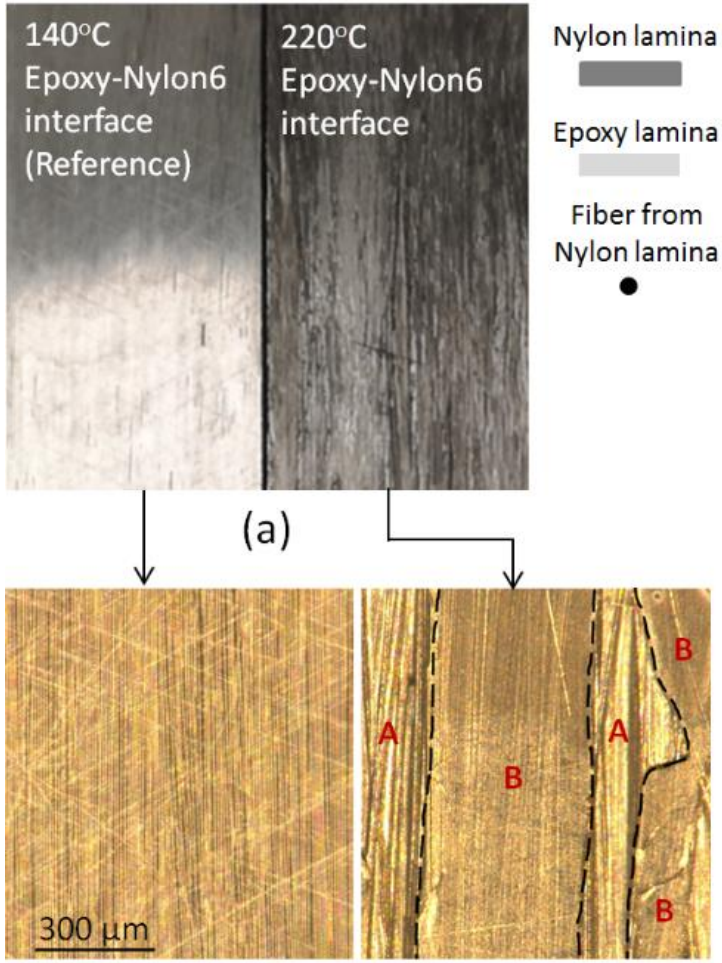


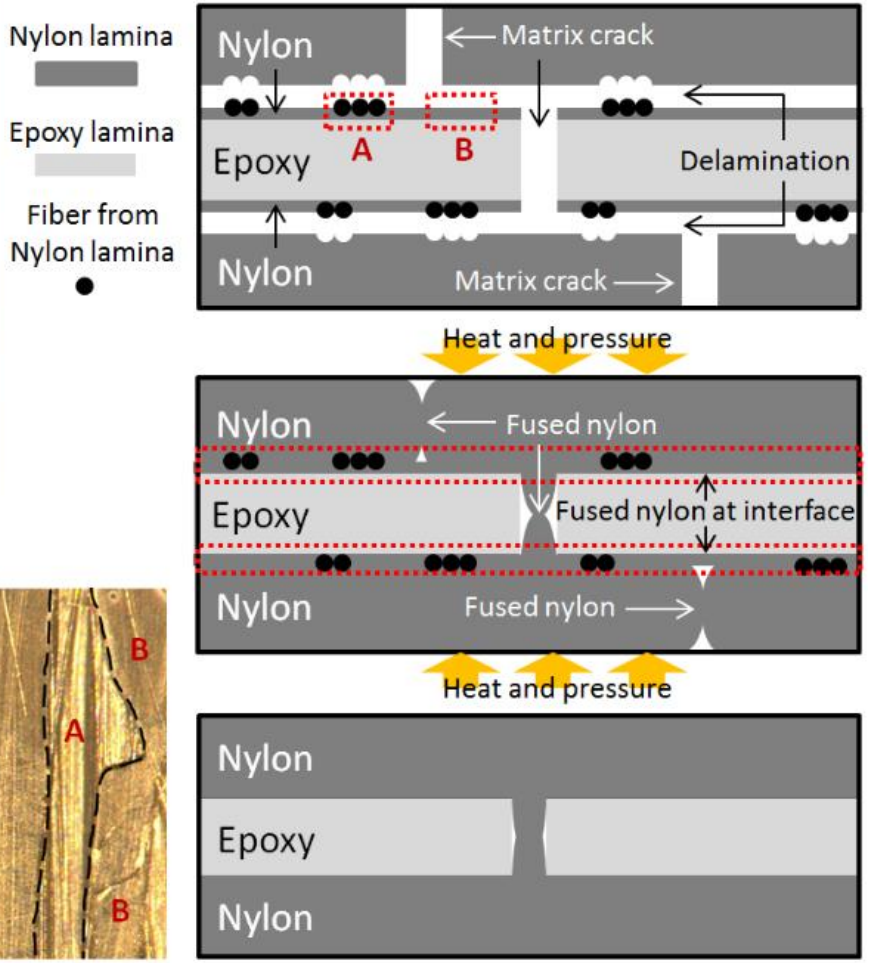
CFRP/CFRTP hybrid

CP47	**$[(0^{o}_{E}/0^{o}_{E}/90^{o}_{T}/90^{o}_{E}/90^{o}_{E}/0^{o}_{T})_{3}/0^{o}_{E}/0^{o}_{E}/90^{o}_{T}/90^{o}_{E}/\ 90^{o}_{E}/0^{o}_{T}/90^{o}_{E}/90^{o}_{E}/90^{o}_{T}/0^{o}_{E}/0^{o}_{E}/(0^{o}_{T}/90^{o}_{E}/90^{o}_{E}/\ 90^{o}_{T}/0^{o}_{E}/0^{o}_{E})_{3}]$**
SH47	**$[0^{o}_{E}/0^{o}_{E}/-6^{o}_{T}/-12^{o}_{E}/-12^{o}_{E}/-18^{o}_{T}/-24^{o}_{E}/-24^{o}_{E}/.../-168^{o}_{E}/-168^{o}_{E}/-174^{o}_{T}/-180^{o}_{E}/-180^{o}_{E}]$**
DH47	**$[0^{o}_{E}/0^{o}_{E}/-12^{o}_{T}/-24^{o}_{E}/-24^{o}_{E}/-36^{o}_{T}/-48^{o}_{E}/-48^{o}_{E}/.../-156^{o}_{E}/-156^{o}_{E}/-168^{o}_{T}/-360^{o}_{E}/-360^{o}_{E}]$**

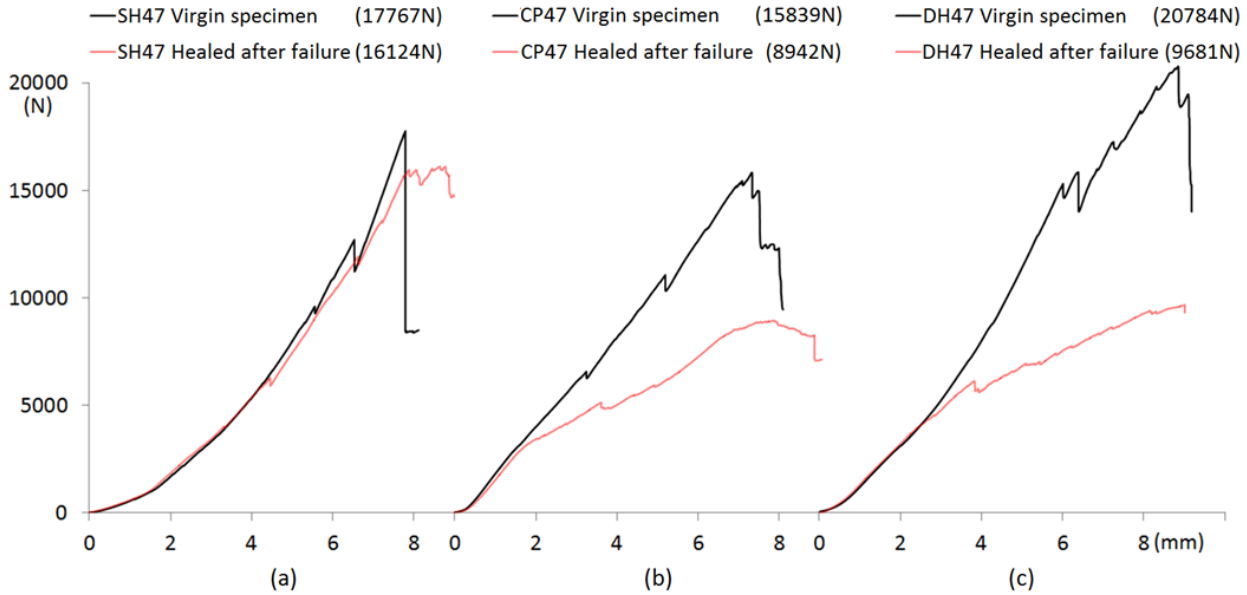


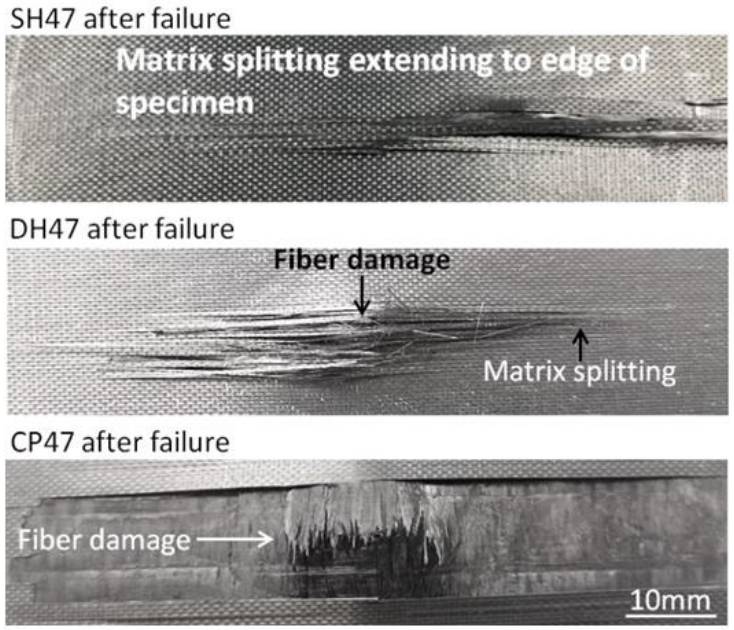


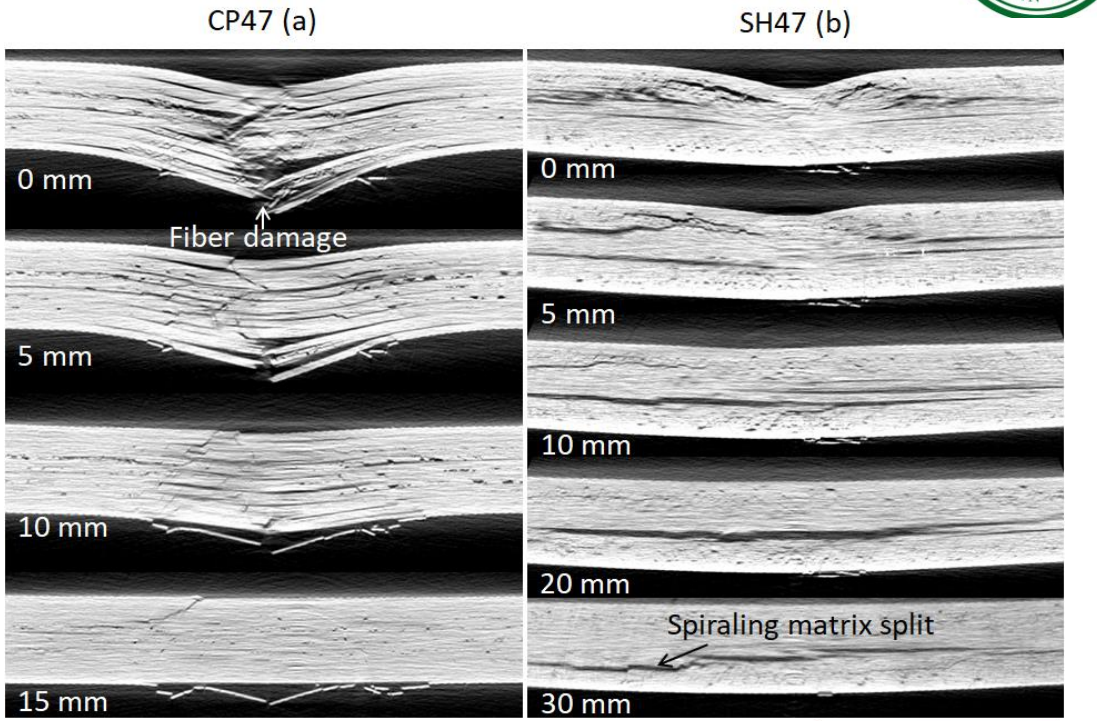


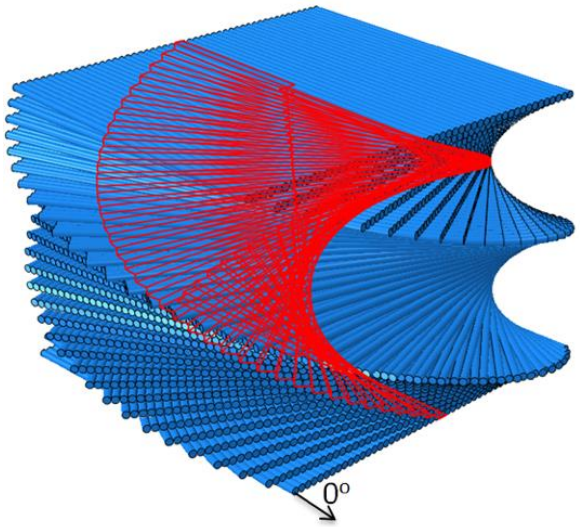


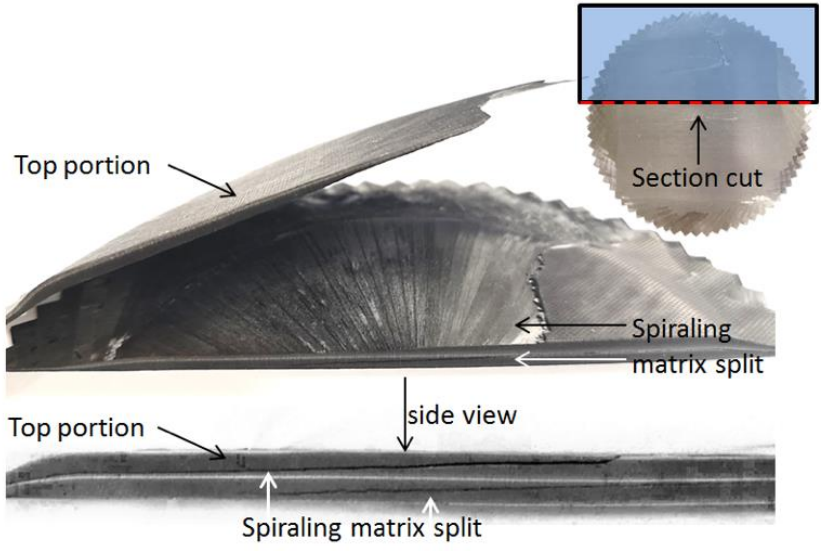
CFRP/CFRTP hybrid



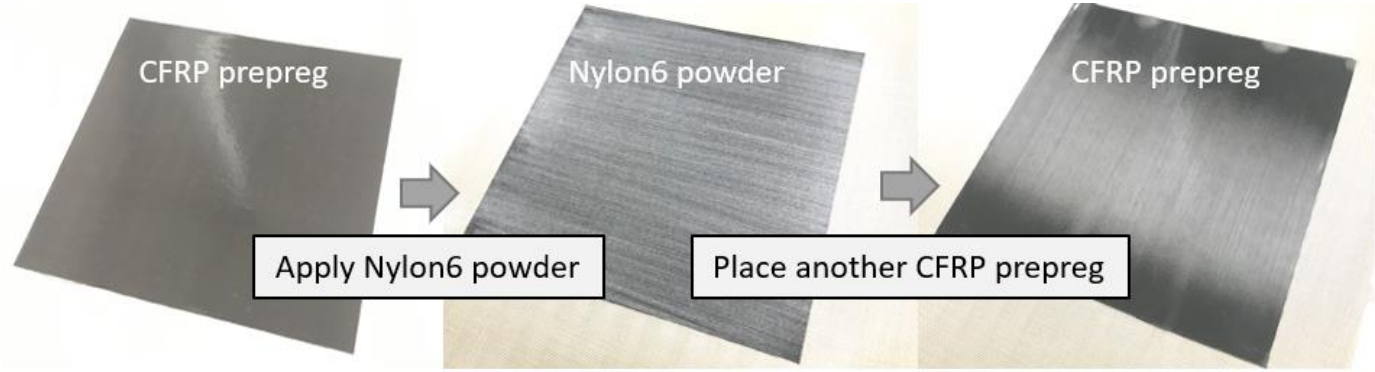


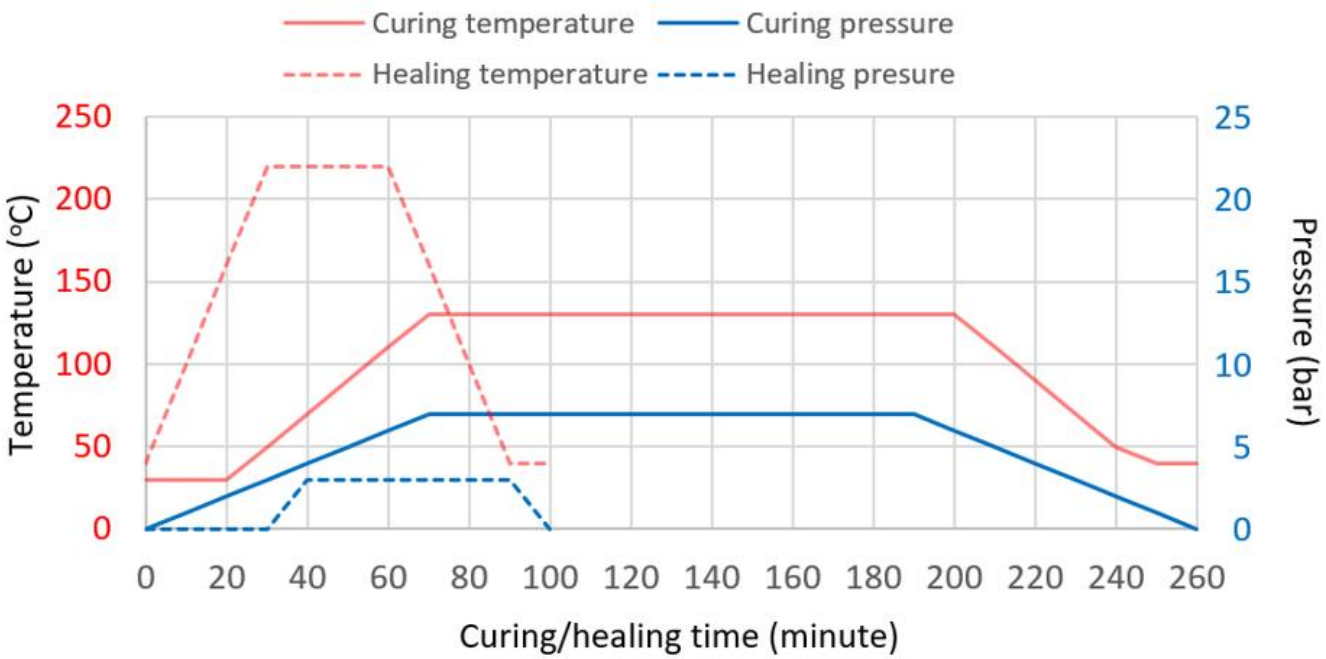


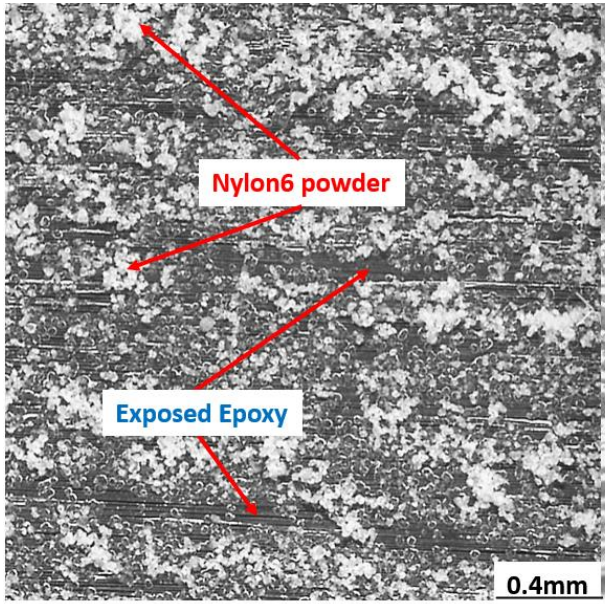




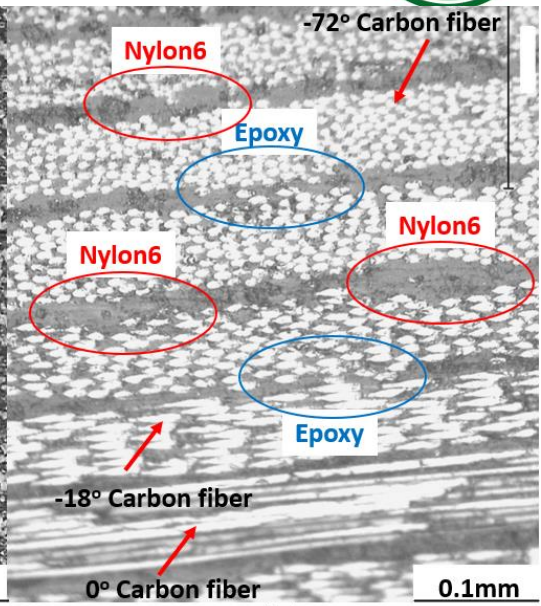
CFRP with nylon toughening/healing particles



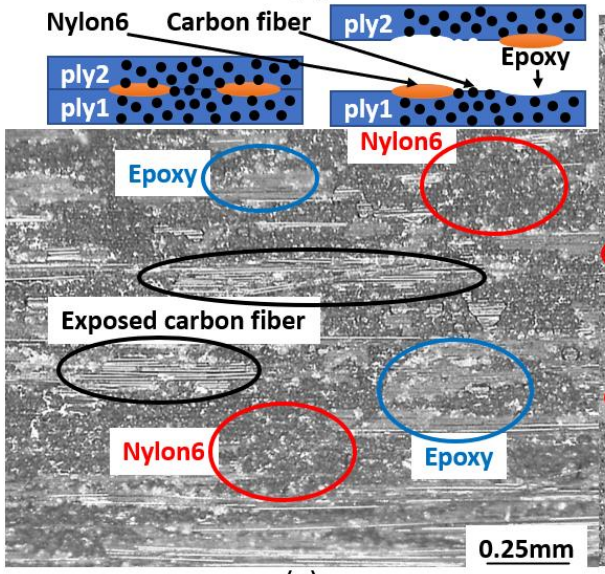




(a)



(b)



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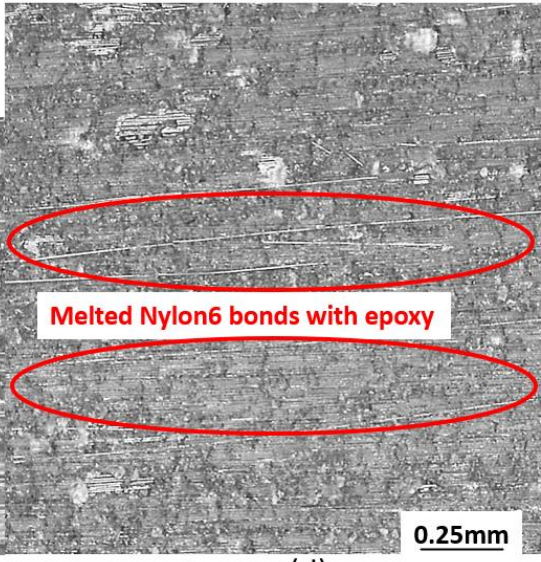
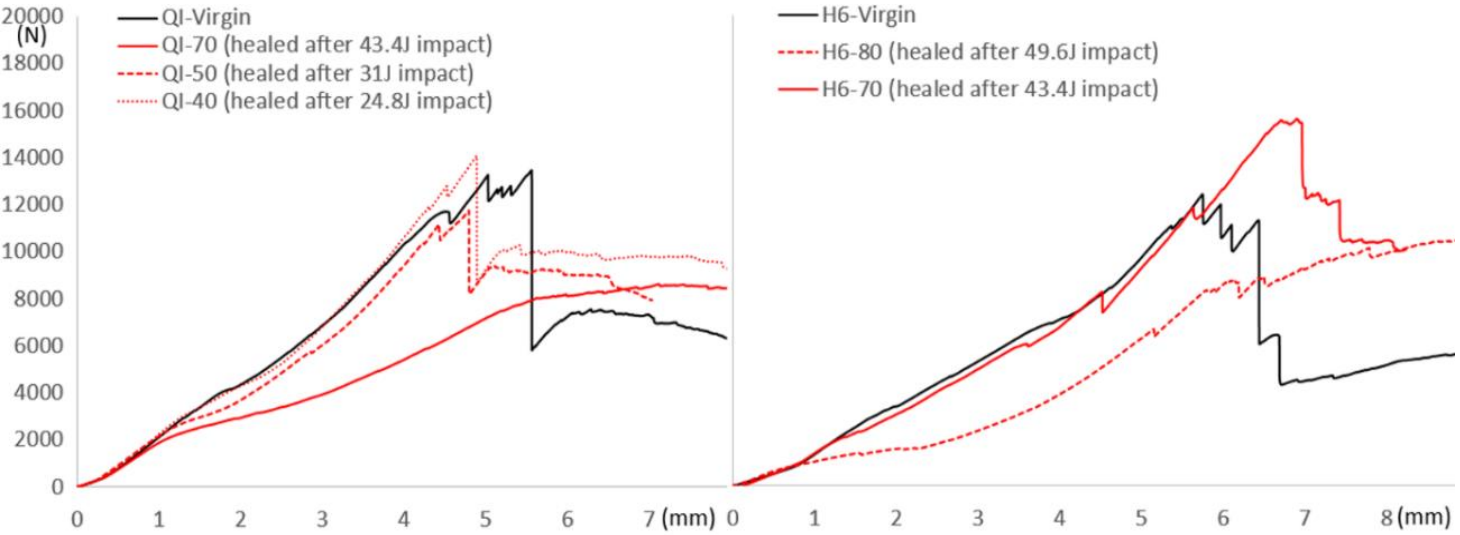
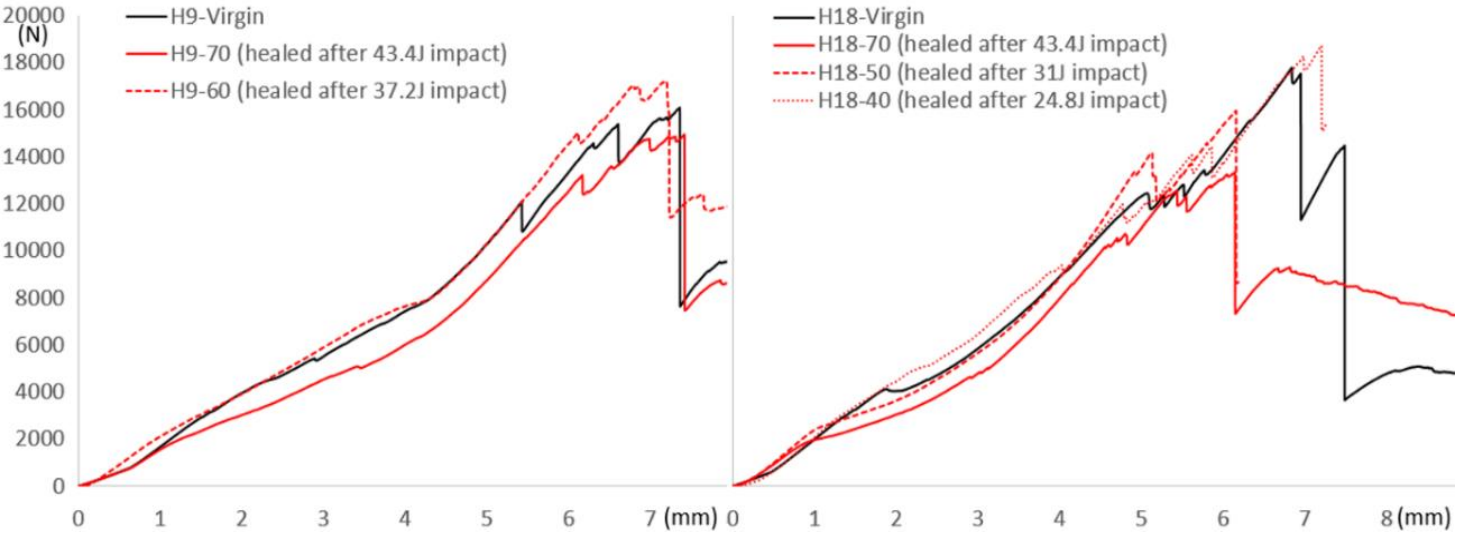
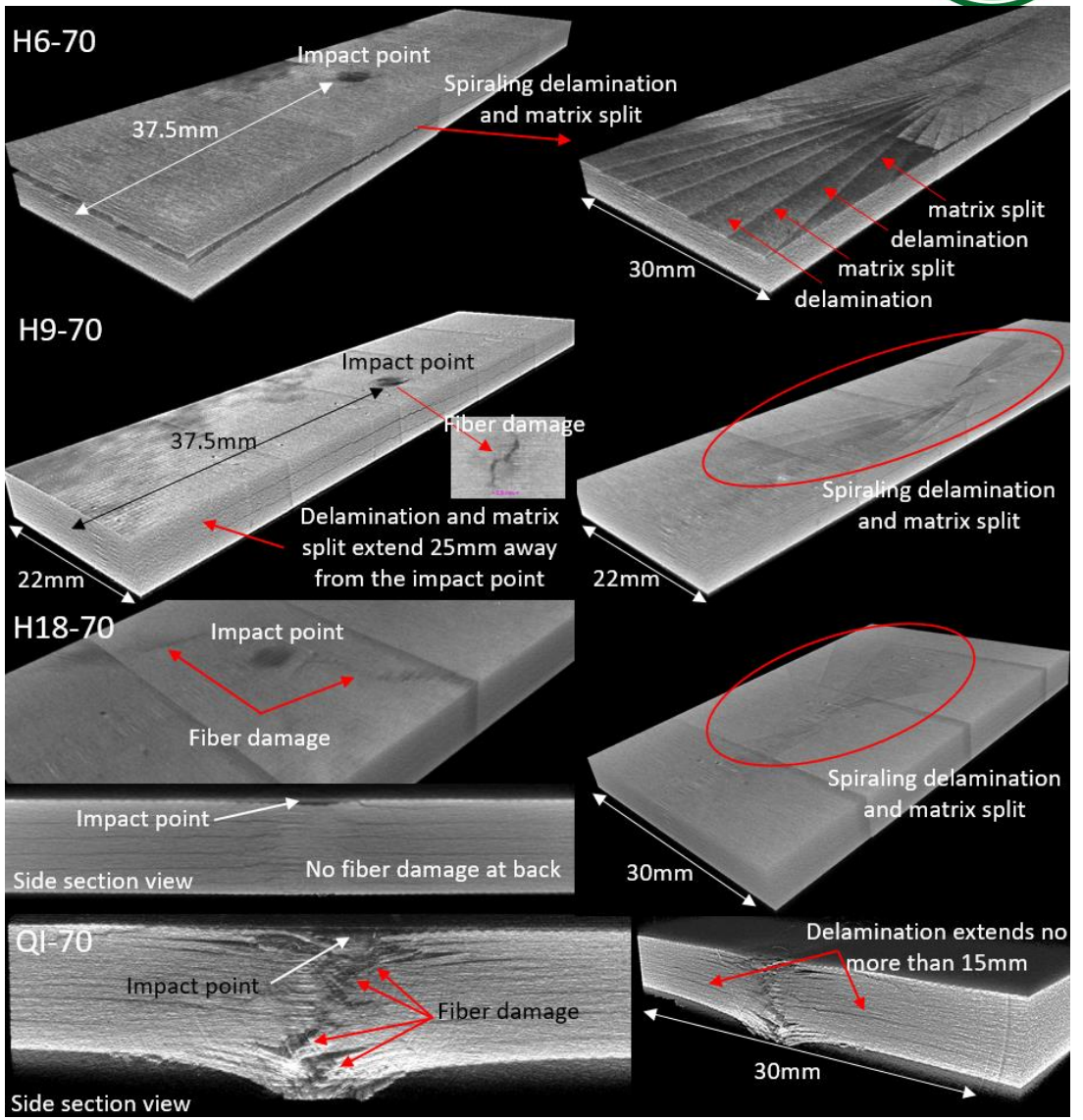


(d)

CFRP with nylon toughening/healing particles

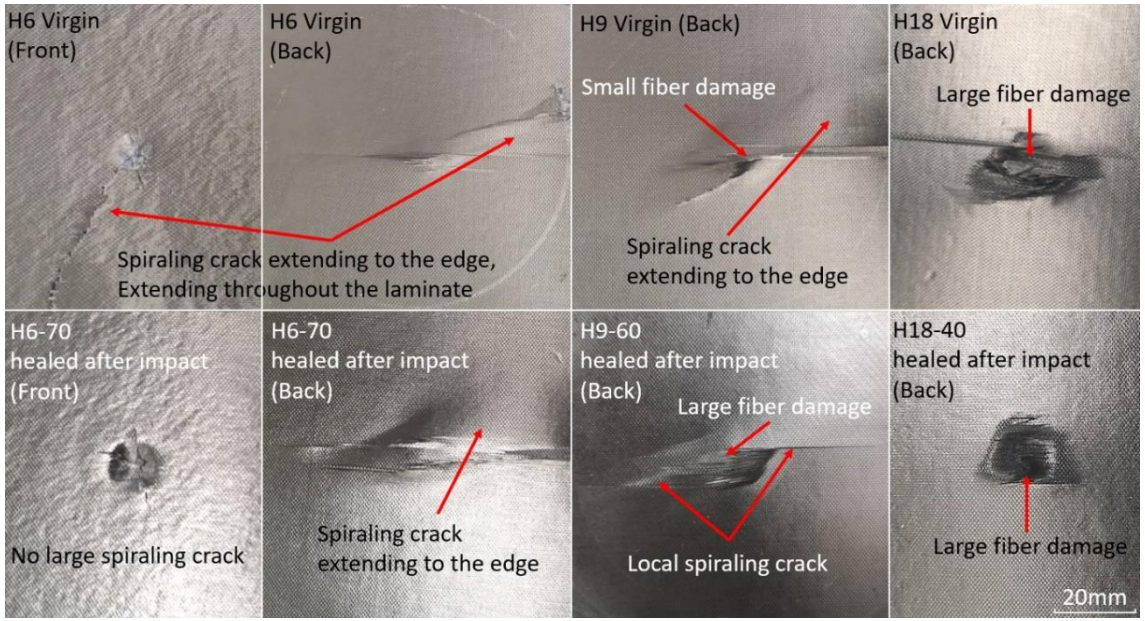


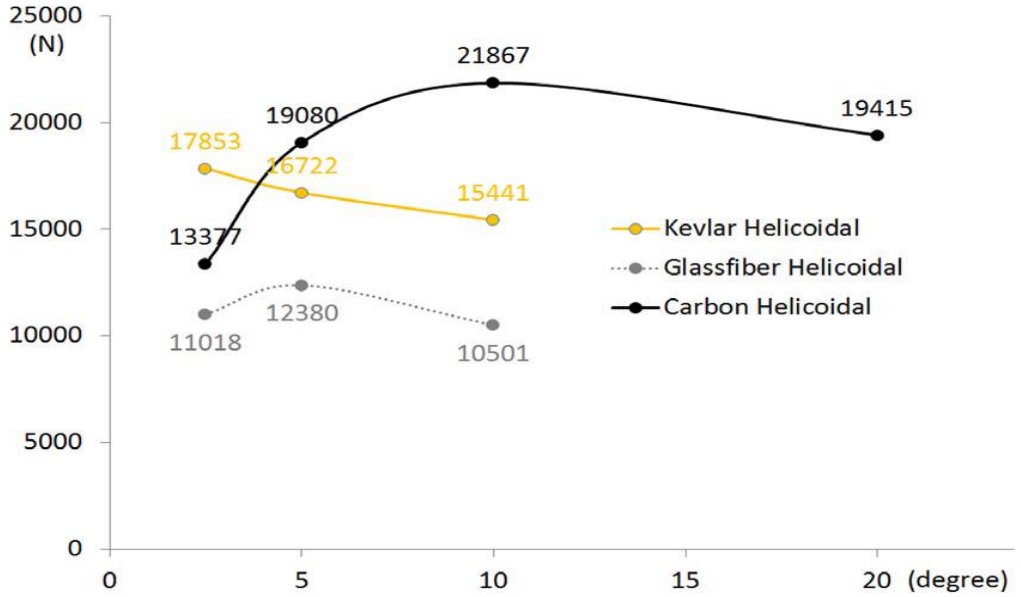


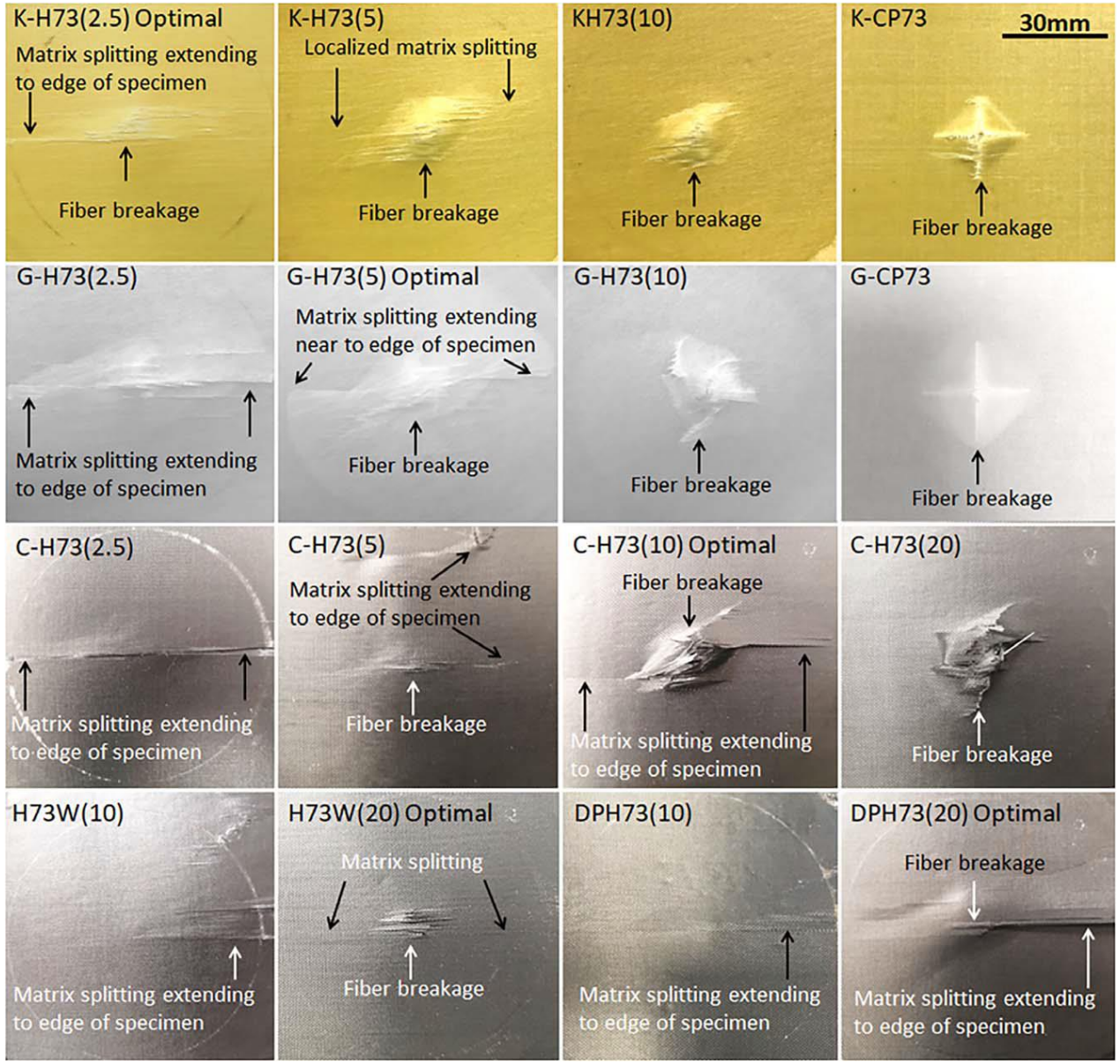


QI: Quasi-isotropic layup; H6, H9, H18: Helicoidal laminates with 6°,9°,18° inter-ply angle

CFRP with nylon toughening/healing particles







Conclusion

Laminates with helicoidal structure resist fiber damage

Helicoidal laminates with smaller inter-ply angle are more resistant to fiber damage

Nylon6 toughens the laminate interface and heals the damaged matrix

Helicoidal laminate with Nylon6 interlaminar toughening/healing agent has good mechanical performance and it can fully recover from a much higher impact energy after healing.

Thank you!