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Advanced Joining Processes Unit

Bio-inspired helicoidal CFRP composite behaviour under out of plane loading

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Why bio-inspired helicoidal CFRP composite

The out-of-plane weakness of composite material, resulting in delamination, limits their performance. Therefore, several strategies have been proposed in the literature to improve the transverse tensile strength of composite laminates, including the use of thin-plies, reinforcement with metals or polymers, and other techniques. Inspired by natural structures such as the mantis shrimp's dactyl club, this study explores bio-inspired helicoidal Carbon Fiber Reinforced Polymers (CFRP) with Non-Linear Rotation Angles (NLRA) to enhance toughness and damage resistance.

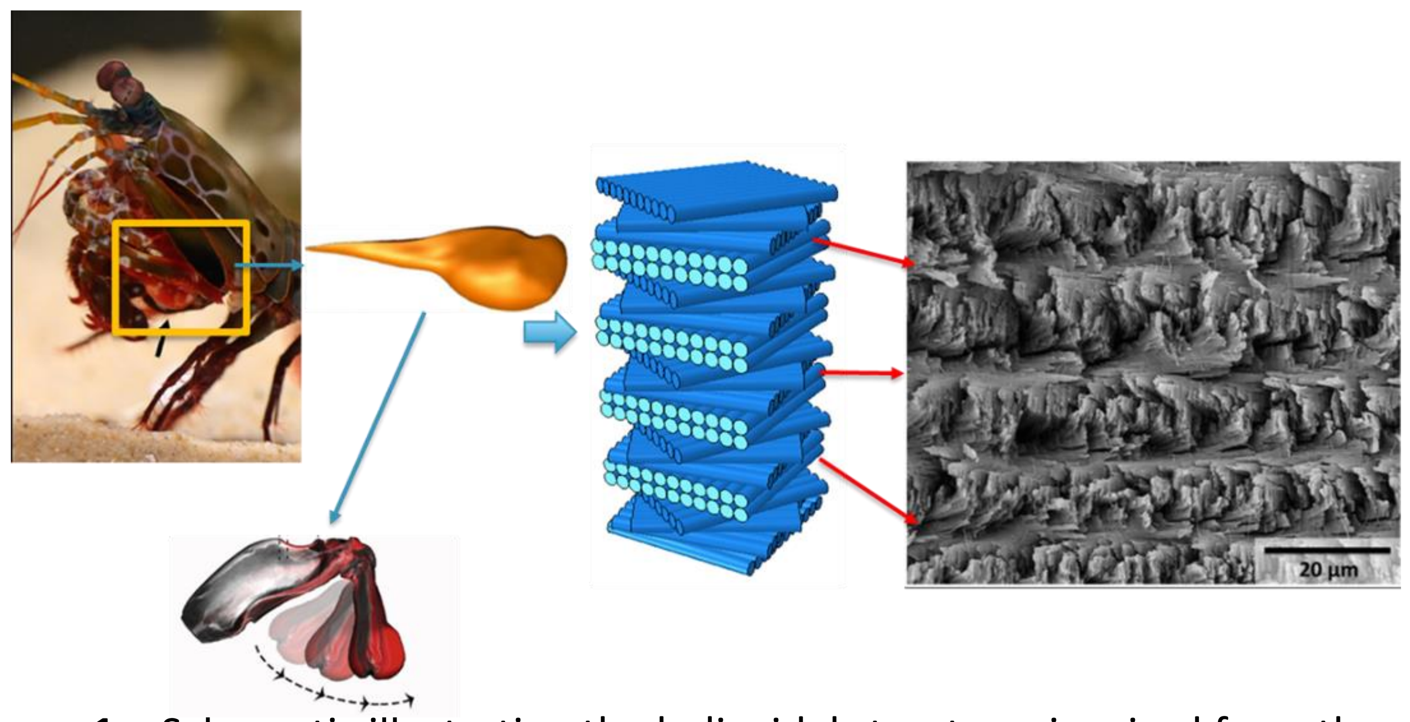

Figure 1 – Schematic illustrating the helicoidal structure, inspired from the mantis shrimp natural structure [1].

Bio-Inspired helicoidal laminates layup

- UD Unidirectional (UD) $[0]_{20}$
- H Helicoidal $[0/20/40/60/80/100/120/140/160/180]_s$
- G Gradual $[0/5/15/60/90/90/60/15/5/0]_s$

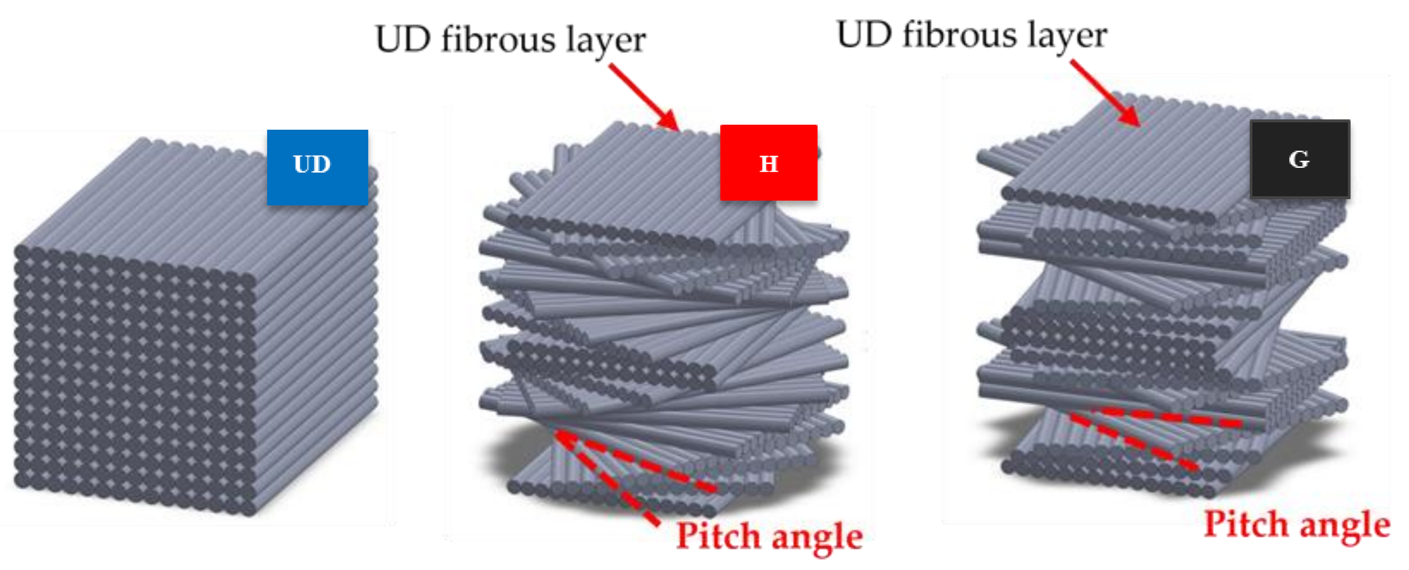

Figure 2 – Schematic design of studied configurations.

Testing method

Five samples for each configuration were manufactured and underwent transverse tensile testing with the speed of 1 mm/min.

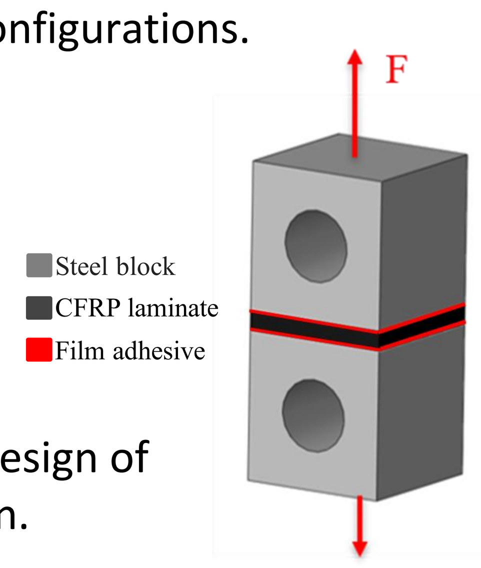

Figure 3 – Schematic design of loading condition.

Results and discussion

1. Influence of Bio-Inspired Configuration on Crack Morphology

Figure 5 displays the locus of the absolute maximum shear stress associated with the ith layer for helicoidal, gradual, and unidirectional configurations

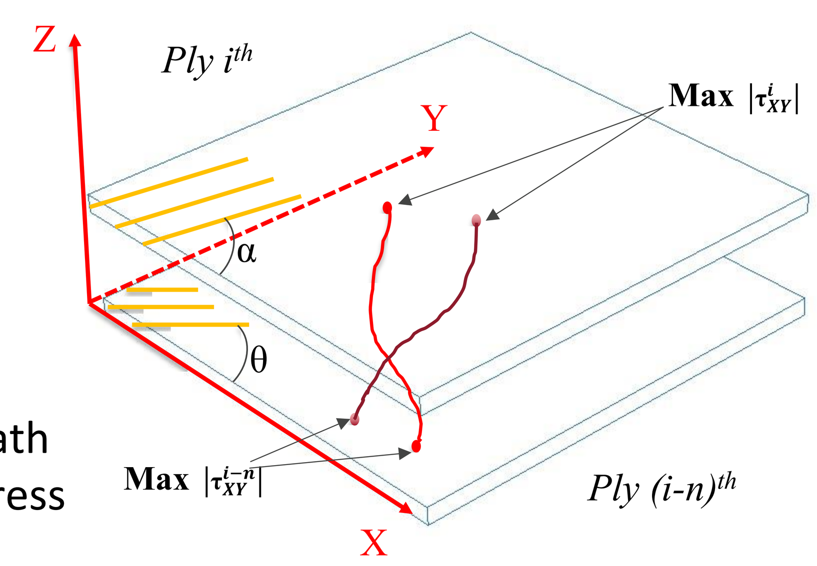

Figure 4 – Assumed crack path based on Maximum shear stress

Results and discussion

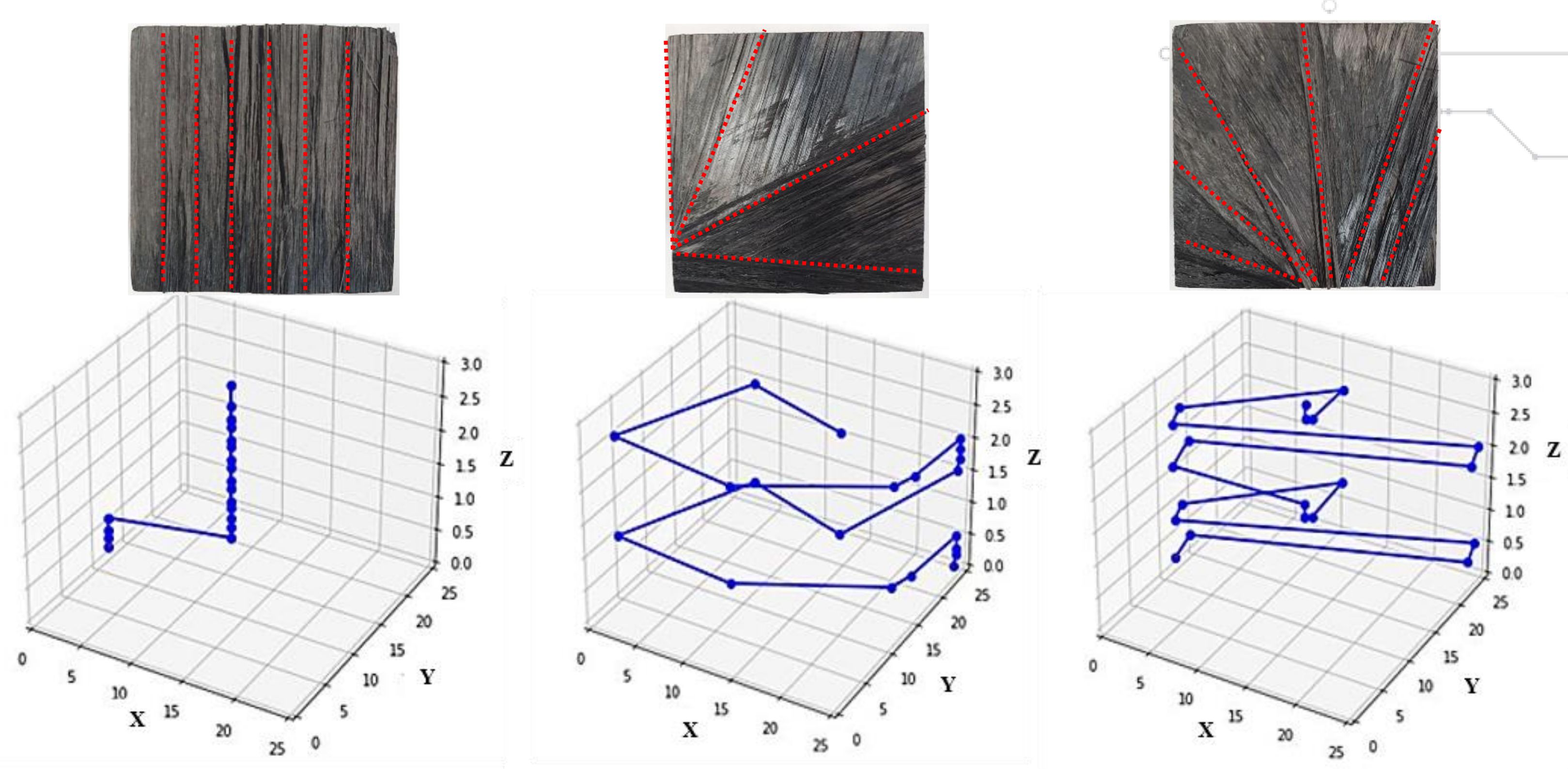

Figure 5 – Crack path for each configurations

2. Influence of Bio-Inspired Configuration on Failure Load

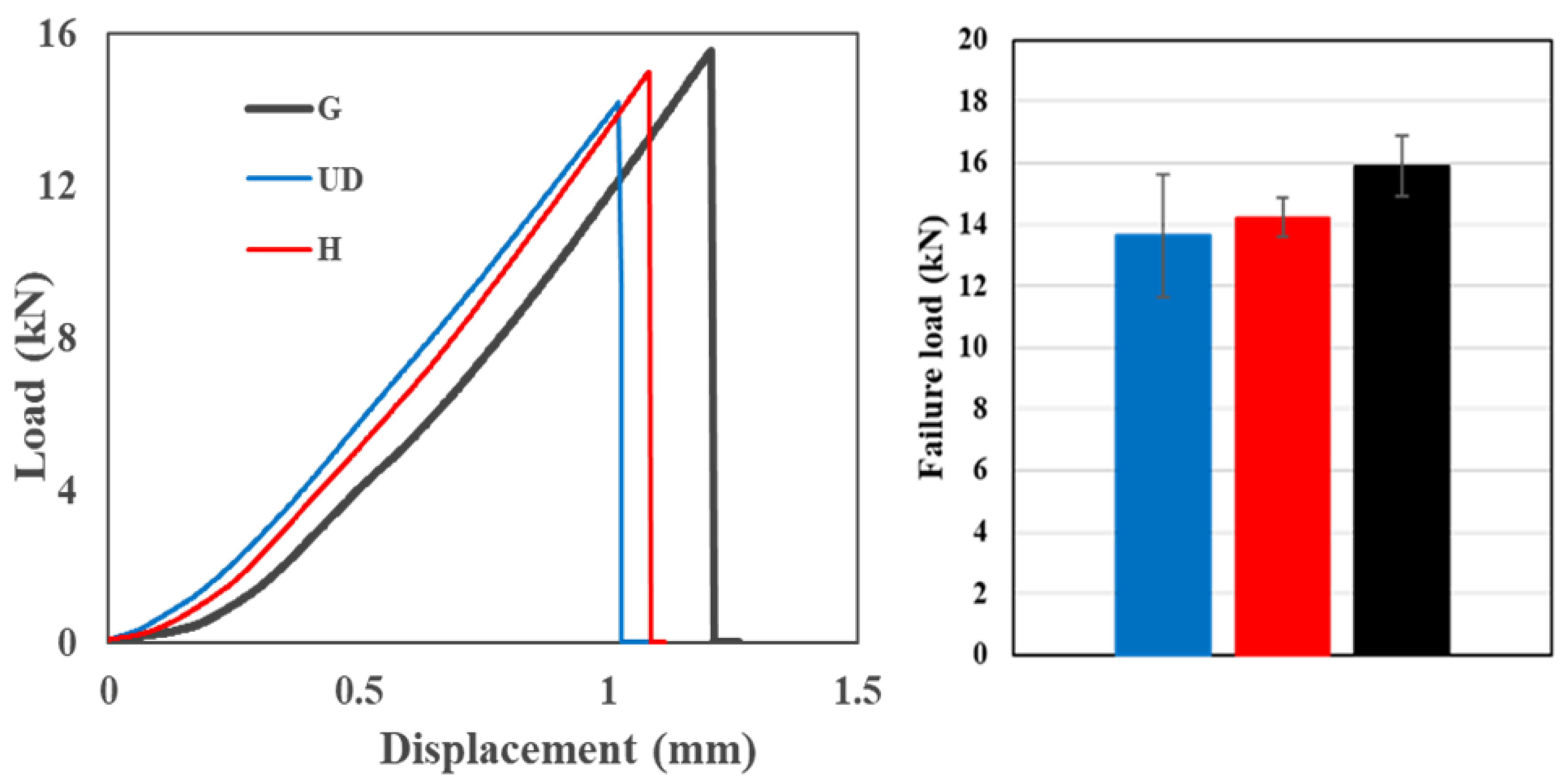

Figure 6 – Obtained failure load for each configurations.

CONCLUSION

- Bio-inspired laminates show lower delamination susceptibility than unidirectional laminates.
- Bio-inspired stacking sequences create complex crack paths, reducing delamination risk.
- Gradual and helicoidal laminates exhibit 17% and 5% higher displacement at failure, respectively, compared to unidirectional laminates.
- Gradual laminates achieve the highest strength, with a 17% improvement over unidirectional and 11% over helicoidal configurations.

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REFERENCES

[1] Malekinejad, H.; Carbas, R.J.C.; Akhavan-Safar, A.; Marques, E.A.S.; Ferreira, M.; da Silva, L.F.M. Bio-Inspired Helicoidal Composite Structure Featuring Graded Variable Ply Pitch under Transverse Tensile Loading. J. Compos. Sci.. 2024, 8, 228.