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EFFECT OF OUT-OF-AUTOCLAVE CURING ON THE BENDING STRENGTH OF TPNCF AND UNIDIRECTIONAL LAMINATES

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ABSTRACT

Out-of-autoclave (ooA) treatments in composite manufacturing draw the attention of manufacturers and designers in aerospace industry by offering numerous advantages over the traditional autoclave processing. Besides, thin ply non crimp fabric (TPNCF) architecture is proven for improved delamination resistance and fracture toughness. The objective of the study is comparing the bending strength of flat and curved beams of TPNCF [0/45] and Unidirectional (UD) [0/45] autoclaved and ooA CFRP parts. The 4-point bending experiment results show that the selection of TPNCF architecture in complex geometries provides an improved strength for ooA specimens.

INTRODUCTION

In aerospace and wind turbine industries, composite materials are involved in the load carrying members such as rib and spar flanges instead of metals [Sørensen et al. 2004, Edwards and Thompson 2005, Vanttinen 2008]. However, use of composites in such complex geometries is not efficient in terms of mechanical properties due to their weakness at the radius. The weakness is caused by high normal stresses in addition to shear stresses that may cause delamination which is separation of layers with significant loss of mechanical toughness. Thin ply non crimp fabric composites, formed by stitching the tow spread thin UD layers in the desired configuration instead of weaving the filaments, are known with improved delamination resistance and fracture toughness [Shin et al. 2007, Arca et al. 2015, Arca et al. 2017].

In addition to mechanical inefficiencies of composite materials, traditional autoclave curing methods in manufacturing of fiber reinforced composites have numerous drawbacks. The fact that an autoclave curing system has high capital and operating costs and that such systems serve in limited sizes cause to composite manufacturers turn into out-of-autoclave processing. However, out-of-autoclaved parts are inadequate in offering mechanical properties of autoclaved parts. The inadequacy of ooA manufacturing might differ for the different composite architectures, stacking sequences or geometries.

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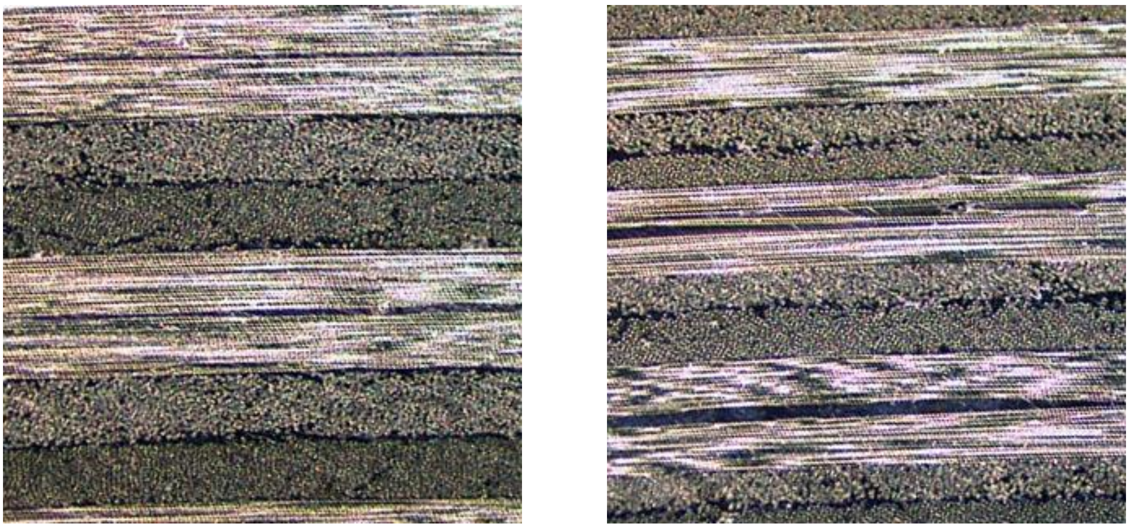
In this study, the effect of composite architectures and curing methods on the mechanical strength of flat and complex geometries is investigated by conducting four point bending tests as specified in ASTM D6415 and ASTM D7264 Standards.

METHOD

Material

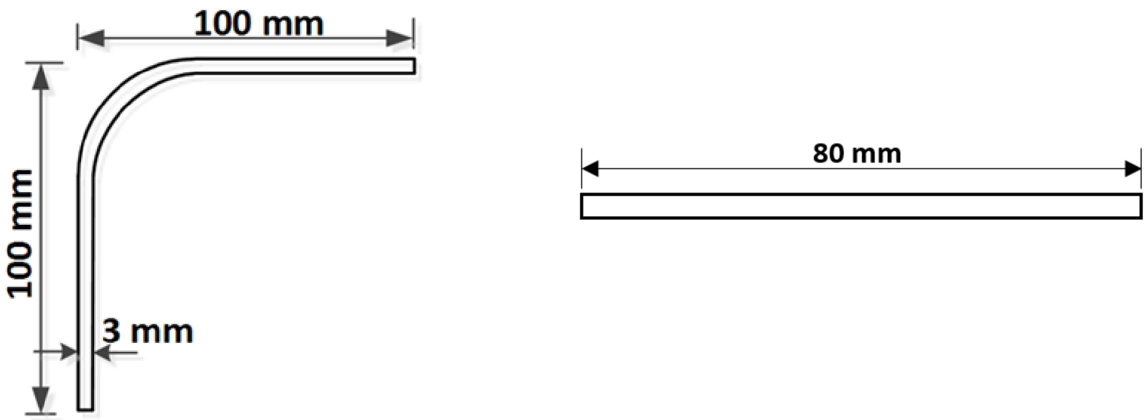
For investigation of composite architecture on mechanical properties, TPNCF [0/45] and UD [0/45] laminates are used. TPNCF laminates compose of 24 plies each having 2 thin plies stitched in the [0/45] configuration. The general stacking sequences are $[0/\text{-}45/45/0]_{12T}$ for TPNCF specimens and $[0/\text{-}45/45/0]_{6T}$ for UD specimens, as shown in Figure 1, and they are produced with Choromat C-Ply (carbon fiber T700) TPNCF and UD prepregs with AR2527 epoxy resin produced. C-Ply TPNCFs have 0.0625 mm ply thickness which is half of the common UD ply thickness.



(a) (b)

Figure 1: Micrographs showing the stacking sequences of (a) TPNCF, (b) UD laminates

In the manufacturing of TPNCF and UD specimens, two different procedures are pursued. For each architecture, one batch (batch 2) is produced by hand layup technique followed by vacuum bagging and cured at 135 °C for 4 hours while another batch (batch 3) is obtained by hand layup technique and cured by autoclaving at 4 bar and 135 °C. The dimensions of L-shaped and flat specimens cut form the two batch are shown in Figure 2.



(a) (b)

Figure 2: Dimensions of (a) L-shaped, (b) flat specimens

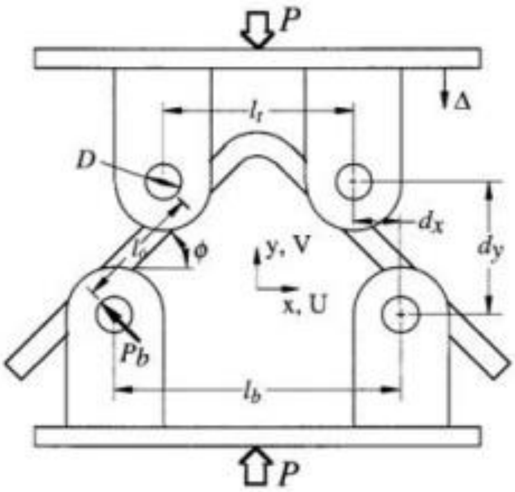
Experimental Method

Curved Beams

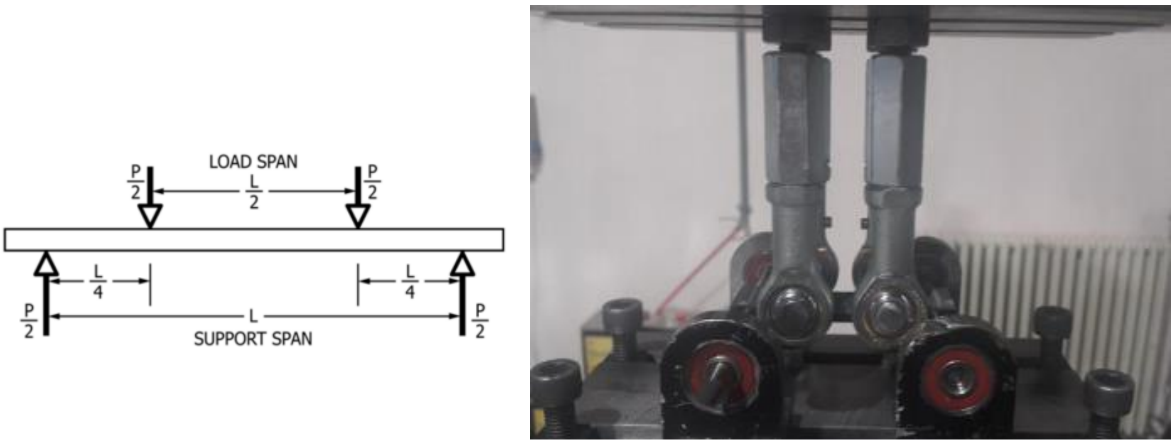
The four point bending tests of curved beams are conducted according to ASTM D6415 Standard. In the experiments of curved specimens, Shimadzu Autograph AGS-J 10 kN displacement controlled, screw driven tensile testing machine were used as the load indicator and load displacement data was recorded by Trapezedium software. Schematic of the experiment specified by ASTM D6415 and the experimental setup are shown in Figure 3a.

Flat Beams

Flat beams are tested by 4 point bending test specified in ASTM D7264. In the experiments, MTS 809 Axial/Torsion Test System is used for loading of the specimen through the vertical motion of lower hydraulic piston of the testing machine. Tests of each specimen are conducted with displacement control. Schematic of the experiment specified by ASTM D7264 and the experimental setup are shown in Figure 3b.



(a)

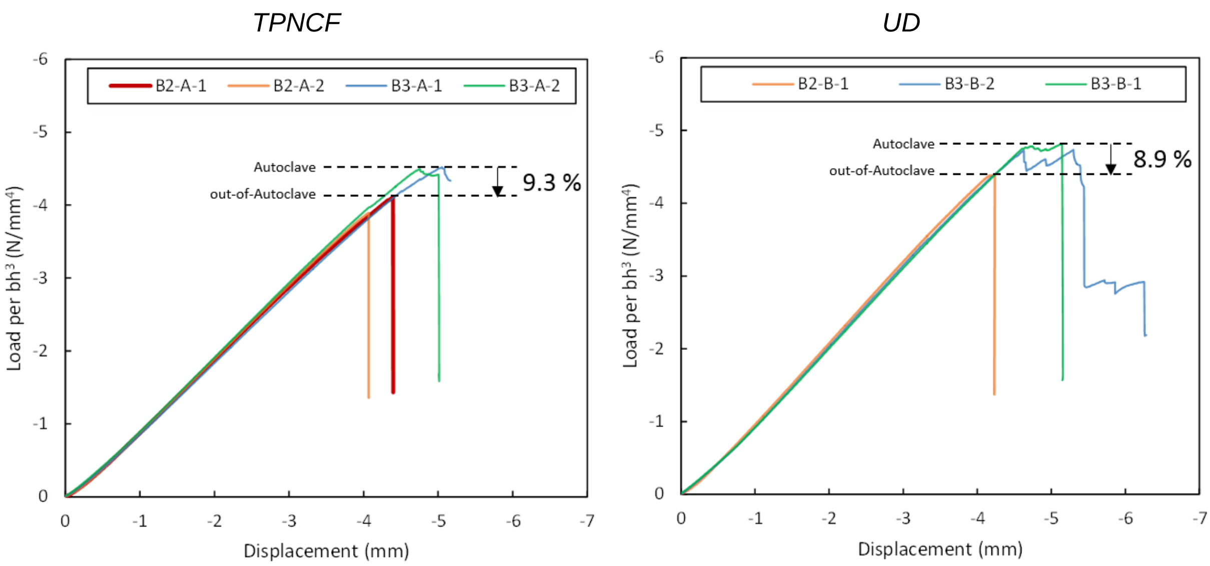


(b)

Figure 3: Schematics of the experiments by ASTM and the experimental setups for (a) curved beams, (b) straight beams

RESULTS

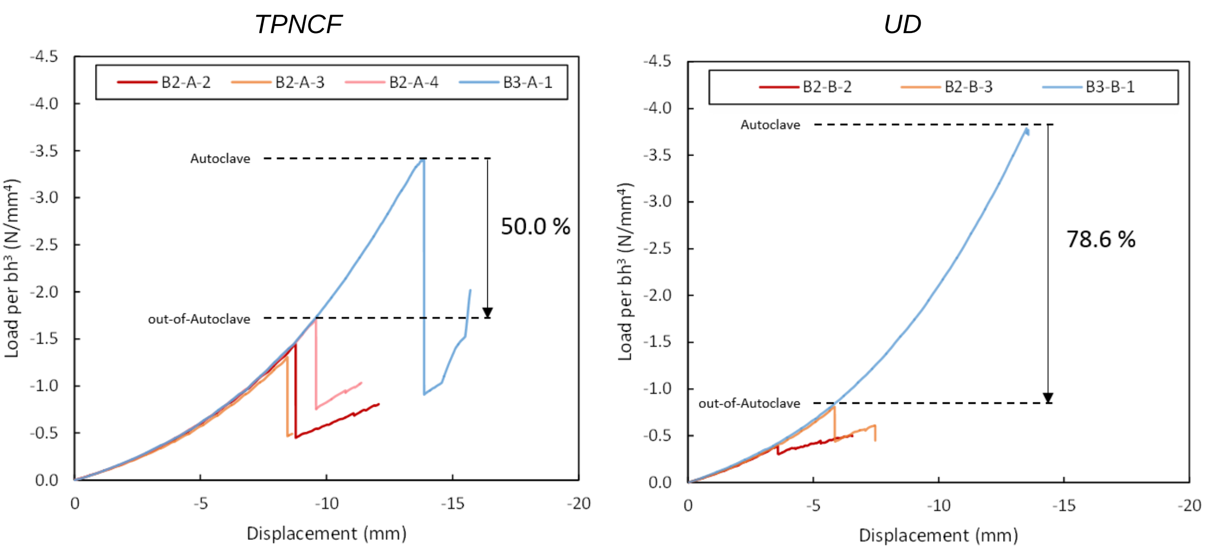
Normalized load vs. displacement curves obtained by the four point bending test of the TPNCF and UD straight beams are seen in Figure 4.



(a) (b)

Figure 4: Normalized load vs. displacement curves obtained by the four point bending testing of the (a) TPNCF, (b) UD straight beam specimens

Figure 5 shows the normalized load vs. displacement curves obtained by the four point bending test of the TPNCF and UD curved beams.



(a) (b)

Figure 5: Normalized load vs. displacement curves obtained by the four point bending testing of the (a) TPNCF, (b) UD curved beam specimens

CONCLUSIONS

Experiments were conducted to determine the four point curved beam and straight beam strengths for the equivalent TPNCF and UD laminates. The four point straight beam strength reductions in ooAs compared to autoclaved specimens are similar for both TPNCF and UD laminates. However, the curved beam strength differences between ooA and autoclaved specimens are higher in case of UD laminates. Therefore, TPNCF beams have a better potential to be used in out-of-autoclave curved geometries.

References

Arca, M.A., Papila, M. and Coker, D. (2017), *“Chapter 6. Experimental Investigation of Strength of Curved Beam by Thin Ply Non-Crimp Fabric Laminates,”* Alan T. Zehnder, Jay Carroll, Kavan Hazeli et al (eds.), Fracture, Fatigue, Failure and Damage Evolution, Volume 8, Conference Proceedings of the Society for Experimental Mechanics Series, DOI 10.1007/978-3-319-42195-7_6, pp. 37-42.

Arca, M.A., Papila, M., and Coker, D. (2015), *“Curved beam strength and toughness of thin ply CFRP non-crimp fabric laminates,”* Paper #AIAC-2015-170, 8th Ankara International Aerospace Conference, AIAC, Ankara, Turkey, September 10-12, 2015.

Edwards, T. and Thompson, J. (2005), *Spar Corner Radius Integrity for the A400M Wing*, Applied Mechanics and Materials, Vols. 3-4, pp. 197-204.

Shin, S., Kim, R.Y., Kawabe, K. and Tsai, S.W. (2007), *Experimental studies of thin-ply laminated composites*. Composites Science and Technology; 67: 996-1008.

Sørensen, B.F., Jørgensen, E., Debel, C.P., Jensen, F.M., Jensen, H.M., Jacobsen, T.K., and Halling, K.M. (2004), *Improved design of large wind turbine blade of fibre composites based on studies of scale effects (Phase 1) - Summary Report*, Risø National Laboratory Denmark, Risø-R-1390(EN).

Vanttinen, A. (2008), *Strength prediction of composite rib foot corner*, Ms thesis,Helsinki University of Technology.