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DAMAGE TOLERANCE OF DOUBLE-DOUBLE LAMINATES

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ABSTRACT

Double-double (DD) lay-up is a new configuration strategy for the design of composite laminates, which allows the use of simplified stacking sequences that leads to potential advantages, such as improved manufacturability and design optimization, as compared to traditional quadriaxial laminates (Quad), which are limited to ply angles of 0º, ±45º and 90º. With the double-double concept, through-the-thickness homogenization is facilitated using thinner sub-laminates and, consequently, profile optimization through thickness tapering becomes possible. In this work, damages after impact and after CAI tests of a double-double laminate $(+50/0/-50/0)_{10}$ and a hard conventional laminate of equivalent in-plane stiffness $(0_3/90/\pm45/0_2/\pm45)_{2S}$ are compared. According to the data presented, maximum delaminated areas were of the same order of magnitude for the quad and for the DD laminates, under both conditions: after impact and after CAI tests. The results contribute to the understanding of potential benefits of the double-double concept to damage resistance and damage tolerance of composite laminates.

EXPERIMENTAL

The material used was T700G/G94 UD prepreg from Toray Composite Materials America, Inc., with nominal fiber volume fraction of 55.1%, fiber areal weight of 150 g/m² and ply thickness of 0.150 mm.
Two forty-ply composite plates with dimensions of 500 mm x 350 mm (L x W) were autoclave cured. The nominal thickness of the cured laminates was about 6.0 mm. Drop-weight impact tests were conducted at impact energy of 74J. Compression tests and compression after impact tests were conducted according to ASTM standards D3410 and D7137, respectively.

RESULTS AND DISCUSSION

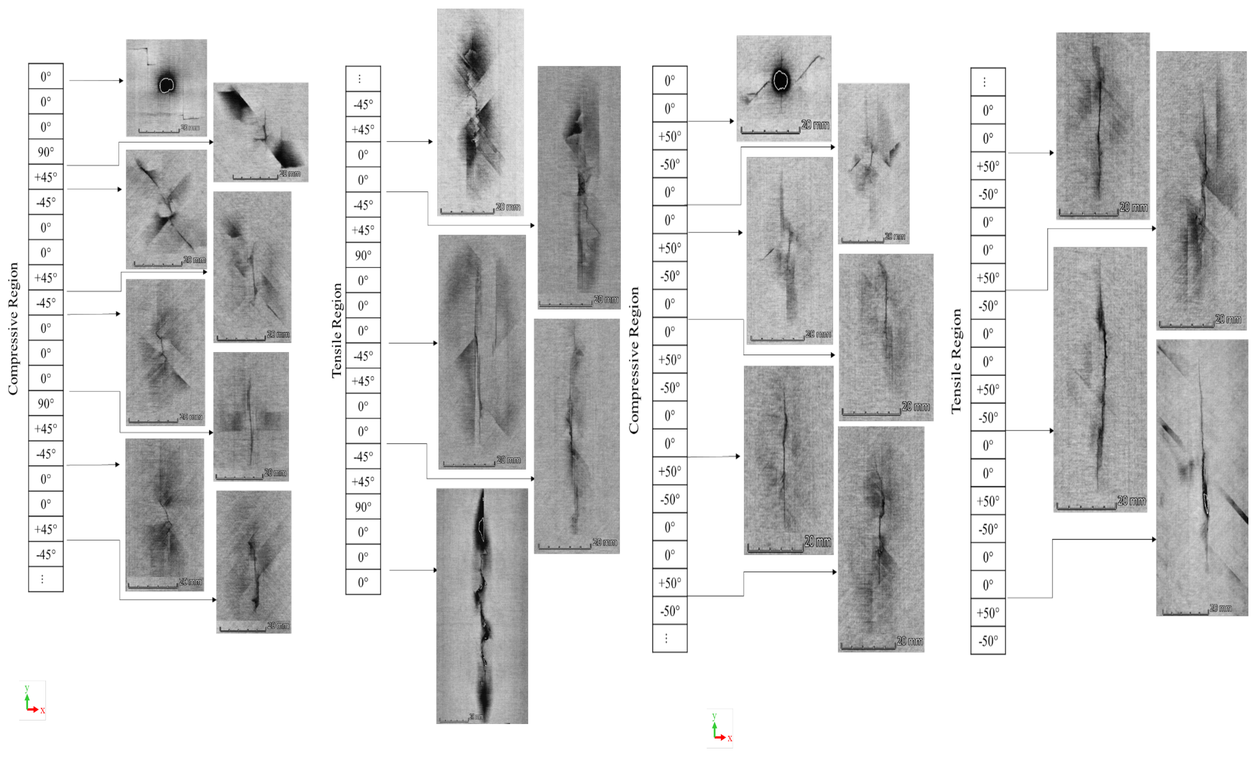

Figure 1: CT Scan images of typical delaminations and cracks in quad laminates $(0_3/90/\pm45/0_2/\pm45)_{2S}$ after 74 J impact.
Fonte: Cunha *et al.* (2023)

Figure 2: CT Scan images of typical delaminations and cracks in DD laminates $(+50/0/-50/0)_{10}$ after 74 J impact.
Fonte: Cunha *et al.* (2023)

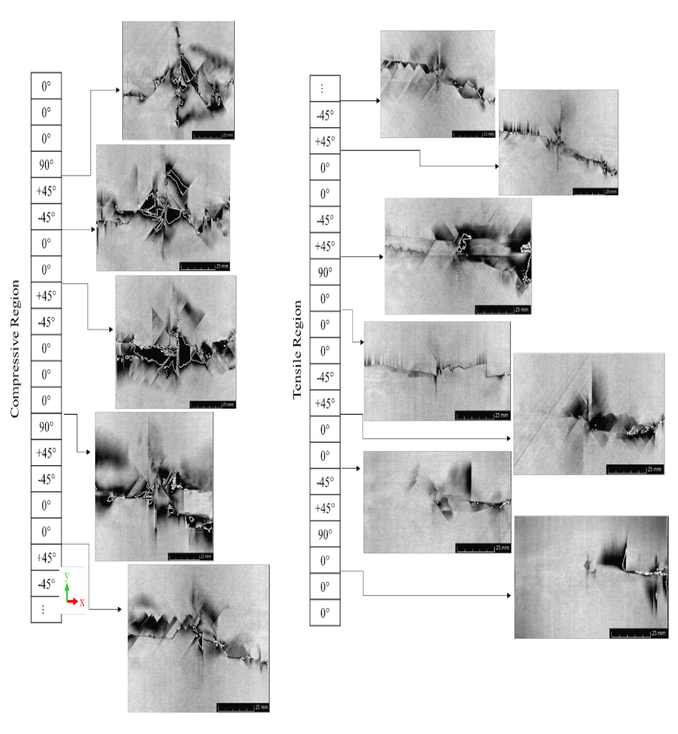

Figure 3: CT Scan images of typical damages in quad laminates $(0_3/90/\pm45/0_2/\pm45)_{2S}$ after CAI testing.

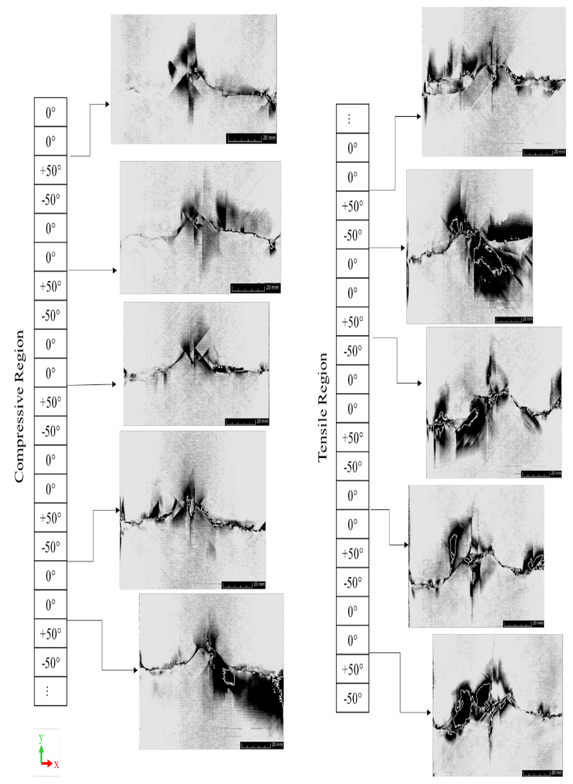

Figure 4: CT Scan images of typical damages in DD laminates $(+50/0/-50/0)_{10}$ after CAI testing.

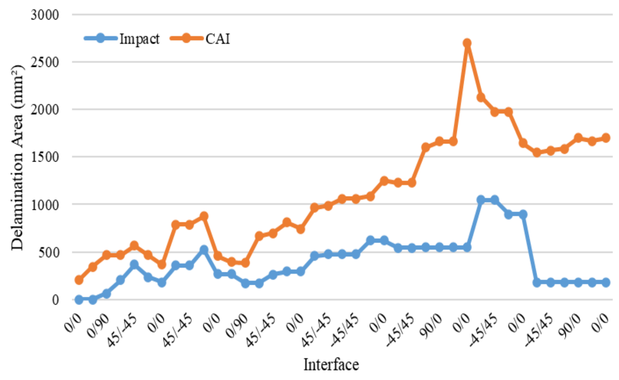

Figure 5: Typical delaminated areas of quad laminate $(0_3/90/\pm45/0_2/\pm45)_{2S}$ before and after CAI test.

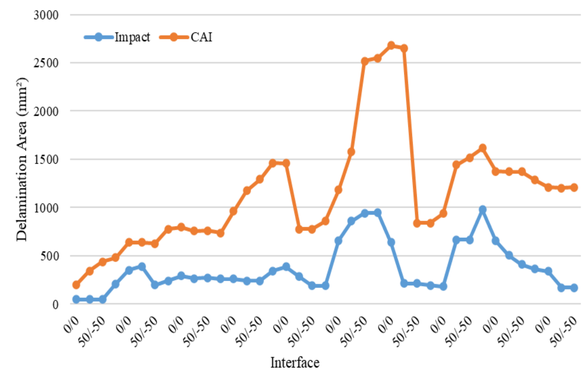

Figure 6: Typical delaminated areas of DD laminate $(+50/0/-50/0)_{10}$ before and after CAI test.

CONCLUSIONS

- Double-double composite laminates offer great potential as a replacement of legacy laminates, with improvements in mechanical properties and manufacturing efficiency.
- Damage resistance and damage tolerance of these laminates were assessed, as compared to conventional laminates of equivalent in-plane stiffness.
- Maximum delaminated areas observed were of the same order of magnitude for the conventional quad and for the DD laminates, under both conditions: after impact and after CAI tests.
- The research contributes to the understanding of the mechanical behavior of these laminates regarding damage, considering the already known advantages for design optimization and manufacturability.

ACKNOWLEDGEMENTS

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