

Experimental study to understand the effect of delamination position on impact damage tolerance using unsymmetrical laminates

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Abstract

Out-of plane loading has been a threat to composite materials despite its improved mass and cost performance over metallic counterparts. Low velocity impact loads introduce characteristic barely visible damage that can impose a reduction of 60% in the residual compression strength [1]. This demands the need to understand the damage scenario during an impact and its effect on the compression after impact (CAI) strength. A clear understanding on the relation between impact damage and its propagation during CAI is compulsory, if one eyes on improving the CAI strength. Researchers have tried to impose delaminations at predetermined locations using ply clustering or varied mismatch angled interfaces, to study its effect on CAI strength [2–5]. Impact loading, being an unsymmetrical loading in the through-the-thickness direction, the delamination initiation and propagation varies with its location. To study the sole effect of top sub-laminate delaminations on impact and post impact response, delaminations are imposed only at the top sub-laminate using ply clustering. An unsymmetrical laminate with zero warping was designed using optimization to realize the purpose of the study. The laminate with ply clustering at the top sub-laminate (Laminate-LPCT) is flipped upside down to form a new laminate with ply clustering at the bottom sub-laminate (Laminate-LPCB), as shown in Figure 1. Impact tests at 10 and 18J were performed on the above two laminates, followed by compression after impact testing. Additionally, quasi static indentation tests at different indenter displacements were performed to elucidate clearly the delamination initiation and propagation scenarios for two laminates. The results reveal that for the laminate LPCT, delamination initiation is delayed and reduced propagation for lower impact energies. At higher impact energies/indenter displacements, extensive delamination growth was found with ply clustering at the top. Laminate LPCT has dominant delamination near to mid-plane even though the ply clustering was imposed at the top sub-laminate. Laminate LPCB, as expected, has the dominant delamination at the last interface. Experimental results also reveal that damage can be pre-determined to occur at the desired location using judicious laminate design.

References

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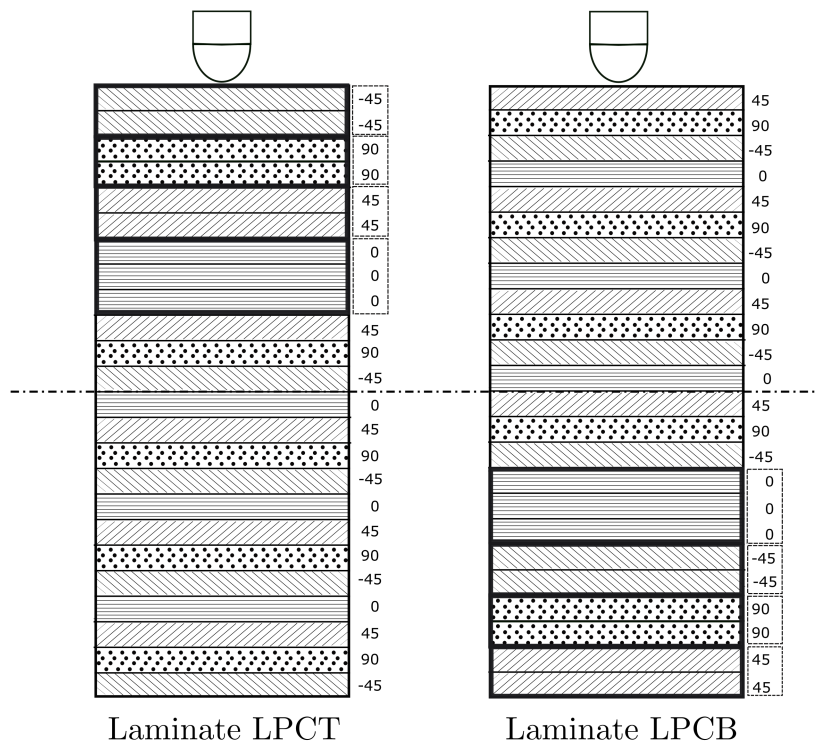


Figure 1: Unsymmetrical laminate LPCT with ply clustering in the top sub-laminate (left) and laminate LPCB with ply clustering in the bottom sub-laminate (right), which is produced by flipping upside down the laminate LPCT. Flipping produces an interchange between 45's and -45's plies