EDGE EFFECT ON CARBON/EPOXY STRENGTH AND DELAMINATION OF CARBON/EPOXY LAMINATE WITH DIFFERENT STACKING SEQUENCE

M.Setvanović, D.Marković, M.Gordić, I.Djordjević
Institute of Nuclear Sciences Vinča, POB 522, 11000 Belgrade, Serbia and Montenegro

Extended abstract

Cross-ply $[(0/90)_s, (90/0)_s, (0/90)_{4s}, (90/0)_{4s}]$, angle-ply $[(0_2/\pm45)_s(\pm45/0_2)_s, (90_2/\pm45)_s, (\pm45/90_2)_s]$ and quasi-isotropic laminate $[(0/90/\pm45)_s, (\pm45/0/90)_s]$ of inverse stacking seque-nce tested in tension and tensile strength values determined on coupons width two widths.

The edge effects are assessed by comparing the strength values of laminates of same lay-up, but with inverse stacking sequence, as well as, by comparing the strength values of coupons with different width of laminates of same stacking sequence.

The established edge effects were analyzed by calculations of edge and near edge inrelaminar stresses and strains in interlayers, as well as, by failure observations and identification of the interlayer where axial cracks initiated at the free edge.

The interlayers stresses and strains were deduced using the Kassapogou and Lagace method based on force and moment equilibrium and on principle of complementary energy minimization [1]. For all the present interlayers in tested coupons, the interlaminar stress and strain components ($\sigma_z, \tau_{xz}, \varepsilon_z$ and γ_{xz}) are calculated along the coupon width <u>b</u>, up to the free edge (Fig.1). The through-thickness edge interlaminar stresses (σ_z^{edge}, τ_z^{edge}) and strain components values (ε_z^{edge} and γ_{xz}^{edge}) as functions of $2z/d$ coordinate (<u>d</u> is the coupon depth) (Fig.2) derived for all the interlayers of tested coupons.

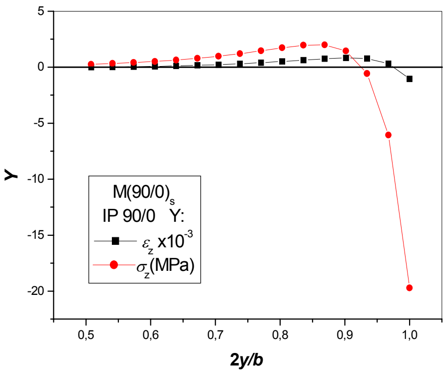

Fig.1. Variation through 0/90 degree interlayer of normal interlaminar stress and strain along the width of $(90/0)_s$ laminate coupon

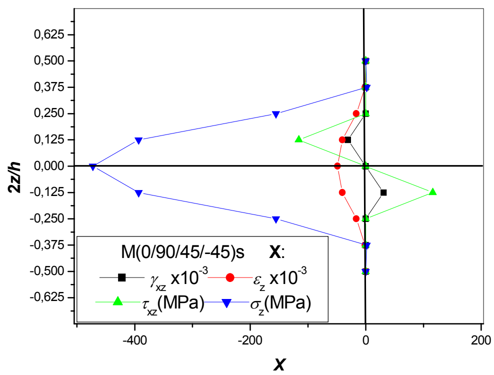

Fig. 2 Through-thickness edge interlaminar stress (σ_z^{edge}, τ_z^{edge}) and strain ($\varepsilon_z^{edge}, \gamma_{xz}^{edge}$) as functions of 2z/d coordinate for M $(0/90/\pm45)_s$

It was found that in the laminates of $(90/0)_s$ and $(0/90/\pm45)_s$ stacking sequence, the edge effect is positive, due to the edge interlaminar normal compressive stress appeared in the 0/90 and 90/-45 interfaces. It was found, also, that in the laminates of $(0/90)_s$ and

$(\pm450/90/)_s$ stacking sequence, the edge effect is negative, due to the edge interlaminar normal tensile stress appeared in the 0/90 and 45/0 interlayers.

As stated earlier for the cross-ply laminates [2], in this work it is approved for quasi-isotropic laminates, too, that sign of the transverse normal edge interlaminar stress determines the edge effect on tensile strength of the laminates: the normal tensile stress is instrumental in precipitating the delamination and subsequent strength degradation, while the compressive edge normal stress inhibits the axial cracks apparition and made the tensile strength higher.

In this work it is shown that extent of the edge interlaminar stresses effect on crack initiation in the interlayer and consequently on measured laminate strength values, can be correlated well with the change in interlayer of strain energy per unit volume of edge boundary region, due to action of normal interlaminar stresses. Determined edge effects are correlated with elastic strain energy stored in edge boundary region of the interlayer, where axial cracks appeared or have been sustained.

As far as concerns the edge effect on strength of angle-ply laminates with 0 or 90-degree orientation ply, it was found that for the tested coupons of $(\pm45/0_2)_s$ and $(\pm45/90_2)_s$ laminates, where the negative edge effect on the laminate strength are established, the edge interlaminar normal strength σ_z and strain ε_z are of tensile type. The results for these laminate are explained by the same manner as for cross-ply and quasi-isotropic laminates.

The strength determined on 15 mm wide coupons of $(0_2/\pm45)_s$ and $(90_2/\pm45)_s$ laminates are higher than the strength values determined on 15 mm wide coupons of $(\pm45/0_2)_s$ and $(\pm45/90_2)_s$ laminates This can be explained by the fact that in laminates where ±45 plies are near mid-plane, the interlaminar normal compressive stress sustains apparition of axial crack in 90/45 and 0/45 interlayer. Contrary to that in laminates with ±45 plies as outside plies, the normal interlaminar tensile stress induces the axial cracks in the -45/0 and –45/90 interply. Such cracks are observed in failed $(\pm45/0_2)_s$ and $(\pm45/90_2)_s$ coupons. Harris and Orringer [4] and Lee [5] reported the edge delamination in □/90 interply in angle ply laminates with 90^o ply.

However, in narrow coupons of laminates with ±45 degree plies near mid-plane, in which the edge effect is more pronounced, the interlaminar shear stress induces the axial crack in 45/-45 degree interlayer and makes the strength of these coupons lower than those of wider coupons.

Underlying that the damage growth in $(0/\pm□_2)_s$ laminates is a complex process, Wharmby and Ellyin [6] observed that crack, initiated at the edge of □/-□ interply, continues to grow through the matrix. The same was recorded by failure observation of tested angle-ply laminate coupons with ±45 degree plies near mid-plane.

References

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