The Effect of Ply Orientation on the Peak and Delamination Threshold Loads of CFRP Composite Plates

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Abstract

This poster presents how the sense of a particular ply can affect the delamination threshold and maximum loads. The investigation was carried out with two families of composite plates, having the following configurations $0_3/\beta/0_3/90_3/45_3/\text{-}45_3$ and $0_3/\beta/0_{12}$, where $\beta = 0^0$, 30^0, 45^0, 60^0 and 90^0. In both, cases the load increased with β, with the exclusion of a drop in the peak load, obtained for the $0_3/90/0_{12}$ plate, reason being its cross plies nature.

Sample preparation

The samples for the test were prepared from a roll of prepreg unidirectional carbon-fibre epoxy composite, having 60% fibre volume fraction.

The stacking of the laminates was made manually.

Curing was accomplished in the autoclave as follows:

- A pressure of 700 kN/m^2 was applied.
- Heated to 175^{0}C at the rate of 5^{0}C per minute.
- Cured for an hour at 175^{0}C.

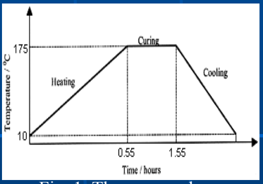

Fig. 1. The cure cycle

Impact testing

- Impact tests were conducted using an instrumented drop-weight impactor of energy capacity 588 J obtained by adjusting the drop height.
- The impacting mass dropped from a height of 0.015m for all tests conducted.
- The samples were rigidly clamped one after the other in the test area of the impact tester and the falling weight guided onto the sample, in a defined manner.
- At impact, the resistive force exerted by the sample on the striker is measured as a function of time and stored.
- The system calculates the corresponding velocity and displacement histories of the impactor, based on these the energy history was calculated.
- The fracture event last, typically for a few thousandths of a second.

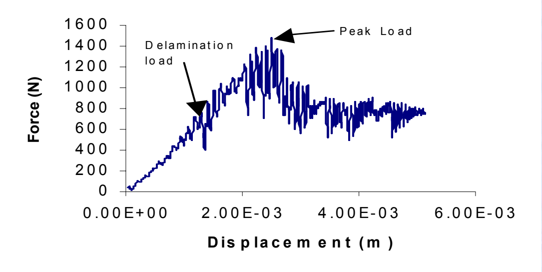

Fig. 2. Force – displacement plot indicating Peak and delamination loads

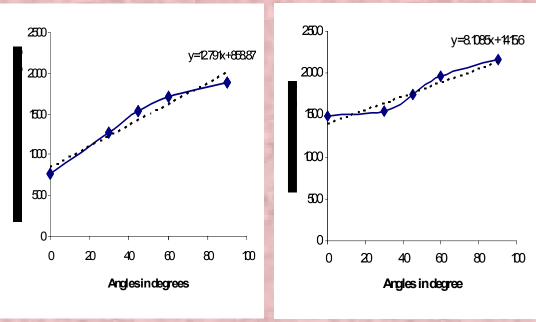

Fig. 3. Delamination and Peak loads Vs β for $0_3/\beta/0_3/90_3/45_3/\text{-}45_3$ Composite

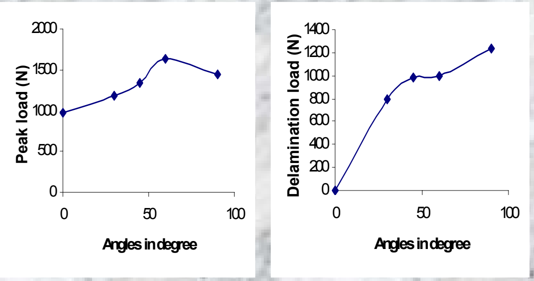

Fig. 4. Peak and delamination loads Vs β for $0_3/\beta/0_{12}$ Composite

Damage inspection

Macroscopic damage modes were:

- Indentation
- Surface cracking
- Delamination
- Back face splitting
- Laminate splitting

Conclusion

- Identified the peak and delamination threshold loads from force – displacement plots.
- Angle plies laminates have better resistance to failure.
- It is appropriate to have 30^0, 45^0 and 60^0 in a composite structure to resist loads distributed to these directions.

Further Studies

- The energy absorption and impact characteristics of curved panels of different radii.
- Failure stresses and the spreading of impact load.
- Glancing impact on composite plates
- Bending Stiffness of Symmetrical and Unsymmetrical Composite Plates
- Surface Ply Stiffness on the Energy Absorption of Curved Panels
- Impact behaviour of hemispheric domes

Experimental results and discussion

- The threshold force of the Hertzian failure varied with different samples, an indication that each sample has its own unique load-bearing capacity.
- The energy absorbing mechanism of the samples showed that fibre fracture dominated the failure mode and internal delamination due to the transverse shear stresses (or strain) and the threshold is associated with a sudden load drop, indicating dramatic stiffness reduction.
- The experimental curves contain stick-slip type of response while loading.
- The delamination load – ply orientation plot for the $0_3/\beta/0_{12}$ group of composites is similar to the typical stress – strain plot of ductile and monolithic metals and their alloys.
- Applying the principle of linear regression, it can be generalised that delamination and maximum loads (P), relate approximately to the ply orientation β, as $P = m\beta + \lambda$, where m and λ are constants that relates to a family of composite configuration.