# Composite Engineer's Viewpoint

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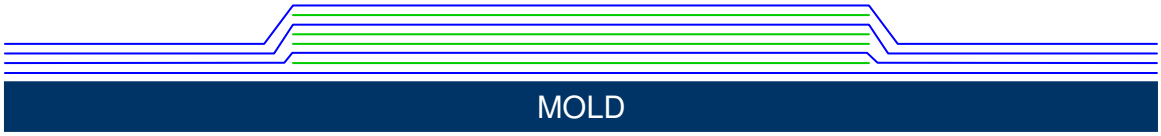
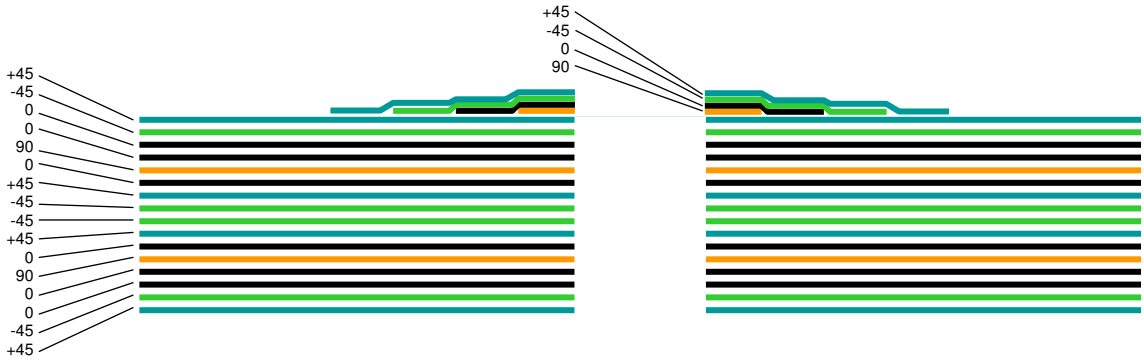
## Designing with Composite Materials
## Part 7D – Detail Design – Ply Termination

Ply termination (drop-off) is a very common feature in many structural composite components. By terminating plies in the laminate construction we can achieve better structural performance with the benefit of weight reduction. As a corollary to ply terminate, we can also add in plies to strength or stiffen a particular area of the composite structure. For example we may need to strength around a hole by adding plies (donuts) or to improve the joint strength if this was a fastener hole.




$[0/90]_4$ ends, $[0/90,+45/-45,0/90,+45/-45]_s$

Example of ply termination in a structural channel section




Example of ply addition around a hole

There are a number of design issues to be addressed when it comes to ply termination or ply addition. The issues to consider are: the number of plies to terminate at one time, the distance between consecutive ply terminations or additions, ply orientation constraints, and induced stress concentrations. Each of these issues are addressed separately. One of the major concerns with ply termination or addition is the adverse effects of induced interlaminar stresses and they impact on strength reduction.

- The number of plies to terminate or add at one time. The maximum recommended number of plies to terminate at one time is 4. In thinner laminates then a 2 ply terminations would be more appropriate, this is also the recommended maximum number of ply terminations for fabric cloth. This recommendation is based on reducing both stress concentrations and interlaminar stresses at the region of the ply termination. Also note that during ply termination or addition that laminate mid-plane symmetry should be maintained.

- The distance between consecutive ply terminations or additions. The recommended practice is to have consecutive ply terminations every 5-10 mm per ply (0.25-0.5 inches). Hence if 4 plies are terminated then the distance to the next ply terminations would be 20-40 mm. Again, this recommendation is

based on the reduction of potential high stress gradients, and this recommended distance will allows for the stress gradient to be recovered.

- Ply orientation constraints. When plies are either terminated or added to the composite structure the terminated or added ply orientation is very important. Terminating or adding too many plies of the same orientation will change the effective local laminate stiffness (modulus by thickness) too severely. This will have an adverse effect on both the interlaminar stresses and the stress gradient or stress concentrations.

- Induced stress concentrations. Ply terminations or additions can induce high stress concentrations. These stress concentrations will reduce the effect load carrying capacity of the composite laminate. The stress concentrations will also increase the interlaminar stresses at the ply termination or addition.

In summary, by careful design and management of ply terminations or additions the adverse effects of stress concentrations and interlaminar stresses can be avoided. Always keep in mind laminate ply mid-plane system when doing ply terminations or additions thus avoiding the effects of unbalanced thermal residual stresses and local laminate warping. The designer should calculate the local change in laminate stiffness before and after the ply termination or addition point to check adverse stress gradient conditions.

In the next article we investigate the general design guidelines for sandwich structures with composite face sheets. Here the benefits and drawbacks of foam and honeycomb cores are considered as well as the basic sizing requirements in a simplified analysis approach. As always I welcome questions, comments and your point of view. Feel free to contact me via r.heslehurst@adfa.edu.au. I may publish your questions and comments, and my response in future articles.