An elastic-interface model for buckling-driven delamination growth in composite panels under bending

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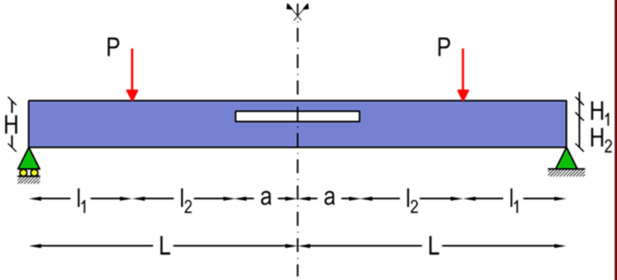
Introduction

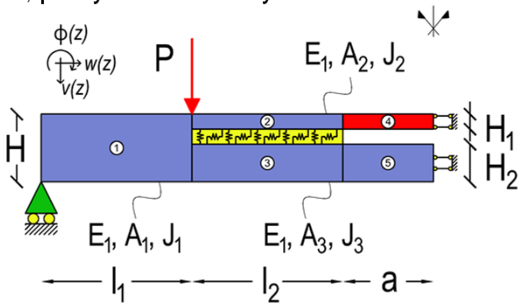
Delamination of composite laminates can have multiple causes, such as manufacturing defects, high interlaminar stresses, low-energy impacts, etc. Delamination cracks propagate under both static and fatigue loads [1].

We analyse the delamination growth promoted by local buckling in a laminate subjected to four-point bending [2].



Mechanical model

The mechanical model considers the specimen as an assemblage of sublaminates, modelled as beams, partly connected by an elastic interface.



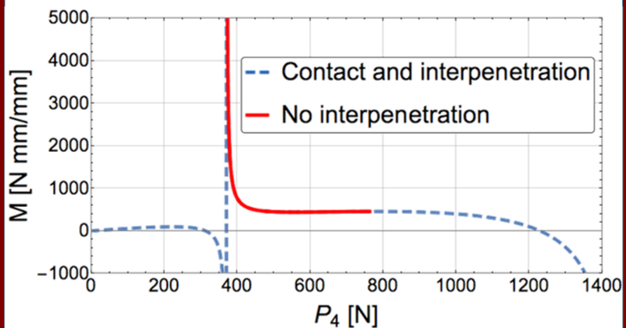
Mathematical problem

The model is described by a set of 10 differential equations + 30 b.c.

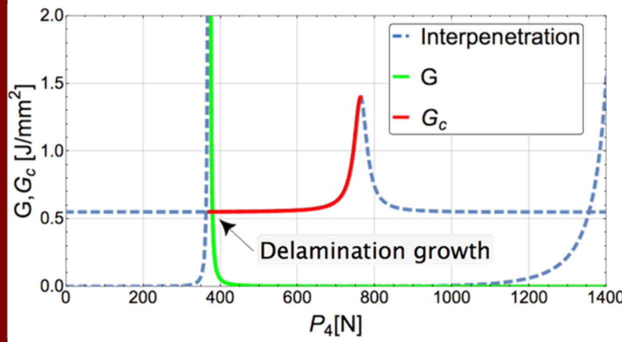
$$
\begin{cases}
E_1 J_1 v_1{}^{\mathrm{IV}}(z) = 0 \\
E_1 A_1 w_1{}^{\mathrm{II}}(z) = 0 \\
E_1 J_2 v_2{}^{\mathrm{IV}}(z) - B k_y\big(v_3(z) - v_2(z)\big) - \frac{1}{2} H_1 E_1 A_2 w_2{}^{\mathrm{III}}(z) = 0 \\
E_1 A_2 w_2{}^{\mathrm{II}}(z) = B k_z \left(w_3(z) - w_2(z) + \frac{1}{2} H_2 v_2{}^{I}(z) \frac{1}{2} H_1 v_2{}^{I}(z) \right) \\
E_1 J_3 v_3{}^{\mathrm{IV}}(z) + B k_y\big(v_3(z) - v_2(z)\big) + \frac{1}{2} H_1 E_1 A_3 w_3{}^{\mathrm{II}}(z) = 0 \\
E_1 A_3 w_3{}^{\mathrm{II}}(z) = -B k_z \left(w_3(z) - w_2(z) + \frac{1}{2} H_2 v_2{}^{I}(z) \frac{1}{2} H_1 v_2{}^{I}(z) \right) \\
E_1 J_2 v_4{}^{\mathrm{IV}}(z) + P_4 v_4{}^{\mathrm{II}}(z) = 0 \\
E_1 A_2 w_4{}^{\mathrm{II}}(z) = 0 \\
E_1 J_3 v_5{}^{\mathrm{IV}}(z) = 0 \\
E_1 A_3 w_5{}^{\mathrm{II}}(z) = 0
\end{cases}
$$

A general analytical solution is deduced for the differential problem. The b.c. are non-linear with respect to the axial force in the buckled sublaminate, P_4. By taking the latter quantity as representation parameter, numerical solutions are determined for specific problems.

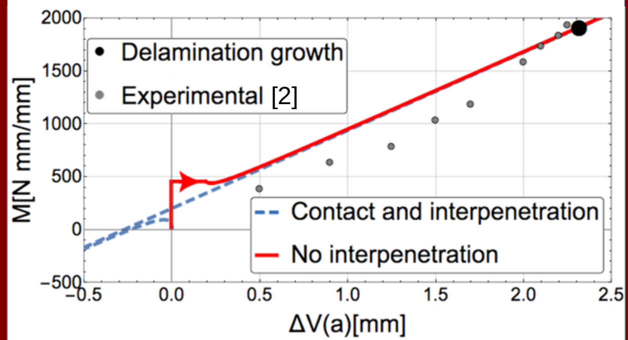
Applied bending moment vs. P_4



Delamination growth



Equilibrium path



Essential references

[1] V.V. Bolotin: Delaminations in composite structures: Its origin, buckling, growth and stability, *Compos. Part B* **27** (1996) 129–145.

[2] M. Kinawy, R. Butler, G.W. Hunt: Bending strength of delaminated aerospace composites, *Phil. Trans. R. Soc. A* **370** (2012) 1780–1797.