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Can Non-Symmetry Improve Composite Performance?

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Non-symmetric laminates are, in general, overlooked by the aerospace industry. This is, in part, due to a historical need to simplify the design process by decoupling in-and out-of-plane behaviour. Continuing advances in analysis techniques reduce the need for such simplification thereby providing an opportunity to exploit coupling for elastic tailoring purposes. Manufacturers remain reluctant to utilise non-symmetric laminates due to the possibility of warpage during cure arising from mismatch in the coefficients of thermal expansion. However, since laminates warp to varying extents, we contend that non-symmetry induced warpage be treated in a manner consistent with other manufacturing induced defects - permitting a nominal build strain. Herein, we identify the highly restrictive nature of the existing "symmetric-only" paradigm, noting that the curtailment in design freedom only increases as the number of plies and permissible angles is expanded. We present the extent of the increased design space using lamination parameters and the equivalent flattening strains as predicted by Classical Laminate Theory, capturing unwanted manufacturing warpage. To illustrate the potential benefits we consider the performance of a reinforced plate, subject to various symmetry and warping restrictions, and identify where a symmetric design may actually reduce performance.

The premise of our argument is straightforward - through relaxing the "symmetric-only" paradigm the design space is significantly expanded at the cost of nominal additions to build stress. Where these build stresses may be determined from the equivalent flattening induced strains. Although in some instances the benefit of such an expansion of the design space may be self-evident we also seek to demonstrate the benefit of non-symmetric layups clearly. We include the results of an indicative study into the behaviour of geometrically non-symmetric structures, typical of those found in aerospace design. We demonstrate that non-symmetry, through the use of in-and out-of-plane coupling, offers an under-exploited route to elastic tailoring.

A summary of results to be included in the completed manuscript are:

- Introduction of lamination parameters and a metric for quantifying continuous non-symmetry.
- Identification of thermal warpage using lamination parameters and Classical laminate Theory.
- Investigation of the extent of the design space for various warping criteria.
- Comparison between discrete and continuous design spaces.
- Details of Abaqus FEA analysis for patch reinforced plate subject to several load cases.
- Optimisation of lamination parameters for various symmetry and warpage constraints.
- Identification of laminates that satisfy the optimised designs.