

EFFICIENT CONVERSION OF LAMINATION PARAMETERS TO PRODUCTION-FRIENDLY BLENDED STACKING SEQUENCES

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Abstract

Fibre-reinforced laminated composites enable highly efficient structural designs through directional stiffness tailoring achieved by layer-wise control of fibre orientation. To explore their extensive design space effectively, an inverse design strategy is typically adopted: continuous optimisation is first used to determine optimal structural properties using lamination parameters (LPs), followed by discrete optimisation to design a manufacturable stacking sequence (SS) that matches these target LPs. In practice, however, this inverse problem of recovering stacking sequences from LPs is computationally demanding. As a result, the approach has seen limited industrial adoption. The difficulty increases rapidly with high laminate thickness, when industrial design guidelines are enforced, and when fine angular resolutions (e.g., $\pm 15^\circ$ increments) are allowed. This computational bottleneck is addressed with this work.

To overcome this challenge, we initially developed a highly efficient and scalable SS design methodology that combines Fast Fourier Transforms (FFT) with a Branch-and-Bound (BB) optimiser. The novel idea here was to interpret LPs as signals and applying FFTs on them. This yields the “frequency components”, which is interpreted as the required ply angle distribution. Knowing the distribution beforehand makes a BB optimiser evaluates far fewer nodes and converge rapidly to SS that closely match the target LPs. The method has been validated against established benchmark problems and demonstrates clear computational advantages over state-of-the-art approaches. It can find multiple unique solutions within a second, despite being fully deterministic and enforcing the complete set of aerospace laminate design constraints (including balance, symmetry, ten-percent rule, disorientation, and contiguity). Building on this framework, we now extend the methodology to blended composite laminate structures. After optimising the thickest laminate region, a dedicated BB implementation determines an optimal ply drop sequence. This enables the efficient synthesis of a fully blended SS across all structural zones, while preserving computational efficiency, determinism, and practical manufacturing requirements like internal ply continuity. Contrary to state-

of-the-art solutions that require several hours for one non-deterministic solution, the developed framework requires just few seconds to design multiple unique deterministic solutions.

The proposed framework is therefore well suited for large-scale composite structure design. It enables designers to fully explore the weight-saving potential of a given material system with finer ply angle resolutions, and not rely on simplified parameterisations like homogenised laminates. Furthermore, it provides a foundation for systematically investigating the influence of complex, non-homogeneous SS, not only on the clear performance benefits, but also on production efficiency.