

PROCEEDINGS

Curing-Induced Deformation of Double-Double Laminates and Ply Angle Optimization Strategies

Yizhuo Gui¹, and Cheng Qiu^{1,*}

¹Institute of Mechanics, Chinese Academy of Sciences, Beijing, 100190, China

*Corresponding Author: Cheng Qiu. Email: qiucheng@imech.ac.cn

ABSTRACT

Double-Double (DD) laminates are favored for their straightforward design and ability to achieve effective homogenization. However, DD laminates fail to deliver the expected homogenization benefits in controlling process-induced deformation (PID). In this paper, a data-driven framework combined with machine learning methods was proposed to extract the statistical patterns between ply angles and PID. Then, flat laminates are investigated through an integrated approach combining theoretical analysis, experimental validation, and finite element simulations to systematically elucidate the influence of ply thickness, layup angles and mold interactions on PID in DD laminates. The results show that, with fixed ply thickness and stacking angle, the curing-induced curvature is inversely proportional to the square of the number of repeating units. Further analysis of various angle combinations reveals that suppressing twist deformation is the measure to minimize the PID of DD laminates. Orthogonal layups ($|\phi + \psi| = 90^\circ$) effectively eliminate twist-related distortions. Moreover, friction at the mold interface induces bending toward the mold side, which can be counteracted by tailoring the stiffness difference between the mold-side and non-mold-side plies via angle combination selection. Following the proposed optimization of choosing appropriate ply angles, the PID of DD can be lower than traditional symmetric or optimized quadratic layups. The findings of this paper can provide a design guideline of DD laminates when controlling PID is of great significance.

KEYWORDS

Process-induced deformation (PID); double-double laminates (DD); theoretical modeling; machine learning; finite element analysis (FEA)

Acknowledgement: This work is partially supported by the Project of Hetao Shenzhen-Hong Kong Science and Technology Innovation Cooperation Zone (HZQB-KCZYB-2020083), the international partnership program of the Chinese Academy of Sciences (Grant No.025GJHZ2022103FN). We are grateful for the constructive discussion with Prof Stephen Tsai from Stanford University.

Funding Statement: This work is partially supported by the Project of Hetao Shenzhen-Hong Kong Science and Technology Innovation Cooperation Zone (HZQB-KCZYB-2020083), the international partnership program of the Chinese Academy of Sciences (Grant No.025GJHZ2022103FN).

Conflicts of Interest: The authors declare no conflicts of interest to report regarding the present study.



Copyright © 2026 The Author(s). Published by Tech Science Press.

This work is licensed under a Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.