2D+ multi-scale method for industrial design of multi-layered bending plates

Julie Triclot*[1], Oriol Lloberas-Valls[2], and Javier Oliver[3]

[1]Escola Tècnica Superior d'Enginyers de Camins, Canals i Ports de Barcelona (ETSECCPB), Universitat Politècnica de Catalunya, BarcelonaTech (UPC), Campus Nord, Edif. C1, c. Jordi Girona 1-3, 08034 Barcelona – Spain

[2]Escola Tècnica Superior d'Enginyers de Camins, Canals i Ports de Barcelona (ETSECCPB), Universitat Politècnica de Catalunya, BarcelonaTech (UPC), Campus Nord, Edif. C1, c. Jordi Girona 1-3, 08034 Barcelona – Spain

[3]Escola Tècnica Superior d'Enginyers de Camins, Canals i Ports de Barcelona (ETSECCPB), Universitat Politècnica de Catalunya, BarcelonaTech (UPC), Campus Nord, Edif. C1, c. Jordi Girona 1-3, 08034 Barcelona – Spain

Abstract

Structures with a multi-layered plate morphology, such as composite laminates, are of great interest to industry due to their high stiffness to density ratio. However, their design phase is long, expensive and requires many experimental tests in order to fulfill the requirements for the uptake of new products. High fidelity simulations are seen as a valuable tool to accelerate these processes but face the challenge of providing accurate and efficient solutions. It Is worth highlighting that the complexity of such materials is found precisely in the thickness dimension, this being remarkably lower that the in-plane ones. This is the reason why full 3Dcomputations are prohibitive since typical discretisations are extremely thin in order to overcome pathologies derived from high element aspect ratios.
In this view, the multiscale methodology presented in (1) (the 2D+ multiscale approach) is adopted in this contribution. The idea is to take advantage of a dimensional reduction of the multi-scale problem at both macro and meso-scales to render extremely competitive computation times while preserving the heterogeneous description through-the-thickness. The strategy is based on the computational homogenization formalism employing a 2D plate with degenerated kinematics at the macro-scale and a 1D RVE (Representative Volume Element) through-the-thickness at the meso-scale. This methodology is not invasive and has been implemented in the commercial software Abaqus as a dedicated user element.

The application of this method to different bending-dominated scenarios results in exceptionally accurate results compared to fine-meshed 3D calculations. Stress distributions are accurately captured both in-plane and through the thickness. A huge reduction in computation time compared to 3D analyses is achieved, reaching speed-up factors of three orders of magnitude. The 2D+ truly accomplishes the goal of being as accurate as the 3D at a cost close to the 2D one. The presented method is an interesting alternative to existing numerical procedures to handle multi-layered bending plates. Furthermore, it provides a solid basis to account for failure modes arising within these materials (e.g. delamination in laminated

*Speaker

composites).
(1): Wierna, P., Yago, D., Lloberas-Valls, O., Huespe., A. and Oliver, J., On the Efficient and Accurate Non-linear Computational Modeling of Multilayered Bending Plates. State of the Art and a Novel Proposal: The 2D+ Multiscale Approach. Arch Computat Methods Eng 31, 2451–2506 (2024).