Simplified modeling of defects in lattice and Variable Stiffness laminates

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Modern structures are becoming increasingly customized, with geometries and material distributions designed with unprecedented degree of flexibility. A first meaningful example is given by lattice structures, whose basic geometries can be nowadays arbitrarily generated via additive manufacturing. A second example is given by Variable Stiffness (VS) laminates, where the fibers' path - hence the elastic distribution - can be shaped to meet the desired internal load path.

Manufacturing techniques based on Automatic Fiber Placement (AFP) and continuous tow shearing have been proposed in this context. One crucial feature in both additive manufacturing and AFP concerns the unavoidable presence of defects in the final manufactured components [1,2]. As compared to nominally pristine configurations, imperfect lattice structures as well as VS laminates may exhibit substantial deviations with respect to their nominal counterparts in their structural response.

This work illustrates a numerical strategy for allowing imperfections to be effectively introduced in lattice structures and VS laminate models. Specifically, the investigation aims at developing new numerical tools for the preliminary design, and is therefore characterized by computational efficiency and ease of modeling.
In a first part, lattice structures are assessed. Typical deviations in their geometry pattern, as well as the presence of porosity are studied and included into a 1D finite element approach, where the constitutive law is inherited from refined 3D models.
In the second part of the work, the modeling of imperfections is illustrated focusing on VS laminates. The proposed strategy relies on a Ritz-based method [3], where the presence of gaps and overlaps is explicitly accounted for.

Both the proposed modeling strategies demonstrate the importance of appropriately including the effect of defects to obtain accurate predictions of the structural response. In turn, this effect is proven to be relevant when preliminary optimizations are carried out.

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References
[1] Cao, X., Jiang, Y., Zhao, T., Wang, P., Wang, Y., Chen, Z., Li, Y., Xiao, D. and Fang, D. "Compression experiment and numerical evaluation on mechanical responses of the lattice structures with stochastic geometric defects originated from additive-manufacturing." Composites Part B: Engineering Vol. 194 (2020)

[2] Dutta, S. and Zhao, W. "Buckling of variable angle tow steered laminates considering gap/overlap defects identified using innovative image processing." Composite Structures, 368, 119221 (2025).
[3] Vescovini, R., Oliveri, V., Pizzi, D., Dozio, L. and Weaver, P. M. "Pre-buckling and buckling analysis of variable-stiffness, curvilinearly stiffened panels." Aerotecnica Missili & Spazio, 99, 43-52 (2020).