Multi-scale Stiffness Optimization of Laminates

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In the present work we describe a optimal design model of non-conventional fiber reinforced laminates based on topology optimization [1] considering the material in the linear elastic range. Conventional laminates have unidirectional cylindrical long-fibres embedded in polymeric matrix and restricted to a set of orientation angles e.g. 0º/90º±45º. At a conceptual design stage the optimality of such standard solutions may be questioned. Therefore, let the geometrical size, shape and connectivity of the fibres be unknown and let the design space be enlarged to come up with improved fibre shapes (or lay-outs) and better staking of layers (lay-ups). With this in mind, one assumes here a mixed set of micro and macro design variables to characterize the distribution of two materials (fibre and matrix phases), and obtain the optimal composite microstructure at the micro design level (or material level) and the optimal fibre orientation and respective volume fractions at the macro level (or structural level). This is a two-scale computational model to design bi-material composite laminates with the objective of optimally design the laminate and its material (at each ply) - multiscale topology optimization model, see [2].

The results obtained demonstrate that the model identifies improved and innovative designs, when compared with classical laminated composite solutions. In addition, these results are helpful to gain insight into the effectiveness of the microstructure features of composite laminates when subjected to different load conditions. As reported in previous works, conventional laminated composite design strongly depends on the orientation of fibers. However, this work shows that strong improvements can be further achieved using topology design of the fiber cross-section. Extensions to treat several unresolved aspects are under study namely, inter-laminar effects (delamination), damage of the fiber, matrix or interface.

References

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