Reliability-based design optimization of composite laminates for aeroelastic applications

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Jeudi 09 mars à 14h
Présentiel : Salle Contensou - ONERA Châtillon
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Abstract

Reliability-based design optimization of composite laminates was performed with uncertainty in ply orientation. This work proposes a new iterative methodology that links two analysis spaces. In the first space, the low-dimensional macroscopic design is managed (using lamination parameters) with gradient information to perform rapid optimization. In the second space, a high-dimensional mesoscopic scale, uncertainties in the design variables are modeled and then propagated to the macroscopic scale. With this methodology, an inverse problem must be solved at each iteration to propagate the uncertainty from the mesoscopic space to the macroscopic design space and compute the required failure probability. For this purpose, uncertainty quantification is necessary to correctly identify a stacking sequence corresponding to the statistical description of the lamination parameters. To this end, a Fourier orthonormal basis has been developed. The optimization methodology is applied to various problems, including instability constraint: (i) the composite plate optimization promoting the plate stiffness with an analytic buckling constraint and (ii) the aeroelastic tailoring promoting the plate flexibility while remaining reliable with respect to the flutter phenomenon. Due to the modal nature of the flutter velocity, a strategy combining a classifier and classic surrogate models is proposed to approximate the quantity of interest and perform a fast reliability analysis. The results demonstrate an improvement in the reliability compared to the deterministic optimized design and a significant computational gain compared to the approach of directly optimizing ply orientations via a genetic algorithm.

Key words : composite material, RBDO, surrogate modeling, multi-scale