

OPTIMIZATION-BASED COMPARISON OF THE MASS EFFICIENCY OF STRINGER-STIFFENED AND SANDWICH COMPOSITE PANELS

David Zerbst, Edgar Werthen, Rakshith Manikandan, Sascha Dähne, Christian Hühne

German Aerospace Center (DLR)

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Abstract

Lightweight composite panels are widely used in thin-walled load-carrying structures in aerospace and wind energy systems. Aircraft wings and wind turbine rotor blades share these structural characteristics but are typically realized using different structural concepts. Stringer-stiffened panels dominate aircraft wings due to their ability to efficiently carry axial loads and increase the bending and buckling resistance of the skin, while maintaining good accessibility for inspection and maintenance. In contrast, sandwich panels are widely used in wind turbine rotor blades where thick lightweight cores efficiently provide these structural functions by increasing the distance between the face sheets and thereby improving bending stiffness. This work systematically compares the lightweight potential of stringer-stiffened and sandwich panels across a broad range of representative load combinations.

The mass efficiency of both concepts is evaluated within a unified optimization framework. To enable efficient exploration of the associated design spaces, a multi-parametric panel formulation with fully continuous design variables is developed. The formulation includes geometric parameters as well as stiffness properties, allowing the computation of analytical derivatives for gradient-based optimization. Laminate stiffness is parameterized using lamination parameters, providing a continuous representation of laminate stacking sequences.

For stringer-stiffened panels, the global structural response is represented using a smeared stringer formulation that incorporates the stiffening effect of the stringers into the global plate stiffness for global buckling evaluation. Local buckling and strength-driven failure mechanisms are assessed using a discrete stringer representation.

Sandwich panels are modeled using the face sheet stiffness and the face sheet and core thicknesses as design variables. The model accounts for global buckling and typical sandwich-specific failure modes, including face wrinkling, core shear failure, and face sheet strength limits.

Both panel concepts are subjected to combinations of load resultants typically observed in aircraft wings and wind turbine rotor blades. In addition, the panel

aspect ratio is varied to capture the influence of panel geometry on the relative mass efficiency of both concepts.

The optimization results provide a systematic comparison of the minimum achievable mass of sandwich and stringer-stiffened panels across a wide range of loading scenarios. Regions in the load space where one concept becomes more mass efficient than the other are identified and visualized using design maps. These enable the derivation of practical design guidelines and support early-stage structural concept selection in aerospace and wind energy applications.