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A Novel Design and Optimisation Tool for the Composite Quilted Stratum Process

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A novel framework for the optimisation of composite structures manufactured using the recently developed Quilted Stratum Process (QSP©) is presented in this paper. Although the excellent mechanical properties of composites over their metallic counterpart have resulted in the growing use of composite materials in aerospace industries, applications to other sectors have been limited due to their higher costs and long processing times. The QSP© is an all-inclusive process suitable for the cost-effective and automated high speed manufacturing of composite parts. It encompasses the continuous production of long and narrow thermoplastic composite patches, their automated cutting, assembly and stamping. In spite of the QSP© potential cost and time benefits, a numerical method for the design of composite parts employing this process has yet to be developed.

In this research, we propose the first method able to design and optimise composite parts manufactured by QSP: the so-called Quilted Stratum Design (QSD©). QSD© is based on a two-level optimisation strategy. A top level structural optimisation problem based on a compact and continuous parameterisation of the laminates design space employing lamination parameters. The stiffness and thickness distributions obtained at this top level are, in effect, ideal and maximise mechanical performances but without consideration to manufacturing constraints.

The second optimisation level, significantly more complex, aims to retrieve a QSP©-manufacturable solution structurally equivalent to the top level ideal design employing meta-heuristics. A QSP© part is built from a net-shape preform, which is an assembly of thermoplastic patches of different attributes such as shape, thickness and material. The QSP© consequently offers extensive design freedom, which conversely require a well-though optimisation method to exclude senseless design options from the search space. To that end, we propose a specific encoding for candidate solutions using two sets of indices. The first index refers to a user-defined thickness-material library representative of composite patches obtained after pultrusion or commercial tape and organosheet. The second index corresponds to a library of shapes, deterministically evaluated based on the ideal stiffness and thickness distributions, and the flattened form of the part. The optimisation framework proposed by the authors as well as an optimised automotive part, used as case-study, will be presented at the conference.