# Multi-stage filament winding: Integrative design and manufacturing process for doubly curved fibre-reinforced polymer components

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## Abstract

The publication to be submitted describes the current state of research on the multi-stage filament winding process (MSFW) for double-curved fibre-reinforced polymer (FRP) components for use in architecture.

The conventional filament winding process is an economical and technically well controllable manufacturing process for the series production of rotationally symmetrical fibre composite components. The quality of the produced laminates is very high due to the controllable process parameters (fibre volume ratio and fibre orientation). In comparison to other common manufacturing processes for fibre composite components, very large components can also be produced using the fibre winding process [1]. Currently, component sizes ranging from small round tube cross-sections to aircraft fuselages are being realized.

Multi-part winding mandrels allow the extension of the form spectrum by double-curved and undercut geometries. For this purpose, the geometry to be produced is disassembled based on changes in curvature. The basic shape of a winding mandrel must always be convex for the manufacturing process. Concave areas of the final component must therefore be produced with a convex replacement geometry. A water-soluble, reusable sand-binder mixture was developed as the core material. Cores composed of this mixture are released step by step after the winding process. The wet laminate is slowly lowered into the resulting cavity and then cures.

The paper discusses the integrative design process from the feasibility study to the final component planning. This includes geometry analysis, determination of the laminate structure, production of the core parts and construction of the associated winding axis and simulation of the winding process.

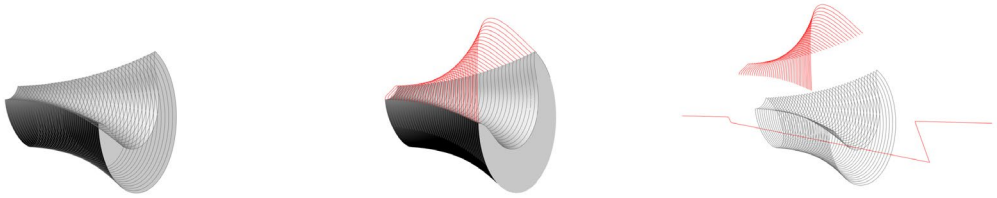

Fig. 1 Multi-stage filament winding (left to right): Final component, convex replacement geometry, final component planning including winding axis

[1] M. Flemming, G. Ziegmann, S. Roht, *Faserverbundbauweisen - Fertigungsverfahren mit durplastischer Matrix*, Springer-Verlag Berlin Heidelberg, 1999, pp 107-208