11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

COMPUTATIONAL OPTIMISATION BY LOCAL TAILORING OF CONTINUOUS FIBRE REINFORCED THERMOPLASTIC COMPOSITE SHEETS

Thomas Rettenwander[1], Michael Fischlschweiger[2], Martín Machado[3] and Georg Steinbichler[1]

[1] Johannes Kepler University, Institute of Polymer Injection Moulding and Process Automation, Altenbergerstr. 69, 4040 Linz, Austria, www.jku.at/ipim
[2] Center for Lightweight Composite Technologies, ENGEL Austria, 4300 St.Valentin, www.engelglobal.com
[3] Johannes Kepler University, Institute of Polymer Product Engineering, Altenbergerstr. 69, 4040 Linz, Austria, www.jku.at/ippe

Key words: *structural optimisation, finite element modelling, principal stress optimisation, thickness optimisation, topology optimisation, patch placement*

Endless fibre reinforced polymer matrix composites show remarkable thermomechanical properties. However their anisotropic material behaviour exhibits a challenging task for engineering applications. To fully exploit composite structures new concepts for component design have to be developed targeting for stiffness and strength improvement or for weight reduction of composite materials.

Computational methods for variable stiffness design have been developed by numerous authors. A good overview can be found in [1] and [2], e.g., a coupled procedure by hybridisation of principal stress and thickness optimisation has been developed by the authors and has been presented in [1].

Underlying work focuses on computational methods for composite component design in an highly automated manufacturing process. Therefore new numerical concepts have to be examined. In this work optimisation algorithms are developed for partial local tailoring of a composite thermoplastic ground structure via a patch placement process, which promises fast production times. The optimisation algorithm is outlined and applied on a component. Numerical results are validated through an experimental procedure.

The optimisation is done on three varying space scales.

1. A global laminate position considers the interaction between a globally defined

straightline fibre format groundstructure with the reinfocement layer. The interaction is considered as a displacement boundary condition.

2. On a local laminate position optimisation of fibre direction in the reinforcement layer is done by a principal stress optimisation resulting in locally varying fibre angles Θ and $\Theta + 90$.

3. On a local ply position Θ and $\Theta + 90$ plies are optimised regarding material distribution. This is done by thickness or density optimisation using a gradient based technique.

In the algorithm it is iteratively switched between space scale 2. and 3. till global convergence is achieved. The boundary condition implemented in space scale 1. is present throughout all optimisation cycles.

The result of a coupled procedure using a SIMP (solid isotropic material with penalization) approach [3] for material distribution optimisation leads to truss like structures reinforcing underlying ground structure. This design is advantageous for interpretation and the application to a patch placement process. Interpretation of continuous fibre paths is done by a multi-linearisation method, where discrete fibre patches are obtained.

The final design is then manufactured for experimental validation. The results can be summerized as follows: For the numerical example additional weight of $3,25\%$ to the standalone groundstructure leads to a stiffness improvement of $63,82\%$. This has been validated in an experimental setup. There the multi-linearised patches with an additional weight of $4,3\%$ leads to an even more impressive rise in stiffness of $76,51\%$.

REFERENCES

[1] T. Rettenwander, M. Fischlschweiger and G. Steinbichler. Computational structural tailoring of continuous fibre reinforced polymer matrix composites by hybridisation of principal stress and thickness optimisation. *Compos Struct*, Vol. **108**, 711-719, 2014.

[2] H. Ghiasi, K. Fayazbakhsh, D. Pasini and L. Lessard. Optimum stacking sequence design of composite materials Part II: Variable stiffness design. *Compos Struct*, Vol. **93**, 1-13, 2010.

[3] M.P. Bendsoe and O. Sigmund. *Topolopgy Optimization - Theory, Methods and Application*. Springer-Verlag, 2003.