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Proposal for Master's Thesis

Numerical optimisation strategies of additively manufactured shells made of carbon short-fibre concrete considering layer thickness, arrangement, orientation and fibre alignment

Supervisor

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Motivation

Concrete is one of the most widely used building materials in the world. The single largest limitation of concrete is its weak and brittle nature under tensile stress. In order to improve this material behavior, reinforcement materials that are strong in tension are embedded into the concrete to avoid brittle failure and increase tensile load capacity.
Tailoring chemical compatibility and micromechanical parameters of cementitious materials towards fiber reinforcement allows for the creation of a material that no longer shows brittle single crack failure but rather a significant pseudoductility. Such composites also show enhanced tensile and flexural strength.

Objective

The aim of the thesis is the development of a structural-mechanical substitute model for the simulation and optimisation of additively and thus layer-by-layer manufactured panels made of carbon short-fibre-reinforced ultra-high performance concretes. In the manufacturing process, the fibres are introduced into the high-strength concrete matrix in the direction of the principal stress direction in order to achieve a reinforcement effect. Based on that principal stress direction, the transversal isotropic material behaviour of the carbon fibres extruded in tensile stress direction is to be mapped by suitable modelling approaches, e.g. by individual material orientations in the layers of the computational mesh. **Figure 1** shows the visualisation of the extrusion paths, which are superimposed crosswise here and which, in contrast to classical composite structures, do not run in a straight line.

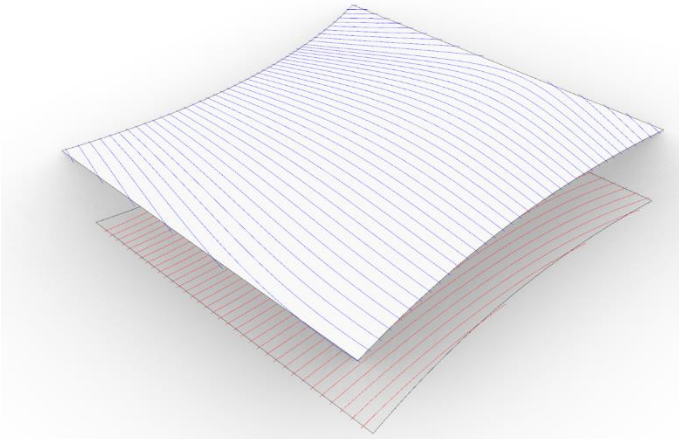

Figure 1: Exploded view of the additively manufactured disc with extrusion paths along the main stress direction (red, blue).

Work Plan

1. Within the scope of the work, it is to be determined to what extent the optimal layer structure should be designed with regard to the parameters mentioned in the title, assuming a non-linear stress-strain behaviour on the compression and tension side.

2. A calculation routine that respects the non-linear material behaviour is to be implemented. The load-bearing capacity and the structural stability may serve as target functions. For this purpose, first indications are to be collected on the basis of a literature study, which serve as input values for the optimisation algorithm. The aim of the theoretical work is a structured representation of optimal design variables under given boundary conditions and the derivation of recommendations for action.

3. In the practical part of the work, representative layer structures are produced by means of an industrial robot and the results of the simulation and optimisation are checked in small-scale tests (tensile tests, bending tensile tests).

Procedure

- Brief introduction to the theory of anisotropic materials, composite structures and the finite element method.

- Development and optimisation of the simulation model in close cooperation and coordination with the supervisor.

- Thesis can both be done in English or German

Previous knowledge

- Basic knowledge of Python (desirable)
- Finite element method (desirable)

References

[1] H. Altenbach, J. Altenbach und W. Kissing, Mechanics of Composite Structural Elements. Singapore: Springer Singapore, 2018.

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[3] F. R. Beyer, "Principal stress trajectories in numerical solid mechanics". Dissertation, Dresden University of Technology, Dresden, 2015.

[4] M. Hambach, "High-strength multifunctional composites based on Portland cement and carbon short fibres". Dissertation, University of Augsburg, Augsburg, 2016.