Form finding of stress adapted folding as a lightweight structure under different load cases

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Abstract

Besides membrane and shell structures, folding structures are among the most efficient design principles that can achieve relatively high load-bearing capacities with a low amount of material. In steel construction, the use of folding is limited to longitudinal folds (e.g. trapezoidal sheets). The efficiency of crease structures can be increased if the fold pattern is oriented according to the principal stress directions [1].

With the intention of a homogeneous material utilization, this paper presents an approach for a form-finding, which in addition to the purely geometric alignment according to the stress directions, also allows the stress intensity to be taken into account. With an algorithm based on "Mixed-Integer Quad-rangulation" [2] a trajectory mesh aligned to the principal stresses is generated, on the basis of which a two-layer pyramidal folding structure is derived. The relationships between singularities, trajectory distances, trajectory progression and stress intensity are discussed and implemented in the approaches of form-finding.

The second part deals with the question of which load case is the most effective basis for the design of the folding pattern when several load cases can act simultaneously. Concerning lightweight structures, the dead load is not always the decisive load case with the result that variable loads may cause stresses in a comparable level. This leads to the question which load case or load combination is most important one to base the construction on. The most related concepts of realized structures (CIAB Pavillon Beijing, Zaha Hadid Architects) as well as research works, such as in [3, 4], are limited to the alignment of bars according to the stress lines to a *single* load case. In addition to the fact that the three-dimensional folding structure behaves structurally much more sensitively than a beam structure, the effects of interrelations between the various load cases on form finding are being investigated.

References

[1] J. Musto and M. Trautz, "The potential of stress oriented foldings," *Origami*, vol. 7, 01 2018.

[2] D. Bommes, H. Zimmer, and L. Kobbelt, "Mixed-integer quadrangulation," *ACM Transactions on Graphics*, vol. 28, no. 3, pp. 77:1–77:10, 2009.

[3] K.-M. M. Tam, J. R Coleman, N. W Fine, and C. Mueller, "Stress line additive manufacturing (slam) for 2.5-d shells," 08 2015.

[4] M. Dimcic, *Structural optimization of grid shells based on genetic algorithms.* Dissertation, University of Stuttgart, 01 2011.