Topology optimisation: a case study

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Abstract

Parametric and computational design play a major role in contemporary architecture and engineering. Designers need no longer conform to predetermined shapes and sections, but are given freedom to explore new geometries and structural forms. An example of how an organic process can be employed to finding the solution to a design problem is presented. Topology optimization is studied to suggest different alternatives for the creation of an open and functional internal tower structure in an educational building.

Keywords: topology optimisation; structural optimisation; parametric geometry; natural structures; biomimetics; lightweight structures.

1 Introduction

Topology optimisation is based on determining the optimum distribution of material within a design region. The constraint parameters are the applied loads, the support conditions, the overall volume of the structure and some possible design restrictions such as the position and size of prescribed holes and solid areas [1].

Frei Otto [2] was a pioneer in linking natural forms to structural design, observing how in nature many structures conform to lightweight principles combining minimum material use with maximum strength and stability. Nature can serve as a source of inspiration, however, direct imitation will likely yield invalid results. A recent study comparing nature's growth processes and topology optimisation was conducted by Lochner-Aldinger, Karl and Adriaenssens [3]. The authors propose a classification of biomimetic structural systems combined with using optimisation, trying to recreate the structure of bones and diatoms via topology optimisation. The study deals with structural behaviour only and does not attempt to unequivocally imitate nature; rather an abstraction process is carried out to transfer natural principles to structural design.

2 Methodology

A topology optimisation process was adopted for the generation of an alternative proposal for a potential tower in the central space of an educational building. The structure was intended to support tiered seating and a crane to lift exhibits to the ceiling. As the university building was designed to host all engineering disciplines, the architect's proposal suggested a gateway that reflected and enthused the concept of engineering. The proposed design conveyed this message through a rational truss structure.

The project engineers were keen to investigate an alternative way of representing their discipline through an organic engineering methodology. This focused on utilising contemporary engineering

technology and separating it from common engineering stereotypes.

Today, with advanced manufacturing processes, optimisation techniques can be applied to find other ways of meeting the necessary requirements, freeing the design from the restrictions of standard topologies and offering more efficient solutions.

Different scenarios with varying supports and load cases were studied, each producing a unique outcome once the topology optimisation was run. This was carried out in Grasshopper[4] using the 2D analysis of the Millipede plug-in[5]. The supporting structure of the event space was represented by a 2D plate with in plane forces. The analysis was then based on a rasterisation of the domain producing a grid of square plate elements on which the topology optimization is carried out.

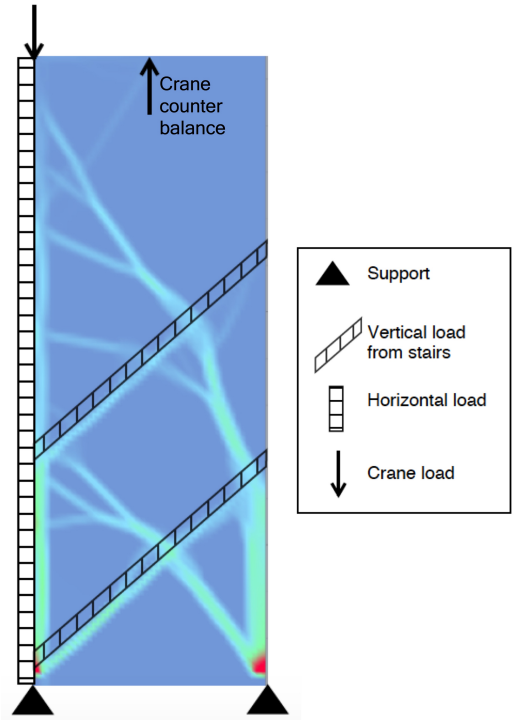

Figure 1. One topology optimisation solution.

3 Discussion

The resemblance to dendriforms is apparent, however, the principle behind the design is similar to that of bone growth, rather than treelike structures. Bones are formed via adaptive mineralisation and build up where more pressure is applied and reduce their mass where not required, limiting the bone's overall weight without compromising the structure [6]. Similarly, the results of the topology optimisation produced morphologies that traced the direction the load followed to reach the support locations, creating striking and suggestive scenarios that best convey what contemporary structural engineering is capable of by combining the imitation of nature with the adoption of optimisation techniques.

4 Conclusion

This research project was aimed at investigating analysis tools for an alternative proposal for the design of an internal tower that would illustrate the potential computational design has brought to the world of engineering. The study shows how designers have greater freedom to explore different forms and solutions as the tools to create more organic structures are now available were previously only more regular and highly ordered structures were possible.

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6 References

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