Reflection

Student: Eva Schoenmaker
Student Number: 4693906
Main Mentor: Dr. Charalampos Andriotis
Second Mentor: Dr. Faidra Oikonomopoulou

1. How are research and design related?

This thesis is part of a larger ongoing research project at the TU Delft regarding structural glass as a novel construction material. Here, the focus is directed towards casting of glass to create completely free-form geometries. Thus far, only smaller components have been created, but a multitude of previous student work explored how the current limitations in the fabrication process could be overcome by using topology optimization to design larger cast glass components. This thesis continues this research by integrating the limitations and remarks concluded from the previous work to further explore the potential of designing large cast glass components using topology optimization.

While commercial topology optimization software exists, the application of those for the design of optimizing glass structures is hampered by their use of von Mises stresses. Glass is a brittle material, with considerably higher compressive strength than tensile strength. The usage of von Mises stresses makes it impossible to utilise both the compressive and tensile strength. A two-dimensional optimization algorithm has been created that integrates the two strength constraints as well as design-specific constraints related to cast glass as annealing and manufacturing criteria. This thesis aims to continue the development of this algorithm and to create a tool that can help generate three-dimensional mass-optimized designs.

2. How is the graduation topic positioned in the studio?

Within the larger building technology studio, this thesis is related to 'Structural Design' and 'Artificial Intelligence'. The Structural Design Studio focuses on the innovation of novel structures that are able to respond to the growing demand for structures in a sustainable way. This thesis researches how computational tools like topology optimization can be utilized in creating mass-optimized structures. Reducing the amount of glass needed for a structure consequently limits the energy needed to produce the component.

3. How did the research approach work out & did it lead to the results you aimed for?

The aim of this thesis was to develop a three-dimensional topology optimization algorithm. As this optimization is quite computationally expensive the chosen approach was to gradually scale-up the experimenting size. During the first steps of this process, the results can be compared with results found in the literature as well as with the outcomes from previous theses.

The step-wise approach made assessing the performance of the algorithm possible. The scaling up of the algorithm proved to have its difficulties. However, adopting new approaches resulted in a design tool that can efficiently optimize a three-dimensional design.

4. To what extent are the results applicable in practice?

The developed algorithm is able to take a large range of constraints into consideration in order to reach a result that is feasible within the structural and design constraints. While the obtained geometry is complex, a recent thesis shows the potential of using coatings on 3D-printed sand moulds to create transparent glass structures with complex shapes.

Some geometrical errors still occur in the structure and a post-processing procedure is needed to obtain a final smooth geometry. Further research can be done to avoid any geometrical issues and non-connected elements in the final structure. Furthermore, physical testing is needed to evaluate the structural performance and validate the results from the computer simulations.

5. To what extent has the project innovation been achieved?

The innovation in this thesis lies in the creation of a custom algorithm to make a three-dimensional calculation possible. A lot of progress was made to limit the computational time of the algorithm to make optimizations over a larger domain possible. Including gradient functions in the optimization was revealed to be the key factor in making a three-dimensional optimization feasible within a reasonable time frame. By increasing the computational effectiveness the algorithm can be used as a base to quickly get an insight into the most optimal material layout for a design. However, still a post processing step is needed, as the optimization result can have geometrical errors.

6. What is the impact of the project on sustainability & sustainable development

The possibility of mass-optimizing glass designs contributes significantly to more sustainable structures. It reduces material use and lessens the energy used for the fabrication of components. Furthermore, the parametric nature of the algorithm makes it possible to use the tool for a multitude of glass types. Making it possible to apply the algorithm in design cases that work with recycling waste glass. Consequently, the algorithm can also be used for materials with a similar behaviour to glass, like concrete.

7. What is the socio-cultural and ethical impact of the project and what is the relation between this project and the wider social context

The growth of the populating and the ageing of the existing infrastructure is putting a high demand on the building industry. Currently, the building industry is already one of the largest emitters of CO_2. Thus reducing the use of resources and including recyclability in designs are becoming increasingly important. This project adds to the research into decreasing material usage by optimizing the structural performance of designs. Furthermore, while the structural use of glass is still very novel, high compressive strength give the possibility to compete with common construction materials like concrete and steel. Here it should also be noted that an added benefit of glass is that it is infinitely recyclable.

8. How does the project affect architecture and the built environment

In short, the algorithm offers architects and designers a way to explore the possibilities of creating large cast glass structures and potentially introducing a new architectural language. This is because the algorithm makes it possible to use cast glass on a scale that was previously not feasible to fabricate. The three-dimensionality of the algorithm showcases the spatial qualities that topologically optimized designs can have. Using the algorithm as a tool, designers can play with boundary settings to create intricate designs that utilize structural performance to minimize material usage. The algorithm ensures structural performance which in turn encourages the usage of cast glass for self-standing structural components. Furthermore, this enables the change in mindset toward glass as a structural material.