UNCONVENTIONAL PERMEABLE MICROSTRUCTURES

AN ENGINEERED POROUS MATERIAL

FINAL REFLECTION

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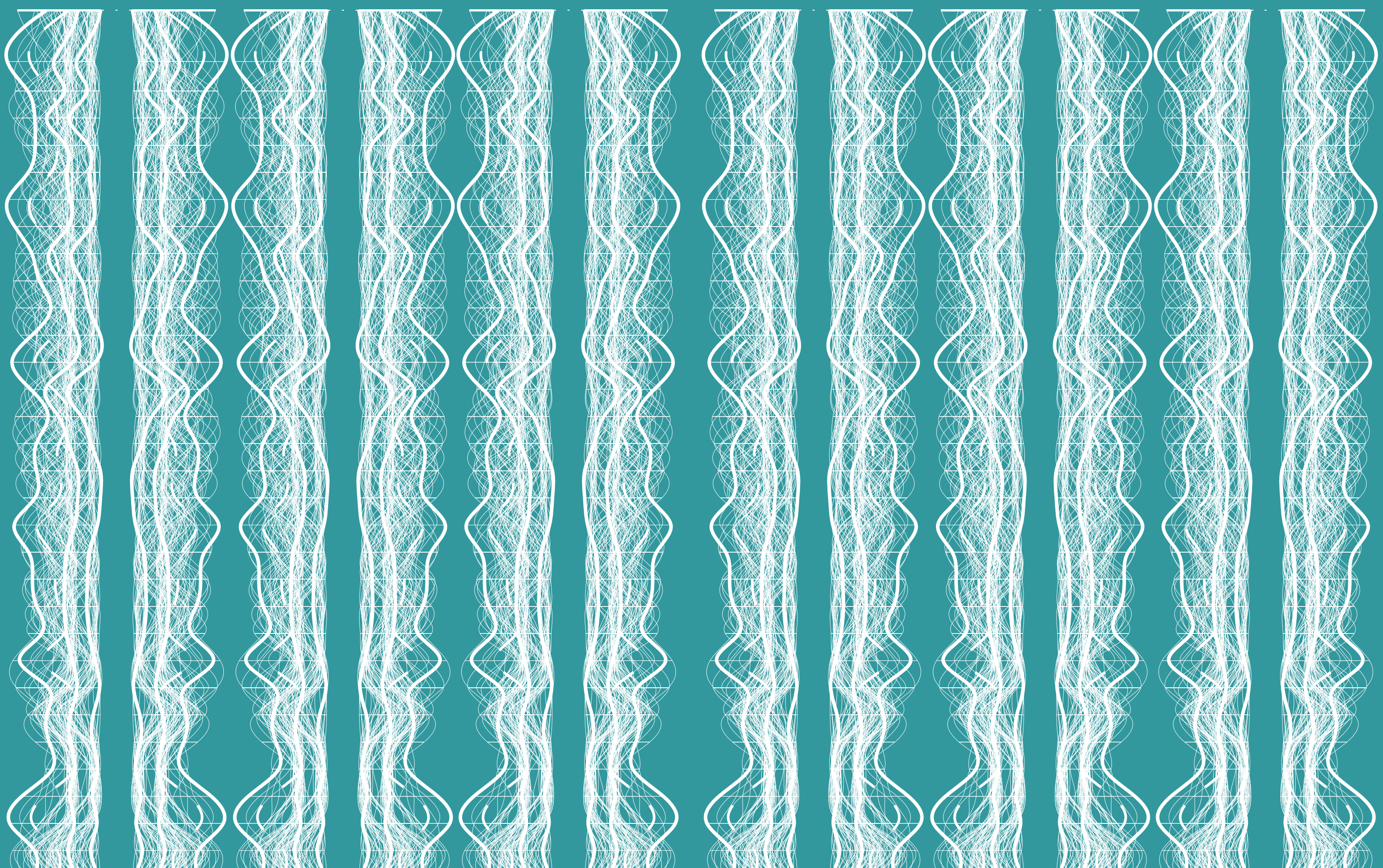

Aspect 1: The relationship between research & design

This graduation thesis focuses on designing a complex microstructure for dynamic insulation that can contribute to airflow regulation and eventually provides better performance for the system. Broad research was done through a literature review that covered different aspects involved in the design, such as the conventional ventilation systems, the essential information about dynamic insulation, different materials, additive manufacturing processes and materials, optimization, etc. Despite being introduced in the 1970s, dynamic insulation is still a novel technology and the lack of precedent projects was clear. As a result, the papers and articles were the primary source of information which made it quite challenging in terms of the validity of the results. As an example, a paper with physical experiments had contradictory results compared to other papers, which later was pulled out of the sources as there were no other papers to support the idea.

In the early stages of the literature review, it was noticed that the material's potential can have a significant influence on the design and performance of the system and it could be a driving force in the design process. Therefore, extensive research was done on different materials that could either be used or their concept could be implemented such as traditional thermal insulators, functionally graded materials, latent heat storage materials, and texture-based meta-materials. Texture-based meta-materials created a whole new field to explore which at the end resulted in the main design concept for this thesis.

Considering the very small amount of work that has previously been done on this topic, there is a need for further research and focusing on details of the system and how it would be applied to practice.

Aspect 2: The relationship between your graduation (project) topic, the studio topic (if applicable), your master track (A,U, BT, LA, MBE), and your master program (MSc AUBS)

Sustainable Design Graduation Studio is the Building Technology studio that focuses on designing for sustainability. Concerning this, the chosen graduation topic aims to increase the efficiency of dynamic insulation. To do so, the optimal goal is to design a fluid microstructure inside the dynamic insulation that adapts itself according to the velocity of the airflow; thus, making the airflow rate independent of pressure difference. This approach ensures that dynamic insulation performs efficiently regardless of the environmental conditions. Improving the performance of dynamic insulation makes it a practical design option that could be implemented in the design of the building envelope; thus, resulting in having a natural ventilation supply/exhaust for the building. Thus, it can reduce the energy use of the building significantly. Although the constructability aspect of the microstructure is not fully explored in this thesis due to lack of time, it is expected that this system would be 4D printed.

Aspect 3: Elaboration on research method and approach chosen by the student in relation to the graduation studio methodical line of inquiry, reflecting thereby upon the scientific relevance of the work.

This graduation thesis followed the methodical approach of the graduation studio. Previous related thesis projects were also considered as references. The research methodology of this thesis has been structured into the following phases: Literature review, establishing design requirements, design through research, evaluation and conclusion.

Phases of research methodology. Source: Author.

To establish the design requirements, different parameters were defined as the preliminary design requirements based on the results of the literature study. These parameters were later adjusted and refined in the design-through-research phase. During design through research, the design process started by experimenting with the approaches that textures could be translated to create geometries. This part was quite time-consuming to figure out how to set the workflow, as related reference papers had done their work using processing platforms.

Design through research and evaluation are in an iterative loop. Therefore it was necessary to start the CFD simulations to understand how to take the design further. After P2, to decide which CFD software to use for validating the results, there were several discussions and meetings with the mentors and experts of CFD simulations from other departments of the faculty. During all the meetings, it was mentioned that the type of geometries in this thesis is rather complex and doing a CFD simulation would be very challenging. Also, due to the existing excessive complexity of the geometries and design, it was decided that the optimal goal, achieving a fluid-structure interaction, should be simplified and static geometries should be used for the CFD simulations.

At first, it was intended to use a general CFD software for an initial screening and then using detailed analysis. However, the general software that was available such as Phoenics did not provide proper results which could be due to the complexity of the geometry or the micro-scale of the geometry. Other tools such as Butterfly plugin in Grasshopper were also tested. However, during the simulation, it was observed that this tool was more aimed for outdoor/indoor airflow simulations and using it to simulate airflow inside a cavity would not produce accurate results.

After testing several CFD software, it was decided to use Ansys Fluent, which was earlier chosen as the final software for detailed analysis. Fluent is a solver in Ansys workbench and it's a powerful and accurate tool. However, it's a very complicated software and just learning the basics and how to work with it would take roughly two-three months. Since this amount of time was not available due to the limited timeline, Ansys Fluent had to be explored while working on the geometries to validate them. Moreover, earlier plans were made to get guidance on Fluent from specialized mentors at the Aerospace faculty. However, due to the spread of Covid-19 and the shutdown of the university, this was not possible anymore. This quite affected the process of using the software.

Aspect 4: Elaboration on the relationship between the graduation project and the wider social, professional and scientific framework, touching upon the transferability of the project results.

Scientific relevance:

The current lack of information and resources about dynamic insulation in the built environment is quite evident. While many papers and articles can be found about this subject, only two built projects exist that could be taken as precedents (although very little information about these projects was available). In this thesis, the aim has been to combine different topics including dynamic insulation, complex geometries, material design and constructability. Although the constructability aspect was not fully explored due to the selected approach in the methodology, it has the potential to be further investigated in terms of the construction process and material selection. While the microstructure of the material can have a rather high impact on its function and performance, the influence of air channels with complex geometries on the airflow rate and pattern is not yet investigated in the design of dynamic insulation. Implementing complex microstructures introduces various aspects to the design of the system and allows for optimization and improving the performance of the system by changing the geometry of the microstructure, the selection of materials, etc. The optimal goal of this thesis (fluid-structure interaction) was beyond the scope of the master studies and therefore, the target had to be adjusted. Plans are made regarding continuing the research after graduation. Still, the link between the dynamic insulation, the mechanical ventilation system and user comfort has to be addressed. Initial calculations suggested good thermal comforts for the user; however, further analysis is needed. In further developments of the research, it is expected that a design toolkit could be created which is based on specific established guidelines.

Societal relevance:

Despite being introduced in the 1970s, the topic of dynamic insulation is still relatively new and there are vague aspects that need to be explored and investigated. As a result, this system is not commonly known in the building industry and the traditional insulation systems are still used in the design and construction process.

Due to the variable U value, dynamic insulation allows for thinner insulation layers, resulting in more lightweight construction. However, this benefit is not explored in the current constructions.

As 3D printing allows for combining multiple design variables, optimum complex geometry can be designed and manufactured according to the climate and context. However, there is a trade-off between the more lightweight, efficient construction and the production cost, which I think would be less problematic in the future once this system is more recognized in the building industry.