Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

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heat transfer. Therefore, it is possible to expect the geometry of the insulation’s channels (pores) affects the velocity of the incoming outside air (different geometries having different effects on airflow and heat transfer). Yet in current literature, the geometry of the air channels inside the porous material is mostly limited to simple geometries. Studies on complex geometric configurations are needed. Finally, it is worth noting that also studies on different materials are lacking so far. While possibly different materials could eventually lead to a better/worse performance of the dynamic insulation.

While additive manufacturing offers the production of complex geometries and the use of various materials, the potential of this technology is not investigated in the design of dynamic insulation components at the micro-scale. Using 3D printing, complex microstructure geometries can be generated.

According to the aforementioned problems, the main objective of this thesis is to explore different geometries using additive manufacturing potentials and investigate their effect on the airflow rate and behavior in the pores and the performance of the dynamic insulation component. Therefore, the following main research question is formulated:

*How can complex microscale geometries contribute to regulating the airflow rate and pattern inside dynamic insulation, using the potentials of additive manufacturing?*

The sub research questions are defined as the following:

1. What are the complex geometries? How can they be generated and how can their properties be evaluated?
2. Why implementing complex geometries in the design of dynamic insulation could offer a potential contribution to the performance of the system?
3. What is the effect of texture on the airflow rate and pattern?
4. What is the effect of surface roughness on the airflow rate and pattern?
5. What are the effects of the geometry’s changing cavity volume
and morphology of the air channels on the airflow rate and pattern?

6. What is the potential contribution of additive manufacturing to this process and research?

**design assignment in which these result.**

The main problem tackled in this thesis regards the current lack of knowledge on the effect of complex geometries in the dynamic insulation channels, as part of the overall building wall. To approach this problem, the thesis focuses on discovering whether and how a designed microstructure (now possible by Additive Manufacturing) in dynamic insulation can offer a solution for controlling the airflow passing through the wall and therefore, improving the performance of the dynamic insulation.

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**Process**

**Method description**

This research has been structured into the following phases:

**Literature study**

To obtain a better understanding of the topic and gather the necessary background information, the literature research has been done by studying various research papers, books, journals, conference papers and presentations, and websites – on the following subjects:

Net-zero energy buildings, fully-airtight buildings, and their problems

Responsive building concepts and elements

Dynamic insulation

Material exploration (functionally graded materials, metamaterials, latent heat storage materials, thermal insulators, texture-based metamaterials)

Additive manufacturing (processes, materials, performance-based design)
Airflow behavior and the possible parameters affecting it

Fluid-structure interaction (principles, mechanisms, manufacturing techniques)

Computational Fluid Dynamics analysis (CFD)

**Establishing design requirements**

Based on the results of the literature study, different variables are defined as the preliminary design requirements including the initial texture as the input for 3D sampling, volume of the cavities, air channel geometry, level of surface roughness, different permeability levels and thermal insulation.

**Design through research**

To achieve the research objectives, various determinants and aspects must be investigated in a design-through-research process including:

- Research on different textures and the 3D sampling method
- Geometry-related factors affecting airflow rate and pattern
- Environmental factors affecting airflow rate and pattern
- Texture-related factors affecting airflow rate and pattern
- Geometry generation

The dominant features of different textures are identified and established as categorizing parameters for textures. Then using the “3D sampling” process, different geometries are generated based on textures with different properties, with the expectation that they would result in different airflow behavior inside the geometries.

The obtained geometries are validated in the evaluation step. Thus, some designs might not be suitable based on the evaluation criteria.

**Evaluation**

To assess the airflow properties in the created geometries, CFD simulations are used
as the analysis tool. Geometries are evaluated using computational fluid dynamics analysis in Ansys Fluent to investigate the effect of different factors on airflow rate and pattern. Fluent is a CFD solver that is part of the Ansys Workbench platform. During the evaluation process, various parameters such as pressure drop, outlet velocity, streamlines' distribution, etc. are monitored and the results are evaluated according to their correspondence to the research objective.

**Conclusion**

Based on the obtained outcome from the CFD simulations, relevant comparisons are made and conclusions are drawn and categorized to answer the main research question and sub-questions. Yet, because the results are derived from a limited number of geometries, it might not be possible to draw definite conclusions with regards to specific aspects of the research.

**Literature and general practical preference**


Mathematically defined tissue engineering scaffold architectures prepared by stereolithography. *Biomaterials, 31*(27), 6909-6916.


Toledo, L., Cropper, P. C., & Wright, A. J. (2016). Unintended consequences of sustainable architecture:


**Websites**


COMSOL. (n.d.). *COMSOL Multiphysics.* Retrieved from https://www.comsol.nl/comsol-
**Reflection**

**Relevance**

**Scientific relevance**

The current lack of information and resources about dynamic insulation in the built environment is quite evident. 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. During the fabrication process of dynamic insulation (using additive manufacturing), the geometry can be locally fine-tuned by using different materials based on the design requirements. 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. As 3D printing allows for combining multiple design variables, an 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.