TEM HEAT DISSIPATION SYSTEM

Increasing performance of a thermoelectrical integrated facade through the heat dissipation system

GRADUATION REFLECTION

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1. GRADUATION THEME

Recent studies show an increase in energy use on buildings due to higher cooling demands, constituting an increase of 17% of the global energy consumption by 2050. Tendencies also show that cooling degree days around the globe will also increase and this will display a greater impact on developing countries with warm climates. Subsequently, this gives interest in reducing energy demands on buildings through both innovative passive and active design strategies that can convert these buildings into energy efficient buildings whilst reaching their desired comfort values. The potential to integrate these strategies for cooling system into a building façade has been looked into by recent research. As is the case of the thermoelectric technology, which is a promising cooling technology that has gained interest from architects in the past few years, and it has a great potential for integration. This device has the advantage of generating a temperature difference between the device's two sides when direct current is applied it and so it has been widely studied and used as coolers at small scale. There are not enough studies and experimentation of integration at façade level has been conducted with this technology, and those that exists show that the system's performance is still much lower than traditional air-conditioning systems.

Thus, this graduation project focuses on a performance-based design, where the heat dissipation system's design and its integration with the TE is explored and investigated, what parameters affects its performance, and, subsequently, their effect on the façade and the architecture of the building within a hot-arid climate in Mexico.

This graduation project combines two fields of the Building Technology track (Façade Design and Climate Design). Within the Sustainable Design Graduation Studio, the topic of sustainability is throughout the whole research project. The thesis project looks into the tree main goals of sustainability: people, planet, and profit. Since the research presents a performance-based design to lower the energy consumptions of an office building, by reducing its cooling loads, so the connection to the planet goal is more evident. In addition to this, the alternative to an air-conditioning system that does not require refrigerants is also highly beneficial for the planet.

The goal of people was also present in the development of this project. They are the main drivers for the objectives and thermal conditions of comfort that the optimised office design building had to achieve. Moreover, when designing the façade, this comfort parameters were always taken into consideration, with the added advantage of having an active façade panel, whose exterior cladding can be customised if desired. The research was divided into 3 main phases: knowledge phase, exploration and design phase and evaluation phase. Within itself it is further divided into component level (heat dissipation system design), façade level and building level.

2. GRADUATION PROCESS

The first part of the project was dedicated to understanding the thermoelectric technology and its main design gaps to be applied at façade level. This research topic was new for me, so the initial months were overall spent understanding the system and how it works through an extensive literature research. Although research was found to be scarce (only in applied systems), since not much research on its application in the façade has been conducted, and some are only conceptual. In this initial phase, research into heat dissipation system to boost the performance of electronic devices was also investigated. Insights into which parameters affect more and could be integrated at façade level were obtained. In addition to this, the context, case-study, and comfort were analyzed so that certain design objectives could be frozen and facilitate the conceptual design process. Thus, the second phase consisted of summarizing all this information into design parameters and strategies for the evaluation phase. Due to the lack of information on this specific topic, information had to be taken for similar systems, such as cooling down of electronic elements. On the other hand, studies on heat transfer for Peltier modules that were working at small scales were reviewed and speculations on which strategies would make sense to apply at façade level had to be taken. Next, conducting some small experiments was helpful in providing empirical information on how things should work, and which elements affected more the design of the heat dissipation system. With my architectural background, this was my first time working on experiments like this, so a lot of trial and error was needed for the results to be useful.

In the third phase, a combination of experiments and simulations were used to determine the effect certain design parameters have on the thermal performance of the heat dissipation system. Parallel to this, an office case study was selected, and simulations performed to determine the ideal passive strategies for reduction cooling load in a hot-arid climate. A stepped methodology was used for the experiments and simulations for the heat dissipation system and a comparative evaluation on different passive design strategies for the office design was applied. A simplified heat transfer model for the heat dissipation of the thermoelectrical technology was developed, where a series of design strategies were possible to be tested. Analysing the results determined which parameters had a greater impact on the design, for the heat dissipation system its performance was evaluated through its COP, and for the office design lower cooling loads were the defining parameter.

In the experiments done at the beginning of the project, they required more time that I expected and since to familiarise with the tools was necessary. The data of most of the initial experiments had to be discarded because of this back and forth of understanding the technology at hand and the tools to test the system. For the simulations at component level, many iterations to the methodology had to be applied, specially once the proper software was chosen and, again, proper familiarization with its use was possible. In this point of the process, a lot of uncertainty was present since only one computer in the Faculty was available to use the software on, and with the closing of the university due to the pandemic, the methodology changed various times until a licence of the software was obtained. This also contributed to some delays in the graduation plan. The understanding of the software and how to simplify the TE technology in a model was the greatest challenge. First, learning how to use the software, secondly establishing a virtual model, and thirdly setting up the required boundaries that the technology needs so that results are in accordance with the those obtained by the experiments (for model validation).The software used had many advantages and accurate results were obtained, nonetheless, the TE technology had to be simplified, so for this the module was modelled as two heat sources rather than a complete thermoelectrical model. This was done since the addition of the element made the simulation model very heavy and the simulation time was too extensive. On the other hand, this project's main objective was focused on the heat dissipation system rather than explorations with the TE module, thus, this simulation model was still useful.

On the other hand, parallel to the component level design, the base case for the office building where the system will be applied was modelled for Design Builder, since it is necessary that the base case can reduce its cooling loads before any active system is applied. After the simulation results for both level A and C are analyzed and the main design strategies followed and chosen, a design was proposed, and a final evaluation conducted at façade level.

3. DESIGN AND RESEARCH

To fully answer this graduation project a loop in between research and design was set-up. The design strategies were based on research and hypothesis developed; these strategies were then evaluated. General trends were identified on both evaluated levels and each show their potential. These were then translated into design guidelines for the heat dissipation system and office building design and then visualized as a final thermoelectrical facade design. An evaluation on the designed TE façade was done, its limitations and potentials stated, as well as future possibilities that be further developed with this technology.

4. SOCIETAL IMPACT

The aim of this project is to substitute the use of air-conditioning systems with Thermoelectric technology, which could consequently lower the cooling loads needed in in an office building. Even though an office building is being used as reference, this could also be applied for other commercial or residential buildings, with similar climatic conditions. The same happens with the case of cities which have a similar climate condition as that of Monterrey, or even goinf farther away into other possible climates is an option. The idea is that this research explores the potential of the system so that it can get closer to becoming commercially available for the built environment, and thus, aiding in the ultimate goal of lowering the energy consumption in the built environment. Even becoming a starting point for further research were this could also be applied at smaller building that require a cheaper air-conditioning system, the possibilities are endless. In this sense, searching for different alternatives in existing technologies and how energy efficient buildings are envisioned could be the next step into reaching zero energy usage buildings.

4. CONCLUSION

The application of TEM in the building industry still requires more research and development before it can become an actual product. Nonetheless, the results enforced that the system has potential to be further developed. It is still in early staged of research and development, but the different analysis and evaluation process done during the research project showed that proper manipulation at the different scales explored does improve the performance of the system and could be adapted to different contextual conditions. As an extra note, I find that I have learned enormous amount of information on the various topics that compromise my research.