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Theoretical Design of an Active Façade System with Peltier Cells

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Abstract

The research is looking for an innovative self-sufficient, industrialized and lightweight façade module that integrates a thermoelectric HVAC system. The principal aim of the research was to try providing a built answer to the current efficiency objectives (Directive 2010/31/CE), creating a façade solution that can be installed in new buildings or in already existing ones. This report tries to explain the theoretical design of this new façade system with Peltier cells.

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Architecture, Thermal Envelope, HVAC, Thermoelectric, Efficiency, Peltier Façade Construction

1. Introduction

The current challenge for the European building sector is providing solutions to meet the goals 20/20/20 and the construction of NZEB [1]. In order to fulfill these objectives, it is necessary to have a very high performance building envelope which allows minimizing the energy demand and incorporate renewable energy sources in buildings.

This research aims to design an opaque module for an active high-performance industrialized façade which meets the Spanish Technical Building Code that also includes a self-sufficient (PV panels) HVAC system providing an answer to the current efficiency objectives.

1.1. State of the art

On the one hand, the design will be based on previous works developed by the University in the field of building envelope [2]. On the other hand, the design incorporates the Universidad de Navarra's Patent [3] of a new thermoelectric (TE) HVAC heat pump [4]. The table 1 shows some results of this research.

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Table 1: Thermal behavior of the system on different situations.

	Set Point	Control	Mode	ΔT Int-Ext (˚C)	Electrical Consumption (kWh)
Behavior on a hot day	19	PID*	COLD	5	2.5
Behavior on a cold day	22	PID	AUTO	15.73	2.75

**PID: The prototype works with the power needed by programming to reach the set point.*

Last researches in the façades field have been oriented towards dynamic solutions [5], façades that incorporate renewable energy [6] or strategies to reduce the building energy demand [7]. TE technology use has been limited to fields where high-tech technology is needed. The aim of this research is not to evaluate the TE performace itself [8], it is to evaluate an application of the technology. In the last few years, some TE application has been appeared in buildings used them as a controlling system of losses and gains through the envelope [9]. Most of these new applications are for transparent façades [10] and use the TE combined with PV panels [11],

2. New façade system design

2.1. Initial requirements

- Design an **active**, **industrialized and lightweight** façade system that can adapt its behavior to different conditions.
- Integrate the TE **HVAC system** into the façade. It is about an air-air HVAC system therefore, the façade composition has three layers and two air cavities
- Drive the TE HVAC system by photovoltaic **solar panels**.

2.2. Adaptable façade system.

The new system will be designed to be capable of adapt its behavior. Fig.1 shows the different behavior of the façade for winter (day and night) and summer (day and night).

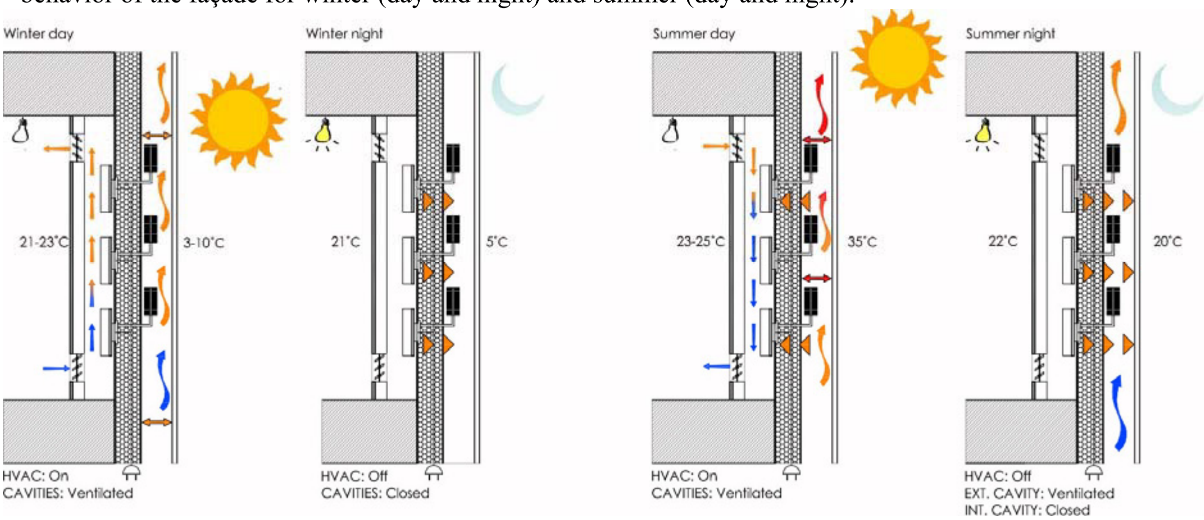

Fig. 1. Winter and summer façade behavior (day and night). It is shown he behavior when the HVAC system is on or off.

2.3. Conditions studied

Firstly, **outer conditions** have to be studied in order to know what has to be face up. The system has been designed for a South orientation in a building located in the Universidad de Navarra in Pamplona (Spain) a city with a climate between those of the Mediterranean and the Atlantic. No buildings around.

Then, **inner conditions** have to be taken on board in order to know which are the inside comfort conditions that have to be reached (temperature and humidity). The Spanish standards are: between 23 ˚C -25 ˚C for temperature and 45% -60 % for humidity during the summer; for winter, temperature has to be between 21 ˚C -23˚C and humidity between 40% -50% [12].

Finally, the **specific determinant requirements** of the new façade have to be deeply studied to meet or even improve the Spanish legal standards (table 2)

Table 2. Requirements for the façade system with preliminary data

Requirement	Base requirement	Performance characteristic (data according with Spanish Standards)
Acoustic protection	Acoustic protection	Insulation against airborne noise from the outside (from 30 to 47 dBA.)
Energy saving and thermal insulation	Restriction of energy demand	Thermal insulation: limit the value of façade U ($U_{máx}$= 60 W/m^{2}K)
		Permeability to air
Fire Safety	Internal propagation	Interior layer's reaction to fire (B- s3, d0)
		Intermediate layer's reaction to fire (B- s3, d0)
	External propagation	Exterior layer's reaction to fire (B- s3, d0)
		Reaching a fire resistance in some areas (>EI 60)
		(Compartmentalize the ext. air cavity to avoid the fire propagation)
Health, safety and environment protection	Protection against humidity	Degree of impermeability to rainwater (intermediate layer)
		Drainage capacity of the air chamber (must be design. Ext. air cavity)
		Condensation limitation (not allowed)
	Hazardous substances	Content or emission of hazardous substances
Safety of use and accessibility	Risk of impact	Impact resistance
	Maintenance	Secure maintenance (design everything in order to maintenance easily)
Structural security	Resistance and stability	Mechanical resistance and stability
	Fitness for service	Deformation (deflection and collapse)
		(Due to: wind, own weight, seismic, change in temperature/ humidity)

2.4. Façade elements

The different elements that make up the façade composition are as is shown in the table 3.

Table 3. Composition of the façade

Layer	Thickness (cm)	Description
Outer Layer	0,6	Aluminum sheet or Photovoltaic layer
Outer air cavity	10	Natural or mechanical ventilation and possibility of sealing. (no- ventilated)
Intermediate layer	6	Thick aluminum sandwich panels with PUR rigid foam core
Inner air cavity	5	Natural or mechanical ventilation and possibility of closing. (no- ventilated)
Inner layer	8,5	Laminate gypsum boards [metal structure and acoustic insulation] (13/46/13+13)

3. Conclusion and discussion

The theoretical composition of the façade module has been obtained; the next step will be building and monitoring it in order to evaluate its behavior. It tries to improve the TE HVAC system already developed as a façade system. It is necessary to be conscious that the more demands are required to building skin, the facilities required will be less and therefore lower energy consumption

The thickness and the way of ventilation (natural or forced) of the airs cavities has to be deeply studied in order to obtain the ideal configuration for the TE HVAC system to work as best as possible.

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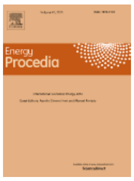

Biography

Maria Ibañez-Puy is a Building Engineer by the School of Architecture of the Universidad de Navarra (2011). She obtained the Outstanding graduate in Technical Architecture Award. Nowadays, she combines teaching in the Construction Science Department at the Universidad de Navarra with a research in advanced active façades