HI-FLEX: MODULARIZED AND AUTONOMOUS BUILDING SKIN SYSTEM FOR MAXIMIZED ENERGY EFFICIENCY

Seongju Chang[1]*, Jeongbae Lee[1], and Minyou Kim[2]

[1] *Department of Civil Engineering, KAIST, Daejeon, Korea*
[2] *Department of Mechanical Engineering, KAIST, Daejeon, Korea*
** Corresponding author (schang@kaist.ac.kr)*

ABSTRACT: HIFLEX is an innovative context-aware modular building skin system capable of operation-time energy and human comfort optimization by being equipped with various sensors, actuators and delicate components for thermal control, solar irradiance regulation and enclosure-based ventilation combined with heat recovery mechanism. Its Low-E coated high performance dual glazing with air cavity in between provides optimized thermal insulation and it also includes photovoltaic film attached motorized blind for solar control while producing electricity to sustain the entire system. The ventilation unit that has a rotating cylindrical fan combined with perimeter heating coil and dampers constitute an omni-directional flexible-air-speed ventilator enabling an autonomously breathing building skin operable with embedded sensing and intelligence.

***Keywords**: High Performance Building Skin, Operation Time Design, Enclosure Based Ventilator, Dynamic Adaptation*

1. INTRODUCTION

HI-FLEX (Highly Integrated Façade with Least Energy Exposure) is a high-tech building envelope system that has a single cavity chamber with a motorized photovoltaic blind. The system is composed of Low-E coated 24mm dual glass, air gap and another set of 18 mm dual glass optimized to reduce heating and cooling energy load by 40% compared to the existing glazing systems. HI-Flex's air ventilation system is capable of omni-directional air flow control as well as air volume and speed controls. Solar control is performed by the motorized photovoltaic blinds for additional power generation required to operate HI-FLEX that has integrated sensor monitoring capability and is equipped with various IT devices to operate.

2. Related Works

Windows of a building represents aesthetic quality, invites natural light and provides external views. However, thermal discomfort due to excessive solar radiation and increased heating and cooling loads triggered the development of double envelopes [1]. A typical wall construction has far less U-value (0.47W/m2K) compared to that of windows (3.84W/m2K) which is much higher. As for the current issue of building skin control, the decisions of the values for control variables are not based on dynamic optimal control theory but mostly rely on rule-based approaches[2]. HI-FLEX system, on the other hand, is based on its predecessor, BBS (Biomimetic Building Skin) which allows real-time solar irradiation and ventilation control directly through the glazing [3].

3. HI-FLEX System Features

(1) Thermal Insulation

To secure super-insulation, physical components of HI-FLEX such as glass type/color/thickness, frame, spacers, low-e coating, reflective coating, air gap and filters are evaluated through 'Window6' and 'Therm6' to extract insulation performance indicators. Comparative energy load analysis is done with Comfen3 to identify energy profiles of HI-FLEX design alternatives.

(2) Natural Ventilation / Heat Exchange

HIFLEX ventilation subsystem uses metal grills and blower fans, as the actuators being operated with motors, to freely control air direction, speed and volume the process of which can be adjusted based on the sensor data(Fig 1). Fig 2 presents 10 different ventilation modes. In heating

season, (mode1~3) the outside air is preheated through heating coil to apply the principle of perimeter heating for maximal thermal comfort.

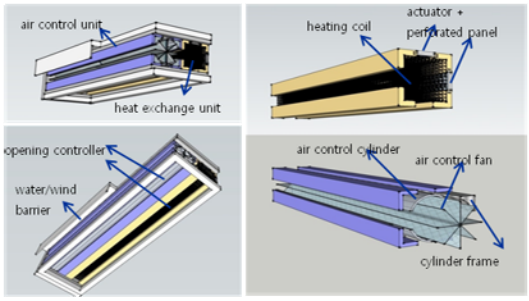

Fig. 1 Anatomy of HI-FLEX ventilation sub-system

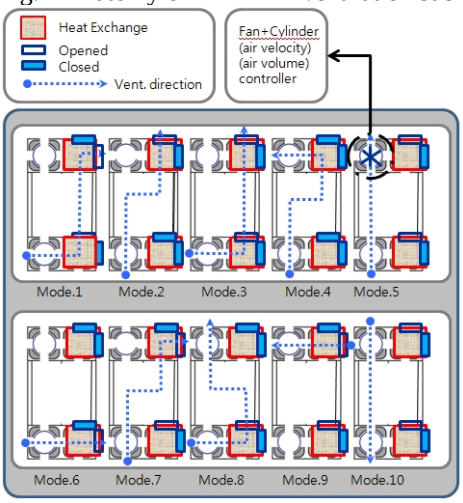

Fig. 2 Omni-directional ventilation operational modes

(3) Energy Harvest & Solar Control

Experiments are done to test energy harvest performance of the solar film attached blind of HI-FLEX (Fig 3). The experiment set is installed on the rooftop of the W16 building at KAIST, Daejeon, Korea and operated 9:00AM to 16:00PM facing the direction of azimuth of 193 ° and solar altitude between 20 ° ~ 80 ° ranges [4]. The blind angle is controlled constantly to be perpendicular to the sunlight. The resulting energy is in the range of 0.01 ~ 0.51 kWh. Its amount is largely depends on the insolation.

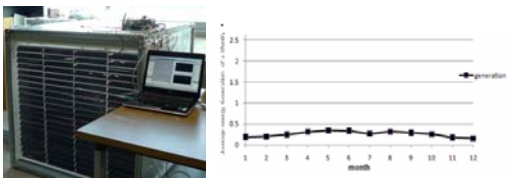

Fig. 3 Photovoltaic blind & power generation profile

(4) Sensing & Embedded Intelligence

As an inheritance from the former BBS system, HI-FlEX is equipped with indoor, cavity embedded and outside sensors to dynamically measure the ambient environmental conditions to actively respond to them. The sensors detect temperature, humidity, air pressure, air speed, dust, wind pressure, airborne pollutants, illumination level, O2, CO2 and even human activities inside.

4. Conclusion and Future Work

HI-FLEX, unlike the conventional window systems, is a cutting-edge hybrid window system allowing smart and dynamic thermal control, solar irradiance control, flexible and context aware natural ventilation, energy production through highly optimized components combined with advanced sensors IT devices. As a new building skin prototype, more analysis is necessary in potential life cycle cost analysis to justify its initial investment. Improvement of its photovoltaic energy output also needs to be explored.

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(EEWS:Energy, Envrionemtn, Water, and Sustainability)

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