Development and Operation of Decentralized Ventilation for Indoor Climate and Energy Performance

The Danish government has targeted full reliance on renewable sources of energy for heating and electricity by 2035. Building renovations save energy and offset requirements for renewable supply. A Danish national action plan therefore expects to reduce heating consumption in existing buildings by at least 35% before 2050. Renovations improve airtightness and often require mechanical ventilation with heat recovery. The market will demand flexible costeffective ventilation solutions and the knowledge and competence for proper implementation. Single-room ventilation provides simple installation, low fan power, and the potential for local heat recovery. This research developed, assessed, and investigated two single-room ventilation units. One development yielded a novel short plastic rotary heat exchanger and another yielded a novel spiral plastic recuperative heat exchanger. Thermal theory guided the selection of a polycarbonate honeycomb rotor with small circular channels for the former and the selection of rolled plastic sheets with planar channels for the latter. Equations predicted their performance with dimensionless groups. Experiments quantified flows and determined temperature efficiencies at several ventilation rates. The methods accounted for heat gains and air leakages with measurements and balance equations.

The measured and modelled temperature efficiencies showed adequate agreement for the rotary unit and exceeded 83% at 7.8 L/s. This result could not directly validate the model due to bypass leakage. All leakages were excessive and should be reduced with proper sealing. Experimental results demonstrated the option to reduce heat recovery by slowing rotational speed. Overall, the first development met preliminary objectives and provided a novel option for heat recovery. The development of the spiral recuperative heat exchanger provided encouraging first results. The heat exchanger provided a corrected supply temperature efficiency of 82.2% at 13.5 L/s. At this flow rate, the total measured pressure drop across the filter and heat exchanger was 40 Pa. The external and internal leakages were roughly 2.7% and 12.1%, respectively, so future prototypes should reduce internal leakage.

Numerical simulations investigated the impact of moisture transfer in the rotary unit. The investigation simulated moisture balance equations with simplified airflows in Matlab. Based on literature, the study assumed that all condensation in the exhaust evaporated into the supply. The simulations evaluated the risk of moisture issues and compared results to recuperative heat recovery and whole-dwelling ventilation. The simulations analyzed the sensitivity of results to moisture production, infiltration rate, heat recovery, and indoor temperature. With typical moisture production, the rotary heat exchanger recovered excessive moisture from kitchens and bathrooms. The unit was only suitable for single-room ventilation of living rooms and bedrooms. The sensitivity analysis concluded that varying heat recovery or indoor temperature could limit indoor relative humidity in bedrooms and living rooms. The rotary heat exchanger also elevated the minimum relative humidity in each room, which could help to avoid negative health impacts from dryness. A discussion emphasized the potential benefits of selecting heat recovery to match the individual needs of each room.

Numerical simulations also investigated the annual impact of demand-controlled single-room ventilation with heat recovery on indoor climate and energy-use. The simulations used the expected efficiencies for the spiral recuperative unit based on anticipated improvements. Simulations of a renovated apartment in Denmark compared the demand-controlled single-room unit to a whole-dwelling unit. Convention and regulations determined the constant flow rates for the whole-dwelling system, whereas a controller determined flow rates in the single-room units based on sensed values of CO2, relative humidity, and temperature. Both types of ventilation provided suitable indoor climate. In a comparison, the single-room unit improved or maintained air quality and thermal comfort while consuming less annual energy for fans and space heating. This provided relative savings of 74% and 4-6%, respectively. The results indicated that single-room ventilation with demand-control could provide a viable alternative for renovated apartments in Denmark.

In summation, the research used theory, literature, design criteria, rapid prototyping, and simulations to successfully develop and investigate single-room ventilation with heat recovery and demand control.