Streszczenie rozprawy doktorskiej w języku angielskim

Abstract of doctoral dissertation

„Energy and environmental efficiency of heating, cooling and ventilation of residential buildings”

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Modern residential construction encounters the challenge of reconciling the comfort of use with minimizing the negative impact on the natural environment. The energy efficiency of heating, cooling, and ventilation (HVAC) systems plays a critical role in reducing energy consumption and greenhouse gas emissions. The main objective of the dissertation was to assess the effectiveness of conventional and alternative methods of cooling rooms in a single-family house with natural ventilation focusing on thermal comfort for occupants, energy consumption for heating, cooling, and ventilation, and greenhouse gas emissions under current and future climate conditions.

In the first step, a review of the literature on the subject of the dissertation was conducted, along with the indication of the research gap. Then, measurement identification of the indoor environment in the selected single-family house was carried out. In the third step, numerical models of this building were prepared: (1) in the EnergyPlus program combined with the CONTAM program, which enabled the co-simulation of the building performance BPS (Building Performance Simulation) taking into account the inter-zone airflow and (2) in the ANSYS Fluent program, to perform CFD numerical prediction to assess the distribution of air parameters in the selected room. Experimental validation and calibration of the numerical models were carried out to ensure the reliability of the simulation results.

The prepared models enabled the case study to be conducted, divided into two parts. The first part investigated conventional and passive methods of cooling the building using the natural cooling potential of outdoor air under current and forecasted future climatic conditions in Poland. Passive techniques analysed included scenarios with manual window operation by residents and the use of automatic actuators. The impact of opening or closing internal doors, the use of internal blinds, and the behaviour of residents in terms

of opening and closing windows on the efficiency of passive cooling was assessed, taking into account the number of hours of thermal discomfort of people and air exchange. Furthermore, energy consumption for heating, cooling, and ventilation in passively cooled versus mechanically cooled buildings was compared. The second part of the case study focused on the impact of passive cooling with outdoor air on the air parameter distribution in a single room. The analysis considered variations in internal door positioning (open or closed), wind speed, and night-time cooling periods. The risk of draughts was also evaluated. Additionally, an environmental cost analysis was conducted, including calculations of carbon dioxide emissions associated with HVAC systems, accounting for different heat sources.

The analysis of the results allowed determining the quantitative and qualitative effectiveness of the proposed passive cooling techniques for residential buildings. The most efficient strategy involved outdoor air cooling combined with automatic window operation, which ensured thermal comfort for at least 94% of the time under current climatic conditions and 87% under the forecasted 2050 climate. Compared to mechanical cooling, this method reduced energy consumption for heating and cooling by 9% under present climate conditions and by 14% under future scenarios, while also decreasing carbon dioxide emissions by an average of 11%. Manual window operation demonstrated lower efficiency, particularly in scenarios in which occupant behaviour deviated from the predefined criteria. A significant limitation of passive cooling via window operation was a difficulty in maintaining acceptable air exchange. During periods of high wind speed, excessive air exchange increased the risk of draught formation, whereas in calm conditions with closed windows, air exchange was insufficient. The CFD simulation results revealed a phenomenon of the formation of “dead air zones" regardless of the wind speed. The airflow with too low speed occurred in a significant part of the room, which was not affected by the air stream blown through the window even with the internal doors open.

The environmental costs analysis of maintaining HVAC systems showed that the use of a gas boiler as a heat source resulted in the lowest emission, while an electric boiler produced the highest one. To further mitigate carbon dioxide emissions, the implementation of photovoltaic panels was proposed, achieving reductions in emissions by up to 60%.

Key words: building performance simulation, CFD, passive cooling, energy consumption, thermal comfort, CO_2 emission