Personalized environmental control systems (PECS): Overview of evaluation methods

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SUMMARY

Nowadays, the building sector faces many challenges on occupant and resource levels. Given many indoor environmental quality (IEQ) complaints collected by field surveys, the first challenge is to provide comfort improvements. The second challenge is to be able to do so without unjustifiably increasing energy costs. The main reason why buildings face such issues is the implementation of IEQ management systems that target the entire space – even unoccupied zones. This doesn't guarantee comfort and wastes building resources. This led to the development of personalized environmental control systems (PECS) that aim to improve IEQ where it is needed – in the vicinity of occupants responding to individual needs while giving them the possibility of control. This not only improves comfort but can lead to energy savings with proper system design and operation. PECS have been extensively studied in the literature via diverse simulation or experimental methods with researchers reporting the performance using different indices and metrics. However, currently; there exists no standardized or universal ways of studying and reporting the performance of PECS. Thus, the aim of Subtask D of IEA EBC's Annex 87 on PECS is to develop such guidelines by first giving an overview of the existing methodological trends on PECS performance assessment. This summary gives an overview of the ongoing literature review with focus on thermal & IAQ PECS and presents some preliminary results.

KEYWORDS

Personalized environmental control systems (PECS), performance assessment, simulations, chamber & field experiments

1 REVIEW METHODOLOGY

The scientific databases of Science Direct, Web of Science, Taylor & Francis, Wiley Online library were searched for terms related to PECS and their impact on thermal comfort, indoor air quality, energy. The search yielded 589 papers eligible for review that included PECS. From the 589 papers, and in line with the review objectives, reports pertaining to personal protective equipment, hospital environments, textiles with no active heating or cooling function were excluded yielding 530 papers. From these papers, 11.3% studied PECS using building simulation tools, 23.7% using computational fluid dynamics (CFD) simulations, 55.5% used chamber studies and 9.4% used field studies.

1.1 Simulation methods

With careful modelling and calibration, simulations allow testing a wide range of conditions at lower cost and complexity than experiments. Building simulations offer a better understanding on the balance between PECS performance and long-term power use under different typologies and climates. CFD offers a comprehensive visualization of the impact of PECS on the airflow field which helps to gain a deeper understanding into its performance and guiding its design. Out of 11.3% studies using building simulation methods, some integrate PECS directly into building simulation tools (EnergyPlus 20.6%, IES virtual environment 13.2%, Modelica 5.6%, ESP-r 5.6%, IDA-ICE 3.7%, TRNSYS 2%, other locally developed software 9.4%) (Shahzad,

2020) or develop their own simplified mathematical model of the PECS coupled with state space models or building simulation models of the space (39.6%) (Makhoul, 2013). The most simulated cases were offices (65.5%), residential (7%), educational (5%), commercial (3.5%) and others (19%). 96% of the PECS simulated were mostly heating and cooling personalized systems with no ventilation function (e.g., heated and cooled chairs, radiant panels). 4% had a ventilation function and assessed comfort, IAQ and energy performance or just energy performance. Out of 23.7% studies using CFD, all of them model PECS directly into the domain and use tools such as ANSYS Fluent (40.6%), Airpak (6%), COMSOL (3%), star-CCM+ (3%), own developed CFD code (2%) with most simulated cases being offices, vehicles and aircraft cabins and focused on ventilative PECS. 79.1% of the studies assessed the performance of personalized ventilation systems mounted in desks or chairs (Sekhar, 2018), while 6% studied local radiant panels for heating and cooling, 4% studied heated or cooled furniture (Shahzad, 2018), 4% ventilated clothing, 2% personalized exhaust and 2% thermal wearables (masks, jackets).

1.2 Experimental methods

Laboratory and field studies allow to determine the impact of a specific technology on human responses including physiological, perceptual, cognitive, and behavioural responses. Lab studies guarantee to examine the impact of PECS on occupants' responses under controlled environmental conditions. By varying both background system and PECS settings, most of the lab studies focus on determining physiological and perceptual changes of the average person. The sample size definition is thus of outmost importance to guarantee a great representativeness of the real population (Pasut, 2015). Moreover, it is quite common that lab experiments involve manikins, resembling a standard man and its physiological reactions, as for the 33% of the reviewed articles (Mustakallio, 2016). Field studies are mainly observational, further looking for occupants' acceptance of the proposed PECS that are generally introduced in the case study after an initial period of observation, representing the reference scenario without PECS. Most of the reviewed field studies took place in office spaces (63%) (Kim, 2019) and dealt with PECS not directly connected to the building structure, such as those associated to furniture elements (51%).

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