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Experimental Study for the integration of an Innovative Air Distribution System in Operating Rooms

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Abstract

Hospital buildings in general and especially the operating rooms are a challenge for building services engineers which are struggling to ensure indoor environmental conditions satisfying all the occupants. The requirements imposed by standards often lead to the discomfort: while surgeons require low temperatures for sanitary reasons, anesthesiologists and assistants feel uncomfortable and prefer warmer conditions. In past studies the estimated entrainment in the case of the jets issued from the lobed perforated panel was found to be greater than in the case of the standard circular perforated panel. The lobed flow offers a larger induction and a longer throw, a more uniform distribution of the flow, allowing thermal comfort improvement if such perforated panels were used. We integrated this concept of perforated air diffuser in the air distribution system referred to as "laminar flow ceiling" for the operating rooms in hospital environments. We found that the lobed perforated panel is performing better than the circular perforated panel in isothermal conditions for several volumetric flow rates. The special geometry do not generate supplementary noise as the sound pressure levels were determined for both grilles for different discharge flow rates while the pressure losses are less than 30 Pa in the velocity range which corresponds to standard application of the air diffusion.

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Nomenclature

CS	Comfort Sense
mrt	mean radiant temperature
PMV	predicted mean vote
PPD	predicted percentage of dissatisfied
RH	relative humidity
t_{eq}	equivalent temperature
t_i	indoor air temperature
t_{OP}	operative temperature
TM	thermal manikin
TSV	thermal sensation vote

1. Introduction

Spaces from hospital buildings and especially the operating rooms are a challenge for building services engineers which are often struggling to ensure indoor environmental conditions satisfying all the occupants. The requirements imposed by the standards often lead to the discomfort of users: while surgeons require low temperatures for sanitary reasons, anesthesiologists and assistants feel uncomfortable and would like warmer conditions. The patient may also have thermoregulatory problems due to non-uniformity of thermal conditions in the operating room. In addition, it was observed from the analysis of standards across the European Union, the minimum and maximum values recommended for indoor air temperature are very different for different areas of a hospital building. Another important observation is related to the fact that different types of ventilation systems have designs, sizes and very different applicability, as well as different dynamics of the resulting air flows. The literature [1] shows that in some situations, a good choice of the ventilation system and of the air distribution pattern can contribute significantly to reducing the transmission of pathogens [2-4].

On the other hand it has been shown in various fundamental fluid mechanics studies [5-9] that a jet from a lobed orifice allows increased induction compared to a jet from a circular orifice. The optimization of the geometry of the elementary orifice and of the spacing between orifices in the case of perforated air grilles was performed numerically [10-13]. It was followed by experimental exploration of the flows coming from the innovative proposed concept, at scale 1 for application in tertiary office buildings [14]. The increase in induction observed for the elementary lobed orifice was also found to be present at the scale of an entire air diffusion grille.

In this study, we propose an analysis of a perforated lobed grille for integration into the air distribution system referred to as "laminar flow ceiling" for the operating rooms in hospital environments. We wanted to experimentally test these perforated panels in real scale conditions in a climatic chamber with the dimensions of a real operating room. One of our most important concerns was related to the thermal comfort assessment methods and we proposed several approaches. Indeed, thermal comfort is a subjective term defined by a plurality of sensations and is secured by all factors influencing the thermal condition experienced by the occupant; therefore it is difficult to give a universal definition of this concept. This way, in this paper we are presenting thermal comfort evaluation of innovative perforated panels using experimental data both from a thermal manikin prototype and a standardized measurement system.

2. Experimental set-up

The two geometries being considered in this study are circular (Figure 1, a and b) and lobed cross-shaped (Figure