INFLUENCE OF GEOMETRY OF THERMAL MANIKINS ON ROOM AIRFLOW

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ABSTRACT

A number of different thermal manikins have been applied in literature to experimentally study the indoor environment. These manikins differ in size, shape and level of geometric complexity ranging from simple box or cylinder shaped thermal manikins to humanlike breathing thermal manikins. None of the reported studies however, deals with the influence of geometry of the thermal manikin. This paper provides an experimental study on the influence of manikin geometry on the global and local airflow around a manikin located in mixing ventilated surroundings.

It was found that the air velocities express little influence of manikin geometry when global flow is considered, that is flow at some distance from the manikin. However, locally the velocity levels showed to be significantly different.

INDEX TERMS

Mixing ventilation, thermal manikin, air movement

INTRODUCTION

In indoor environmental engineering and research occupants are often accounted for by person simulators. In experimental work these simulators can be categorised as either *thermal manikins* (heat source and obstacle) affecting the room airflow pattern and temperature distribution or so-called *breathing thermal manikins* that in addition can be used as a tool for assessment of thermal comfort, indoor air quality and personal exposure.

A number of different thermal manikins have been applied in literature. Bjørn and Nielsen (2002), Brohus and Nielsen (1996) and Xing, Hatton and Awbi (2001) focus on thermal comfort and personal exposure, while others take a fluid dynamics point of view in the investigation of airflow and temperature distribution around the human body (Chang and Gonzalez, 1993; Myers, Hosni and Jones, 1998; Lewis et al., 1969).

The manikins applied in indoor environmental research differ in size, shape and level of geometric complexity ranging from simple box or cylinder shaped thermal manikins to humanlike breathing thermal manikins. Simple manikins are often preferred as they are cheaper to buy and more easy to operate. Topp, Nielsen and Sørensen (2002) and Topp (2003) investigated the influence of geometry of computer simulated persons on local and global air distribution and convective heat transfer as well as concentration distribution and personal exposure by means of Computational Fluid Dynamics. The results showed that a simple geometry is sufficient when global flow is considered while a more detailed geometry

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should be used to assess thermal and atmospheric comfort. None of the experimental studies reported in literature however, deals with the influence of geometry of the thermal manikin. It is straightforward to believe that the more humanlike geometry provides the better results but so far there is a lack of information on how much better the results would be.

This work focuses on the influence of manikin geometry on the global and local airflow around a manikin located in mixing ventilated surroundings. In another study Topp et al. (2003) studies the influence of manikin geometry on concentration distribution and personal exposure in a displacement ventilated room.

METHODS

A series of full-scale experiments with four different thermal manikins were performed. The geometries of the thermal manikins are highly different while height and surface area are almost identical, see Figure 1.

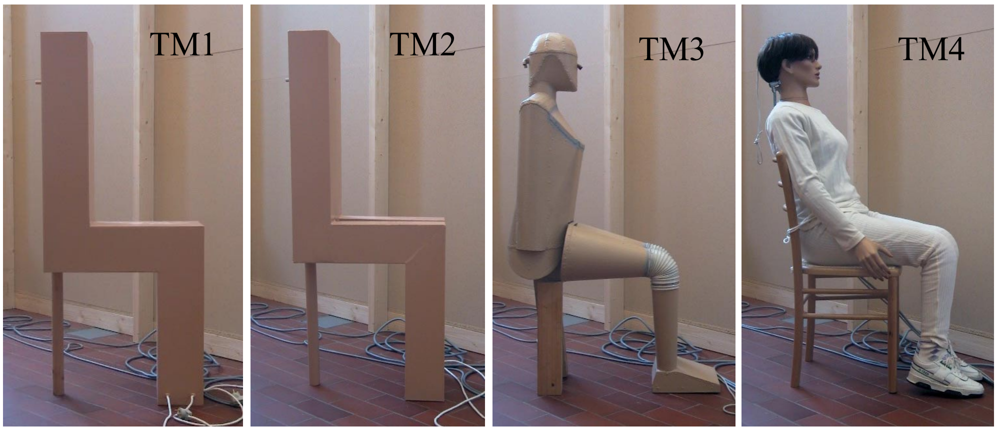

Figure 1. The investigated thermal manikins.

Both thermal manikin 1 and 2 (TM1 and TM2) is a simple rectangular shaped geometry of a seated person based on a standing Computer Simulated Person proposed by Brohus (1997). TM1 has “no legs” that is air is not allowed to pass between the legs, while TM2 has a space between the legs. TM3 and TM4 are breathing thermal manikins with a more complex and humanlike geometry. The manikins are identical with those applied in Topp et al. 2003.

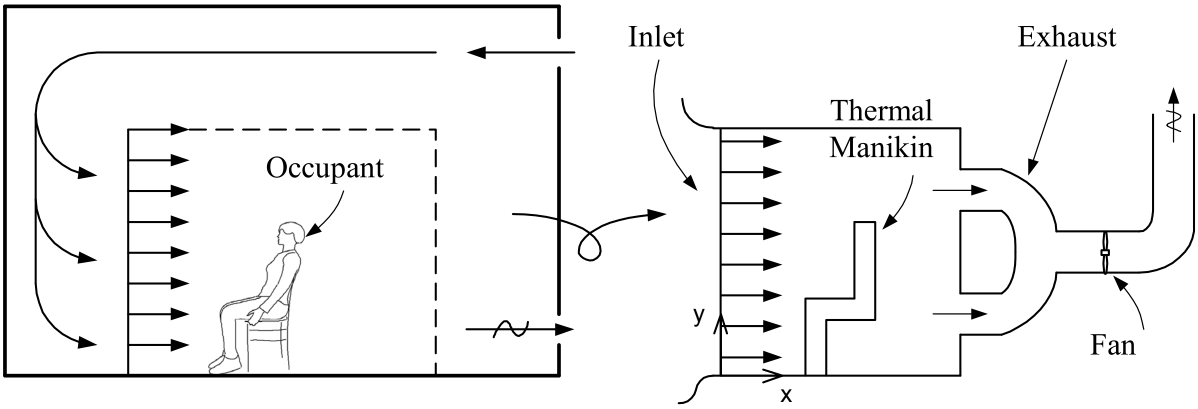

Figure 2. Airflow pattern in mixing ventilated surroundings (left) and the experimental set-up (right). The experimental setup is a channel-like geometry with dimensions L×H×W = 2.50 m × 2.44 m × 1.18 m.

In the present study the thermal manikins are seated and face a unidirectional flow field that can be considered similar to the flow field a person is exposed to in a mixing ventilated room, as illustrated in Figure 2.

The unidirectional flow field is created by two circular exhaust openings behind the thermal manikins, whereas air is supplied in the full cross sectional area in front of the manikin. The manikins are seated at a distance of 0.7 m from the inlet and centered on the x-axis.

Air velocities were measured with hot-sphere anemometers in three vertical planes in front of and behind the manikins. A Laser-Doppler anemometer was used for measuring velocity profiles close to the manikins. The air was supplied at 0.2 m/s from a surrounding laboratory hall with a temperature of 22.9°C±2.5°C. The manikins were set to a heat output of 79.8 W corresponding to the activity level of a person with sedentary work (1 met).

RESULTS

The air velocities measured were evaluated both globally, that is in three vertical planes in front of and behind the manikins, and locally at the mouth and the center of the torso.

Global flow

Velocities were measured in front of and behind the thermal manikins to evaluate the global flow pattern. Figure 3 shows the vertical velocity profiles in the centerline. For the empty enclosure the desired unidirectional flow field was obtained.

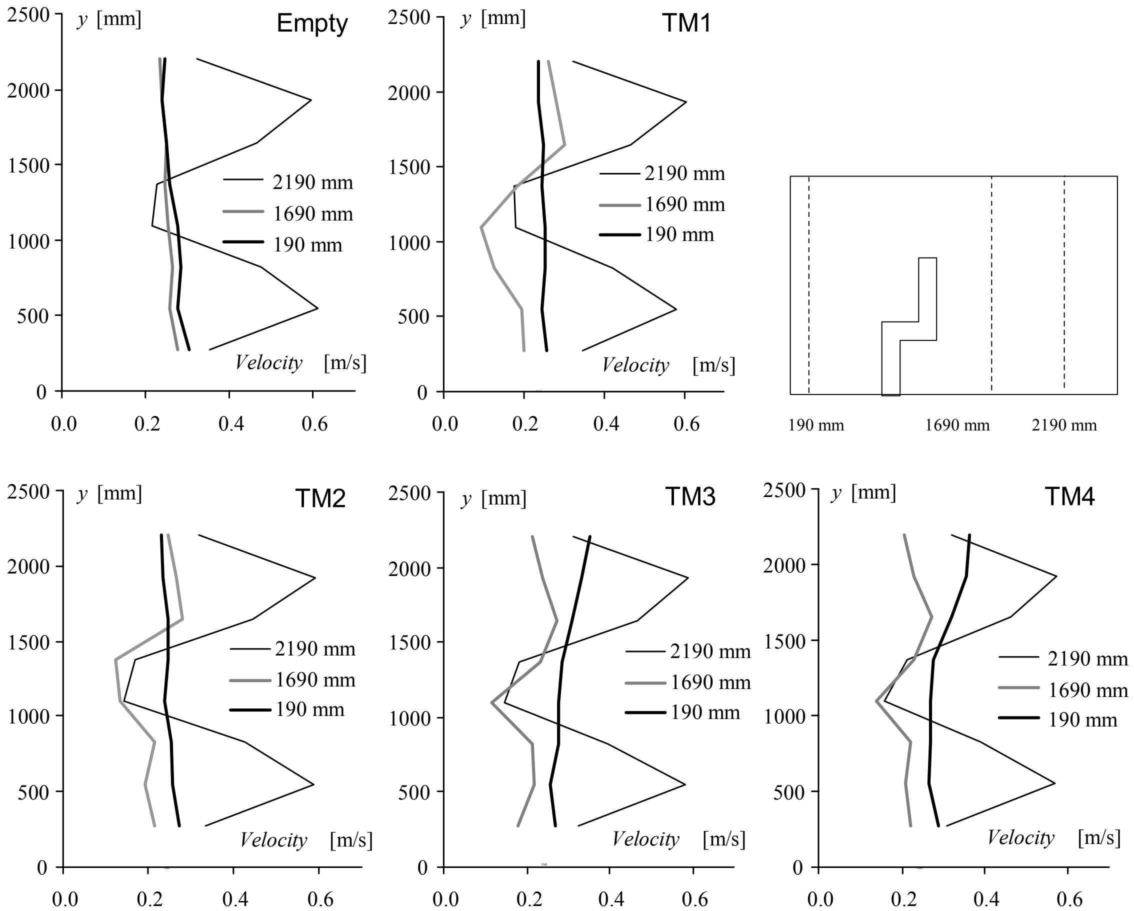

Figure 3. Vertical velocity profiles (centerline) in front of and behind the thermal manikins. The inlet velocity and temperature was 0.2 m/s and 22.9°C±2.5°C, respectively.

Almost identical profiles are observed in front of the manikins in the lower part of the enclosure. In the upper part however, higher velocities are observed for TM3 and TM4. This is due to the fact that TM1 and TM2 have no head and thus have the same width in their entire height while TM3 and TM4 have heads allowing air to pass above the shoulders.

Direct behind the manikins at x=1690 mm, the profiles express lower velocities behind the body and higher velocities above the head as the manikins obstruct the flow. Close to the floor only a slight difference between TM1 and TM2 is observed although the air flows around TM1 and between the legs of TM2. For TM3 and TM4 the low velocity zone behind the manikins is smaller as the velocities behind the necks are higher than for TM1 and TM2.

The velocities measured at x=2190 mm are clearly influence by the two exhaust openings. In addition the profiles are almost identical for all manikins indicating no significant influence of manikin geometry and good repeatability of the experiments.

Local flow
The local velocities are evaluated from horizontal velocities measured at the mouth (Figure 4) and the center of the torso (Figure 5).

The profiles at the mouth of TM1 and TM2 express the typical boundary layer behaviour where the velocity increases from zero to its maximum value at some distance and then drops to the free stream value. For TM3 and TM4 the typical boundary layer profile is not obvious and the velocities in the immediate vicinity of the mouth are lower than for TM1 and TM2. The head and shoulders that allow air to pass around and not only above TM3 and TM4 cause this.

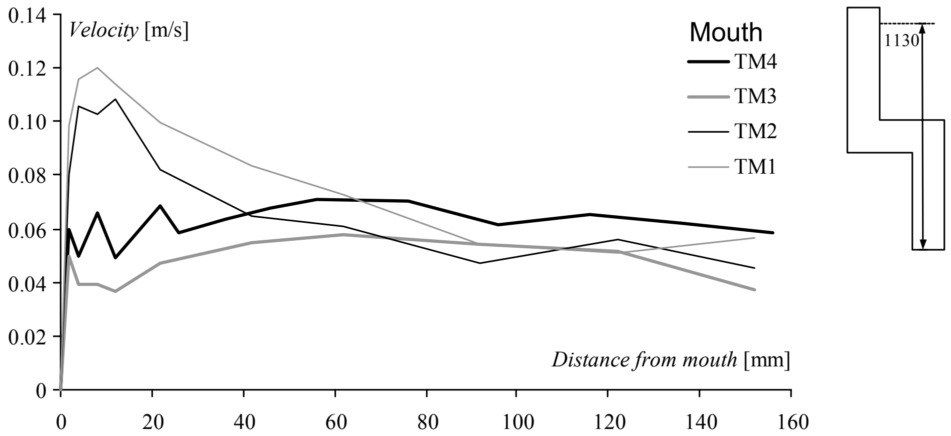

Figure 4. Local velocity profiles at the mouth.

From Figure 5 it is seen that the velocity profiles at the center of the torso differs not only in magnitude but also in direction. The profiles for TM2, TM3 and TM4 show an upward flow direction while the air flows down for TM1. This indicates that a vortex is established above the lap of the manikin. The free stream velocities for TM2 and TM3 that are both close to zero, point to stagnant flow in that region.

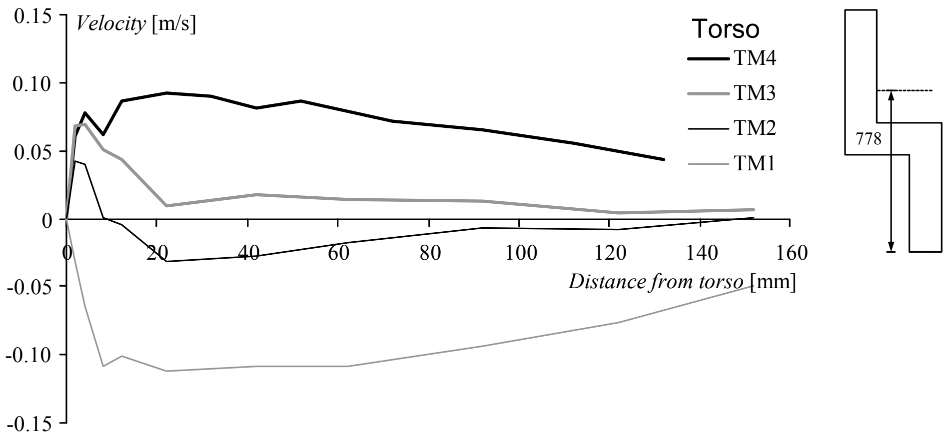

Figure 5. Local velocity profiles at the center of the torso.

DISCUSSION

A series of experiments were performed to investigate the influence of manikin geometry on the global and local airflow around a manikin located in mixing ventilated surroundings. In general, the two simple manikins (TM1 and TM2) show similar results as well as the two more detailed manikins (TM3 and TM4).

In front of the manikins the results show that the manikin geometry has little or no influence on the velocities in the lower part of the enclosure while the manikins with a head (TM3 and TM4) experience higher velocities in the upper part than the manikins without head.

Behind the manikins the velocities are clearly influence by the manikins. At a distance of approximately 0.5 m behind the manikin the flow is still disturbed and a protected zone with lower velocities is established. For the detailed manikins (TM3 and TM4) the protected zone is smaller as air can pass above the shoulders. Slightly higher velocities are observed in the leg region for the manikins that allow air to pass between the legs.

CONCLUSIONS AND IMPLICATIONS

From the present study it can be concluded that when interested in global flow conditions a thermal manikin with a simple geometry can prove sufficient. Global flow conditions are evaluated when interested in the overall airflow pattern, temperature and contaminant distribution in a ventilated room. When interested in local conditions a more detailed geometry would be necessary to evaluate thermal and atmospheric comfort close to the occupant.

It is the future objective to further extend the knowledge on influence of manikin geometry on airflow, personal exposure and contaminant distribution to assess tasks suitable for geometrically simple manikins and tasks where a more complex geometry is required, that is to provide guidelines for choice of manikin geometry based on problem characteristics.

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REFERENCES

Bjørn, E. and Nielsen, P. V. 2002. Dispersal of exhaled air and personal exposure in displacement ventilated rooms. *Indoor Air*, Vol. 12, p. 147-164.

Brohus, H. 1997. Personal exposure to contaminant sources in ventilated rooms. PhD Thesis, Aalborg University, Denmark, ISSN 0902-7953 R9741.

Brohus, H. and Nielsen, P.V. 1996. Personal exposure in displacement ventilated rooms. *Indoor Air*, Vol. 6 (3), p. 157-167.

Chang, S. K. W and Gonzalez, R. R. 1993. Air velocity profiles around the human body. *ASHRAE Transactions*, 99 (1), p. 450-458.

Lewis, H. E., Foster, A. R., Mullan, B. J., Cox, R. N. and Clark, R. P. 1969. Aerodynamics of the human minienvironment. *The Lancet*, Saturday June 28 1969.

Myers, J. B., Hosni, M. H. and Jones, B. W. 1998. Interaction of air motion with the human body. *ASHRAE Transactions*, 104 (1B), p. 863-882.

Topp, C., Hesselholt, P., Trier, M. R. and Nielsen, P. V. 2003. Influence of Geometry of Thermal Manikins on Concentration Distribution and Personal Exposure. *Proceedings of Healthy Buildings 2003*, Singapore.

Topp, C. 2002. Influence of Geometry of a Computer Simulated Person on Contaminant Distribution and Personal Exposure. *Proceedings of ROOMVENT 2002, Eight International Conference on Air Distribution in Rooms*, Copenhagen Denmark.

Topp, C., Nielsen, P. V. and Sørensen, D. N. 2002. Application of Computer Simulated Persons in Indoor Environmental Modeling. *ASHRAE Transactions*, 108 (2), p. 1084-1089.

Xing, H., Hatton, A. and Awbi, H. B. 2001. A study of the air quality in the breathing zone in a room with displacement ventilation. *Building and Environment* 36, p. 809-820.