Aalborg **UNIVERSITY** Denmark **&** Gävle **UNIVERSITY** Sweden

Benchmark

Benchmark Test for a Computer Simulated Person - Manikin Heat Loss for Thermal Comfort Evaluation

Håkan O. Nilsson, Henrik Brohus and Peter V. Nielsen.

Version of February 2007

Foto: HO Nilsson

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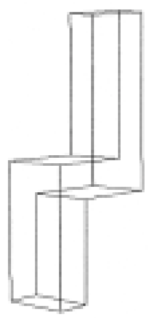
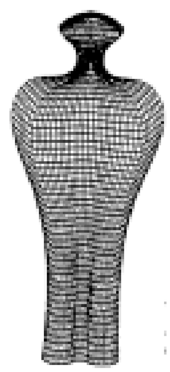
Introduction

Researchers around the world have developed many different configurations in order to represent a computer simulated person (CSP) or a virtual CFD manikin. These manikins are different with respect to size, form, heat generation, turbulence models and computer codes used, etc. The variations reflects the various possibilities and limitations in software as well as different subjects of interest as manikin effects on the airflow, thermal comfort as well as pollutant production and exposure. The levels of detail are also of great interest as well as recommendations on how and when to simplify the CSP. This evolution can be shown with the following examples:



Simulated Occupant
Gan (1994)



Computational Thermal Manikin
Murakami et. al. (1997)

Berkeley Comfort Model
Huizenga et. al. (2001)

Nielsen et. al. (2003) introduced two benchmark tests focusing on the airflow around virtual thermal manikins or CSPs. The new benchmark test described here will focus on the different heat losses from the manikin with the aim to predict how humans will react to different climatic situations and is developed in cooperation between Aalborg University and the University of Gävle, Sweden. The earlier mixing ventilation benchmark test has been developed by Aalborg University within the framework of the International Centre for Indoor Environment and Energy, and the displacement ventilation case has been developed at the University of Tokyo and Keio University.

This paper introduces a benchmark test for a CFD manikin or a CSP. This test is evaluated in full scale to get measurements for comparison with CFD predictions. The idea behind a CFD manikin benchmark test, which define the boundary conditions around a real as well as CFD manikin, have the following reasons: If different versions of virtual CFD manikins can be tested with the same boundary conditions, it is possible to make comparisons, and perhaps make some new decisions on geometrical level of details of the design, turbulence model used, type of grid etc. This will hopefully lead to a more focused development of a simplified, comparable, easy to use virtual CFD manikin with respect to both geometrical and physiological properties also taking into account usability and limitations. This research will give us some general requirements for the design and development of future computer manikins and CFD manikin systems.

The manikin heat loss benchmark test aims at connecting results from human experiments and thermal manikin measurements to develop a methodology based on a virtual manikin positioned in a CFD simulated environment. The results can be presented not only as whole body influence, but also with local information on how the thermal climate varies over the human body (Nilsson 2004). The development of virtual models is an efficient complement to traditional evaluation of the thermal environment.

Manikin Heat Loss Case

The experimental setup is a box shaped geometry with a window on the side and dimensions X×Y×Z = 2.44×2.46×1.2 m (Figure 1). The incoming air is supplied in the full cross sectional area in front of the manikin. This unidirectional flow field is evacuated thru two circular exhaust openings behind the thermal manikin (Figure 2). The manikin is seated at a distance of 0.7 m from the inlet in the centre of the wind tunnel. Air velocities were measured with hot-sphere anemometers (Dantec Dynamics 32 channel indoor flow system with 54T21 transducers) in 5 levels in front of and behind the manikin. Another measuring stick was used to measure the temperatures at 4 levels (0.1, 0.6, 1.1 and 1.5) to the right close to the manikin. The air was supplied at 0.27 m/s from a surrounding laboratory hall with a mean temperature of 20.4°C.

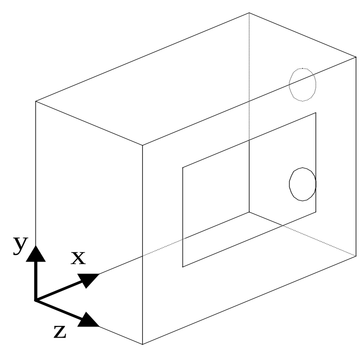


Figure 1. *The geometry and coordinate system of the wind tunnel test environment at Aalborg University. The inlet to the left and the two exhaust holes to the right.*

The measurements were made with a female manikin Comfortina (pt-teknik.dk) Madsen (1999). The manikin run in constant surface temperature mode at 34ºC, without clothing in order to get fast and accurate heat loss levels. The manikin was seated facing a unidirectional flow field similar to the flow field used in the previously benchmarked mixing ventilation case (Topp C et. al. 2003), see Figure 2. The flow field situation was made as identical to the earlier “Mixing Ventilation Benchmark” Nielsen et. al. (2003) with the intention that flow field data will be interchangeable and comparable between the two tests.

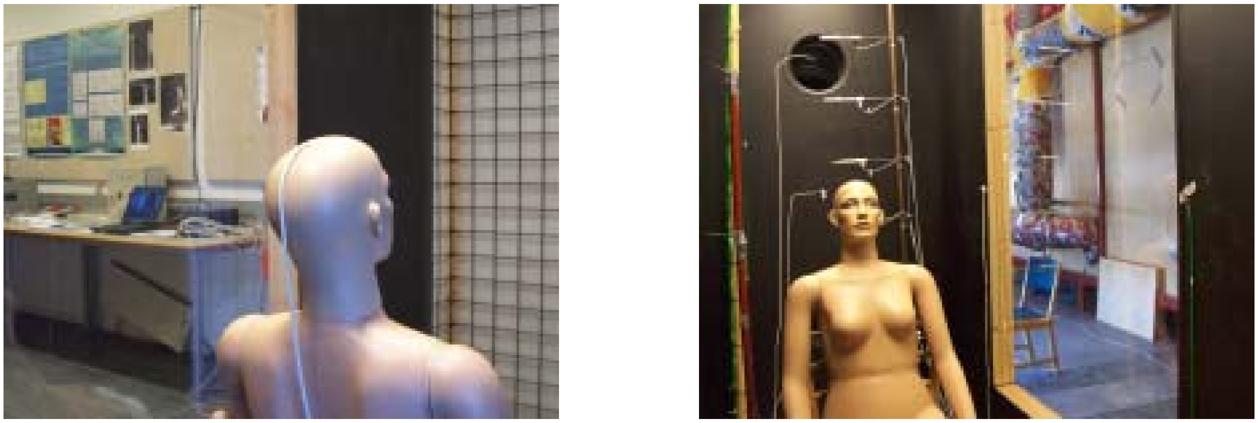
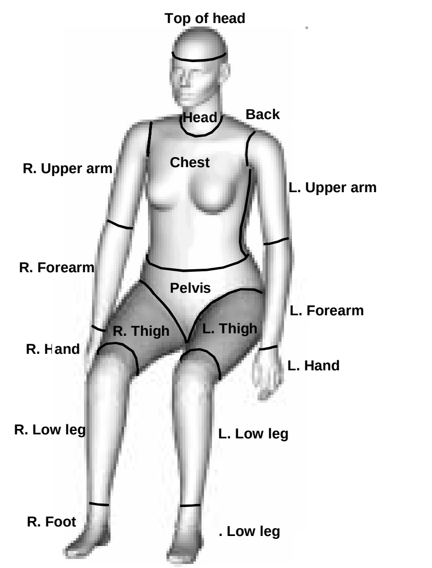


Figure 2. *The manikin was positioned centred inside the tunnel with the arms hanging down and no clothing or hair. To the left a view thru the window and towards the front inlet and to the right the manikin and one of the two exhausts for recirculation of the air.*

Table 1. Coordinates and positions of the sensors during the measurements.

Thermal manikin: Comfortina, No clothing, Software 3.0.30.

	Body Segments
1	L. Foot
2	R. Foot
3	L. Low leg
4	R. Low leg
5	L. Thigh
6	R. Thigh
7	Pelvis
8	Head
9	Top of head
10	L. Hand
11	R. Hand
12	L. Forearm
13	R. Forearm
14	L. Upper arm
15	R. Upper arm
16	Chest
17	Back
18	All



Temperatures: Fluke Helios Plus 2287A with 40 Thermocouple Channels.

	Position	Coordinates x	Coordinates y	Coordinates z
1	Vertical 1	-1.08	0.2	0.6
2	Vertical 2	-1.08	0.4	0.6
3	Vertical 3	-1.08	0.6	0.6
4	Vertical 4	-1.08	0.8	0.6
5	Vertical 5	-1.08	1	0.6
6	Vertical 6	-1.08	1.2	0.6
7	Vertical 7	-1.08	1.4	0.6
8	Vertical 8	-1.08	1.6	0.6
9	Vertical 9	-1.08	1.8	0.6
10	Vertical 10	-1.08	2	0.6

11	Vertical 11	-1.08	2.2	0.6
12	Vertical 12	-1.08	2.4	0.6
13	Vertical 13	2.19	0.2	0.25
14	Vertical 14	2.19	0.4	0.25
15	Vertical 15	2.19	0.6	0.25
16	Vertical 16	2.19	0.8	0.25
17	Vertical 17	2.19	1	0.25
18	Vertical 18	2.19	1.2	0.25
19	Vertical 19	2.19	1.4	0.25
20	Vertical 20	2.19	1.6	0.25
21	Vertical 21	2.19	1.8	0.25
22	Vertical 22	2.19	2	0.25
23	Vertical 23	2.19	2.2	0.25
24	Vertical 24	2.19	2.4	0.25
25	Air 0.1	1.22	0.1	1.1
26	Air 0.6	1.22	0.6	1.1
27	Air 1.1	1.22	1.1	1.1
28	Air 1.5	1.22	1.5	1.1
29	Ceiling	0	2.46	0.6
30	Floor	1.85	0	0.6
31	Floor	0.59	0	0.6
32	Floor	0	0	0.6
33	Mid ceiling	1.22	2.46	0.6
34	Window wall	0.59	1.23	1.2
35	Window wall	1.85	1.23	1.2
36	Door wall	1.85	1.23	0
37	Door wall	0.59	1.23	0
38	Upper outlet	2.44	1.84	0.6
39	Lower outlet	2.44	0.63	0.6
40	Back wall	2.44	1.23	0.6

	Air velocities:	Dantec Dynamics Indoor Flow System with 5 54T21 Omnidirectional Transducers.		
1	Air vel. 1	0.19	1.300	0
2	Air vel. 2	0.19	1.100	0
3	Air vel. 3	0.19	0.875	0
4	Air vel. 4	0.19	0.550	0
5	Air vel. 5	0.19	0.275	0
6	Air vel. 6	2.19	1.300	0
7	Air vel. 7	2.19	1.100	0
8	Air vel. 8	2.19	0.875	0
9	Air vel. 9	2.19	0.550	0
10	Air vel. 10	2.19	0.275	0

Heat loss measurements have been made for the manikin heat loss case and they can be downloaded in Excel format from cfd-benchmarks.com in the file manikin_heat_loss_benchmark_2007.xls. The spreadsheet contains 6 worksheets one for each condition tested as well as a sheet with the mean values of the 6 very similar tests and an information sheet in the beginning. The mean value sheet (MEAN@va0.27ta20) is intended as the “Manikin Heat Loss Benchmark”. Heat losses from the 16 manikin zones and whole body heat loss as well as air velocities and air temperatures are reported.

Numerical Methods and Boundary Conditions

The overall conditions are the same as for the mixing ventilation case; with the exception that in this benchmark is the focus primarily on heat losses not air flows.

CFD code
There are no limitations on the code. The complete origin of the code should be reported in order to allow comparisons.

Computer Simulated Person (CSP) or CFD manikin
Posture: **seated**
Geometry: **free and if possible reported as journal or macro file**
Clothing: **no clothing or hair**
Heat flux: **constant surface temperature at 34ºC resulting in adaptive heat loss**
Breathing: **no**

Grid
There are no restrictions on the grid. The specification of the grid should be stated.

Quality of the CFD prediction
Comments should be made on the quality of the predictions in the same way as the mixing and displacement ventilation cases.

Results
The heat transfer rate of each manikin segment should be listed in the presentation or in the report:
• Area and position of each manikin zone (m^2)
• Heat loss rate for each manikin zone (W/m^2)
• Convective heat transfer coefficient for each manikin zone (W/m^2 ºC)
• Radiative heat transfer coefficient for each manikin zone (W/m^2 ºC)
• Temperatures of surrounding surfaces (ºC)
• Characteristics of the air stream, speed (m/s), temperature (ºC) and turbulence intensity (nd.) according to the coordinates in table1.

Measurements for Comparisons in the Manikin Heat Loss Case

In order to furthermore visualise the benchmark situation three movies of the setup was made (smoke_side_HONilsson.mov, smoke_head_HONilsson.mov and smoke_outlet_HONilsson.mov) visualising the flow around the manikin with smoke. The moving pictures try to show the fact that the air stream around the manikin was very stable and symmetrical.

Literature and references

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7I3M (2008). The seventh meeting (7I3M) 7th International Thermal Manikin and Modeling is scheduled to take place sometime during the year of 2008. The venue is still to be decided by a committee based on previous organisers (Ingvar Holmér, Håkan Nilsson, Mark Richards, Victor Candas and Jintu Fan). You are welcome to mail your application with a short description of the event to the Board of Organisers.

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Part 1: ISO 14505-2:2007 Principles and methods for assessment of thermal stress.
Part 2: ISO 14505-2:2006 Determination of Equivalent Temperature.
Part 3: ISO 14505-3:2006 Evaluation of thermal comfort using human subjects.
Part 4: ISO/NWI 14505-4 Principles and methods for computer simulation of vehicle climate.