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What is the impact of a group of people on the conditions in model chamber? - numerical analysis and validation

Weronika Radzikowska - Juś, Andrzej Juś

Abstract— The paper presents an issue of people's influence on the conditions prevailing in the model chamber in which they are staying. The tests aimed at determining temperature changes as a result of the presence of several heat sources (representing people). The issue is raised in two ways: experimental and using numerical algorithm implemented in Elmer FEM software. Afterward compared simulation and empirical results. The results allowed to develop methodology of research and analysis enabling solution of the issue.

Index Terms— convection , Elmer, FEM modelling, heat exchange, heat transfer, heat flux, model chamber

1 Introduction

Development of the numerical tools and constant increasing of calculation power allows to conduct numerical simulations that more and more accurately simulate real phenomenon. It creates opportunity to create better and better models of experiments. Such implementation and validation of empirical results is presented in the paper.

The paper presents comparative analysis of numerical simulation and empirical tests results of a group of people influence on the temperature distribution in the model chamber. Simulation was performed using Elmer FEM software. The paper consist of three parts: first part presents results of empirical tests, second part presents numerical analysis and third part presents validation of such results.

2 Empirical research

Tests were conducted in the model chamber with dimensions of 560x290x260cm. Inside the chamber 10 temperature sensors (K-type thermocouples) were placed as presented in Fig.1.

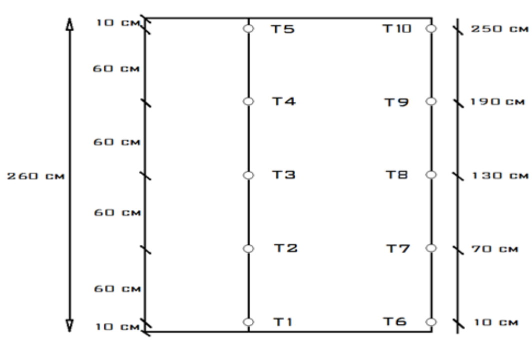

Fig. 1. Location of sensors in the model chamber during tests abbreviated.

In tests 7 people: 3 women and 4 men at the age of 26-30 years old took part. After turning on the measuring device, the participants of tests entered to the room and sat in the indicated places. Temperature was recorded for 15 minutes with 1 second interval. The volume of the room was about 42 m^3. It is appropriate value because it reflects normative value of volume per person (4 or 6 m^3) in civil shelter. To provide higher comfort of people the higher of these values 6 m^3 per person was assumed.

Fig. 2-3 presents characteristics of temperature changes in the chamber in conditions as described above. Thermocouples T1-T5 were placed in a distance of 1 meter from the nearest person, whilst thermocouples T6-T10 were placed 1 meter from T1-T5 sensors.

Results of research for one person inside smaller model chamber are presented in [3][4].

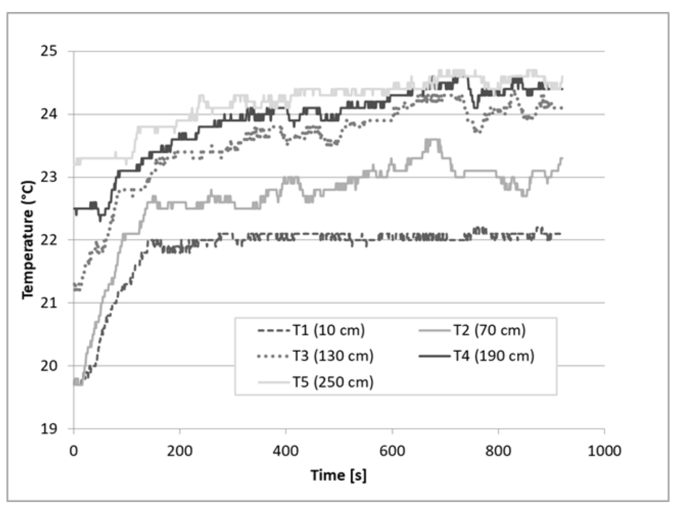

Fig. 2. Characteristics of temperature changes inside the model chamber measured by T1-T5 thermocouples

- *Weronika Radzikowska – Juś, Faculty of Civil Engineering and Geodesy, Military University of Technology, gen. Witolda Urbanowicza 2, 00-908 Warsaw, Poland, E-mail: weronika.radzikowska-jus@wat.edu.pl*
- *Andrzej Juś, Institute of Metrology and Biomedical Engineering, Faculty of Mechatronics, Warsaw University of Technology, A. Boboli 8, 02-525 Warsaw, Poland*

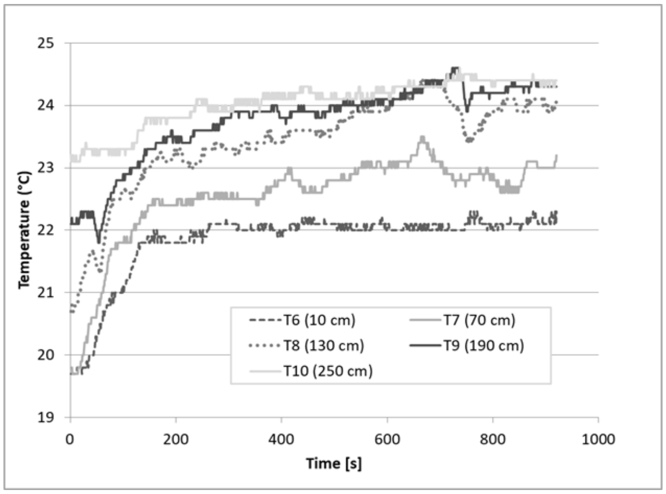

Fig. 3.Characteristics of temperature changes inside the model chamber measured by T6-T10 thermocouples

Analyzing above characteristics observed, as expected, that the higher sensors were placed the higher initial temperatures were measured. Directly after the entry of people into the room temperature was increasing in all points. Stabilization of temperature followed after 180 – 300 second of tests.

3 Numerical Simulation

To consider empirical and numerical results geometry of the room and the mesh were generated using Netgen 5.3 software. To reduce the complexity of problem calculations were made in 2D. The mesh is presented in Fig.4. People inside the room are represent by rectangular heating sources in the bottom part of the mesh.

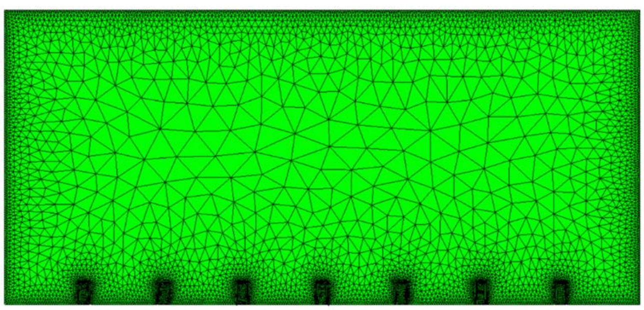

Fig. 4. Geometry of the model chamber with triangular mesh generated using Netgen 5.3 software.

The simulation assumed a constant temperature of heating sources – 36 °C. Furthermore assumed that the heat flux transferred outside each heat source corresponds to the power of 100 W. This is a norm value of a power generated by sitting relaxing man with a weight of 75 kg [1][9]. Gender, weight and dress of each person taking part in the experiment were not included. However, despite these assumption results confirm correctness of the conducted reasoning.

Calculations performed in Elmer FEM software based on Finite Element Method. Selected time steps of simulation are presented in Fig. 5-7.

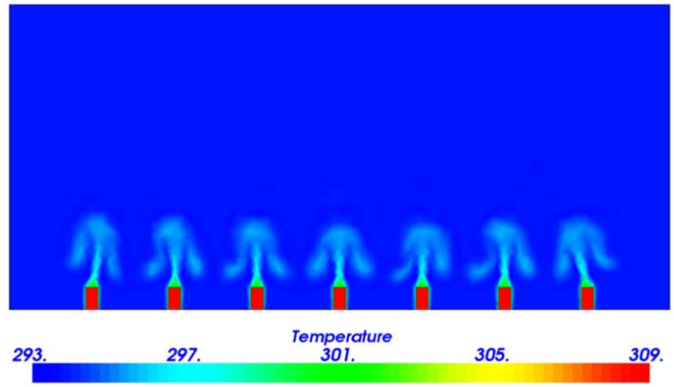

Fig. 5. Temperature distribution in the model chamber after 20 seconds from the start of simulation.

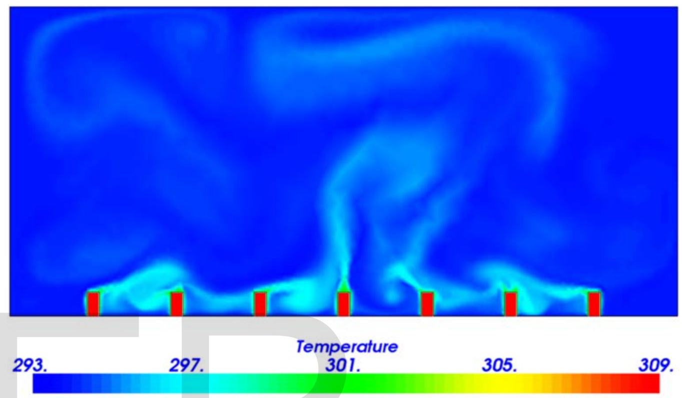

Fig. 6. Temperature distribution in the model chamber after 100 seconds from the start of simulation.

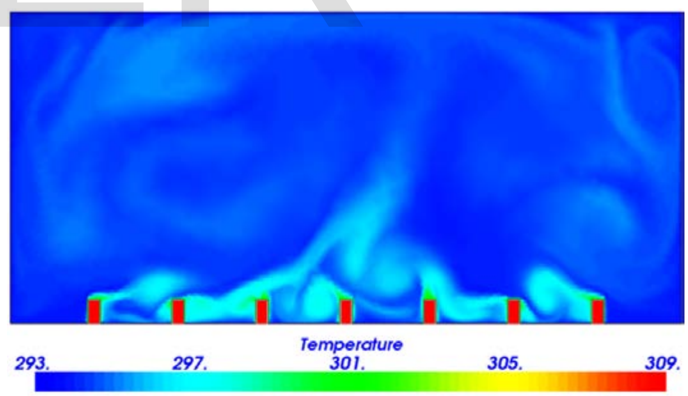

Fig. 7. Temperature distribution in the model chamber after 200 seconds from the start of simulation.

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4 Model validation

To validate the results three points, at different heights (10 cm, 130 cm, 250 cm) in the model chamber were selected. In these points characteristics of temperature changes over time were determined. Results from measurement and simulation are presented separately for each point in Fig. 8-10.

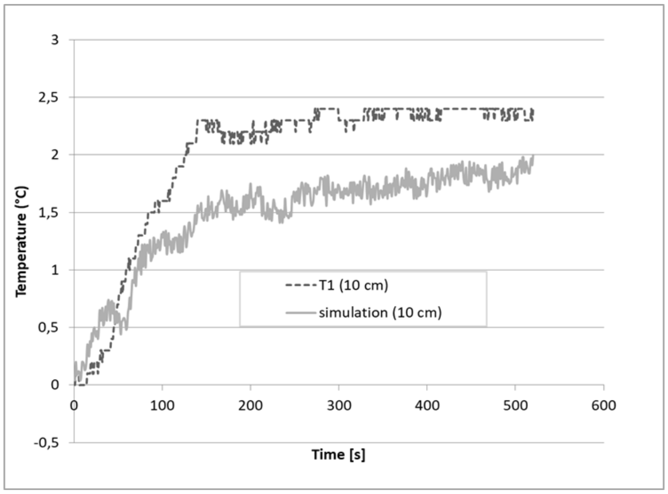

Fig. 8. Characteristic of temperature rise in function of time at 10 cm over a bottom edge (flat) of the model chamber (room)

For T1 measurement point fast temperature rising in both cases (simulation and measurement) was observed. It is related to the proximity of heat sources (people). Due to the significant effect of heat escape to the upper parts of the room, the results obtained during simulation are underestimated in relation to experimental results. This indicate too strong consideration of convection in simulation.

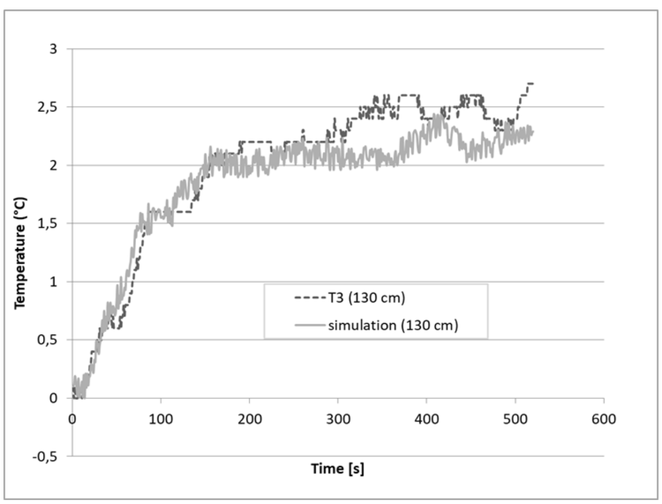

Fig. 9. Characteristic of temperature rise in function of time at 130 cm over a bottom edge (flat) of the model chamber (room)

T3 measurement point was placed in the middle height. Above characteristics shows high convergence of empirical and simulated results.

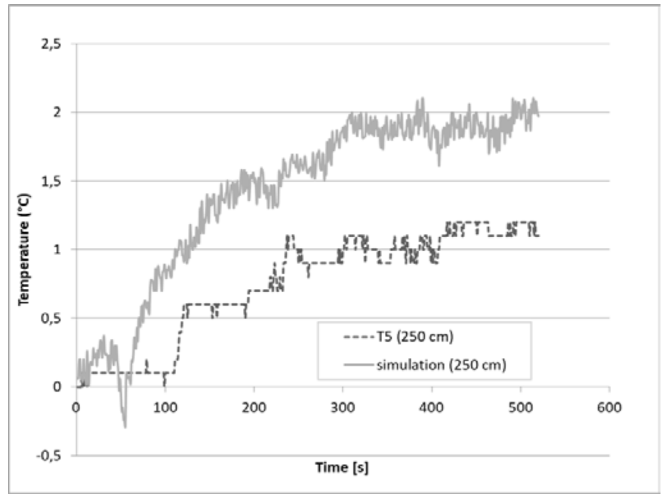

Fig. 10. Characteristic of temperature raise in function of time at 250 cm over a bottom edge (flat) of the model chamber (room)

T5 measurement point was placed just below the ceiling. Above characteristics shows that simulation results exceed measurement temperatures. It is related to the dominant influence of convection on simulation results. However raise of simulation results in T5 is lower than analogical rise of temperature in point T3 – it is related to the significant effect of heat outflow through the walls and ceiling of the room – assumed value 6W/m^2*K. Low temperature increase of empirically measured temperature results from a considerable distance from heat sources, as well as from the significant impact of heat outflow near the upper edge (ceiling) of the room. The largest distance from heat sources also results in the biggest delay of temperature changes.

4 Conclusion

As a result of empirical studies, the characteristics of temperature changes (just after entering people into the room) over time were obtained. As a result of the numerical simulation obtained the model of temperature distribution over time in conditions as above. Comparison of these results shows their significant convergence.

It is worth noting that convection and conduction are not the only ways of heat outflow from a heat sources (in the presented case from people) - other ways are also radiation and evaporation. Percentage share of these ways depends on the nature of adhere matter. Furthermore always some heat outflow outside a system. Therefore to carry out more accurate - real-world simulations, it is necessary to take into account these factors and other heat dissipation paths. Thanks to that, it will be possible to obtain a comprehensive picture of the impact of vary heat sources on temperature distribution in the room.

Acknowledgment

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