Numerical Analysis of Radiant Heat Emission Systems

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Abstract

Radiant heating generally addresses all heat emission systems having a share of radiant heat emission of more than 50 %, compared to a radiator, convector or fan coil where the heat is transferred mainly by means of convection.
The implementation of the concept of NZEB [3] will lead to a further reduction of the heating demand of new buildings. Also, the heating demand of the building stock will decrease by applying deep renovation. The technology to achieve very low energy demands is available since about 25 years, when the first Passivhaus was built in Darmstadt, Germany [2]. Technology and products have been further improved since then and cost-effectiveness has been significantly improved. However, in order to improve the economic feasibility of these very efficient buildings, cost-effective heating systems are required. In parallel, the share of renewable energies (such as PV or wind) in the electric grid will further increase. Both these developments make electric heating interesting again in spite of the fact that because of thermodynamic principles electricity should not be used for heating.
Recently, so-called infrared-heating systems are increasingly discussed as a cost-effective heating system. Relatively small areas of typically 0.6 m x 1.2 m with high surface temperatures of up to about 120 °C are used. The following questions have to be answered:

- What is the appropriate dimensioning of the radiant system depending on the load of the building?
- What are the comfort conditions with radiant heating systems and how should they be determined and evaluated?
- What is the energy performance compared to reference systems such as hydronic floor heating, e.g. with air-sourced heat pump?
- Is there a benefit in intermittent operation due to the fast response of these heating systems?

In order to investigate radiant heating systems in detail, physically correct building models are required. Standard building simulation models use simplified approaches for the long-wave radiation exchange (star node model, e.g. EN ISO 13790, TRNSYS or 2-star model, e.g. Energy+, IDA ICE, Dynbil) and cannot distinguish between different positions, geometries and sizes of the heat emission system [4]. Comfort conditions are usually evaluated based on the operative temperature calculated as mean of the convective temperature and the area weighted average of the temperature of the surrounding surfaces, which does not allow distinguishing different sizes and positions and control strategies in detail.

Detailed steady state and transient physical models has been developed in MATLAB® based on the radiosity approach. The required view factors for the radiation exchange between all surfaces and between each surface and a sphere representing a person or a comfort in different positions of the room are calculated using COMSOL Multiphysics® software. The new model is cross-validated against a simplified analytical radiation model (6 surfaces, [5]) as well as against standard dynamic building models.

Reference

[1] EN ISO 13790: Energy Performance of Buildings: Calculation of Energy Use for Space Heating and Cooling (2008)

[2] W. Feist, Passivhaus - die langlebige Lösung | Prof. Dr. Wolfgang Feist, Passivhaus Institut, 20th International Passive House Conference, Darmstadt (2016)

[3] J. Kurnitski (Ed.), Cost Optimal and Nearly Zero-Energy Buildings (nZEB) Definitions, Calculation Principles and Case Studies, Springer (2013)

[4] M. G. Davies, Buiding Heat Transfer, Wiley (2004)

[5] VDI Heat Atlas, Springer (2010)

Figures used in the abstract

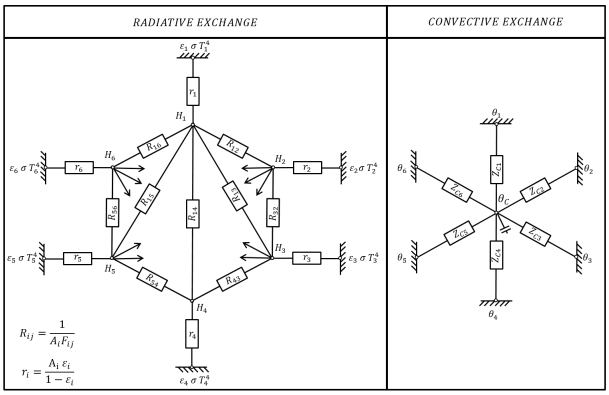

Figure 1: Long Wave Radiation Model.

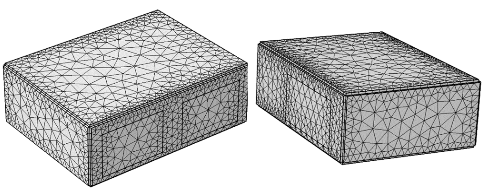

Figure 2: 3D COMSOL FE Model.

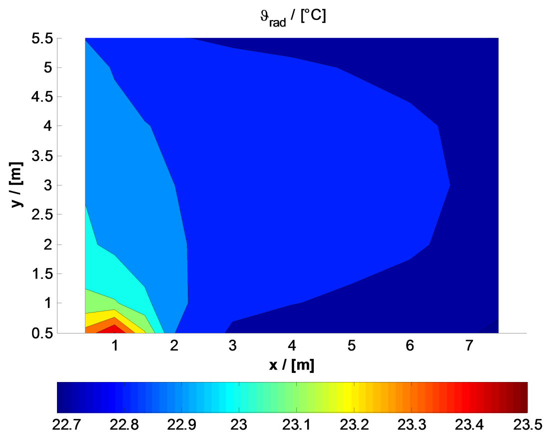

Figure 3: 2D Contour Plot - Spatial Distribution of Radiation Temperature for Asymmetric Heater at Wall.

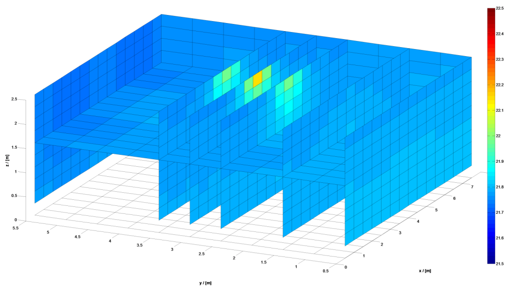

Figure 4: 3D Slice Plot of Operative Temperature for Heater in Center of Ceiling.