Modelling long-wave radiation heat exchange for thermal network building simulations at urban scale using Modelica

Moritz Lauster, Peter Remmen, Marcus Fuchs, Jens Teichmann,
Rita Streblow, Dirk Müller
RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings
Mathieustr. 10, 52074 Aachen, Germany
mlauster@eonerc.rwth-aachen.de

There are different options for modelling indoor and outdoor long-wave radiation exchange in thermal building models for simulations at urban scale. For improving these building models, a good trade-off between accuracy and simulation time is a major challenge.

During investigations of individual building model components with the help of the American Standard ASHRAE 140 [1] , we identified long-wave radiation exchange as one key part for optimization. It seems to have major influence on heat demand [2]. This paper provides four different methods to calculate outdoor long-wave radiation exchange. While three of them are based on the implementation of an equivalent air temperature, one calculates the heat exchange based on the Stefan-Boltzmann law. In addition, two methods to calculate indoor long-wave radiation exchanges are tested, one based on a linear approach, another based on Stefan-Boltzmann law.

For the comparison, we set-up three test cases on a generic room and a single family dwelling and analysed surface temperatures, heat demands and simulation times. The generic room corresponds to a test case of ASHRAE 140; the single family dwelling was constructed in accordance to German Energy Savings Ordinance 2009 with a high thermal mass. We varied the number of radiation sources between the test cases to observe radiation heat exchange under generic and real conditions.

The results of the test cases show promising potential for an outdoor radiation exchange model based on a modified approach from German Guideline VDI 6007. It includes important simplifications that lead to short computing time while keeping a sufficient accuracy. For indoor radiation exchange modelling at constant temperatures, a linear approach significantly reduces simulation time without any major accuracy losses.

Modelica proved thereby to be a promising modelling language for urban scale building simulations. Major prerequisites and advantages are solvers with variable time steps and the use of object-oriented and acausal modelling approaches.

References

[1] American Society of Heating, Refrigerating and Air-Conditioning Engineers. Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs(ASHRAE 140-2007). Atlanta: ANSI/ASHRAE; 2007.

[2] Shi Z, Zhang X. Analyzing the effect of the longwave emissivity and solar reflectance of building envelopes on energy-saving in buildings in various climates. Solar Energy 2011;85(1):28–37.