Thermal Modeling in a Historical Building - Improving Thermal Comfort Through the Siting of a Passive Mass of Phase Change Material

D. Groulx[1], F. Herbinger[1], L. Desgrosseilliers[1]

[1]Mechanical Engineering, Dalhousie University, Halifax, NS, Canada

Abstract

The Toronto Carpet Factory, a large historical building situated in downtown Toronto, has been converted into office spaces, which are subject to space temperature fluctuations outside of the ASHRAE comfort level guidelines (i.e., 23°C < T < 26°C during the cooling season). One way of passively controlling and reducing those temperature fluctuations is with the use of a passive mass of phase change material (PCM) inserted in the space. To that regard, a research collaboration is underway with Internat Energy Solution, a Toronto based company, to investigate the performance of such a heat storage strategy in improving the thermal comfort of occupants in select rooms. Ongoing COMSOL® simulations performed in Dalhousie University's Lab of Applied Multiphase Thermal Engineering have the goal of simulating the heat transfer in the room and study the impact of siting a PCM on the temperature recorded in the room.

Figure 1 shows the geometry of one of the rooms used in the simulations. The room is 9.9m wide, 8.1m deep, and 4.21m high. The three shaded rectangular prisms represent the window sills where the sun rays enter the room. The wall with contact to the outside air is a four layer brick wall which is 0.46m thick, and the interior walls measuring 0.2m in thickness are gypsum wallboard with white paint. Wood oak flooring makes up the ceiling (0.5m in height) and floor (0.13m in height), and the interior domains in the room and window sills are composed of air.

The two physics interfaces used in this work are Heat Transfer with Radiation in Participating Media, with Heat transfer from surface-to-surface radiation checked, and Laminar Flow. Important sub-nodes include an external radiation source to model the path of the sun and determine ray tracing and heat transfer with phase change to model the phase change materials. The exterior of the floor, ceiling, and gypsum walls are thermally insulated and the interior boundaries of the room experience natural convection and surface-to-surface radiation. The model couples heat transfer from conduction, convection, and radiation. Objects with thermal mass as well as those with heat generation, such as humans and computers, will be added in the near future.

A geometrically explicit model (see Fig. 2) based on first principles that determined the location of the lit parts of the floor and walls was also developed. The model relied on the solarad_v16

Excel® model from the Washington State Department of Ecology, which provided values for the solar azimuth (θ), elevation (Φ), and intensity at a specific longitude, latitude and time of year. Comparisons of the detailed output as well as computational performance will be made between the built-in solar model in the COMSOL Multiphysics® software and the geometrically explicit model.

Work is ongoing and preliminary implementation of the physics and geometric model look promising; radiation on the floor and walls from the sun is well simulated (see Fig. 3).

Figures used in the abstract

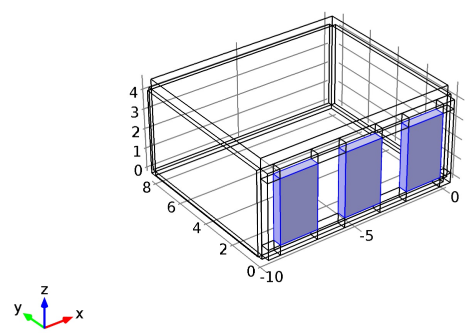

Figure 1: Room geometry.

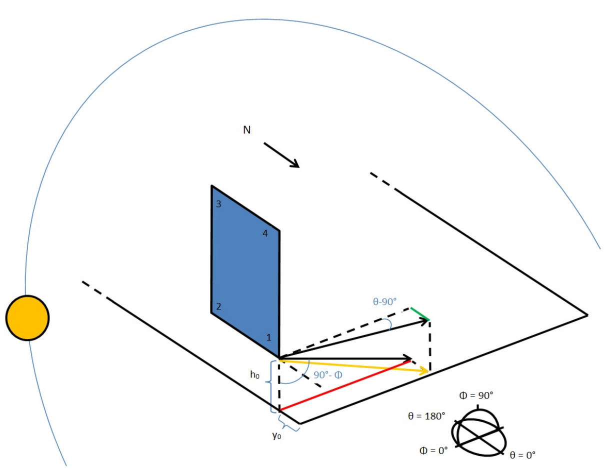

Figure 2: Trigonometry used in geometrically explicit model.

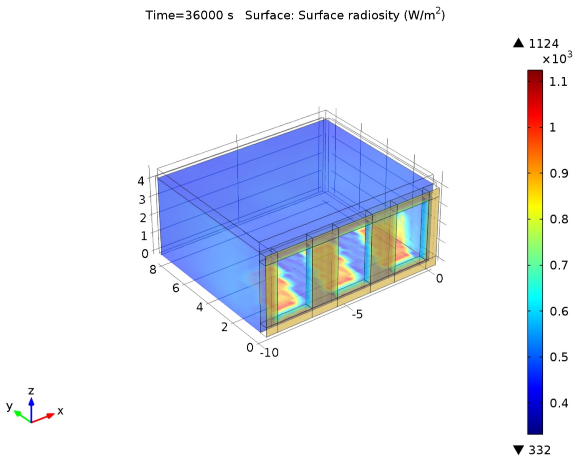

Figure 3: Modelling radiation.